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Using small streams to answer big river questions — hydraulic models to manage New Zealand's braided rivers

Braided gravel-bed rivers pose major management problems in many regions (e.g. USA, Canada, the European Alps and New Zealand). Braided rivers form a major part of New Zealand's water resources for irrigation, hydropower, fisheries, recreation, wildlife and environment, and their long-term management requires an ability to predict how the river will respond to engineering works, flow modifications and changes in the river sediment budget.

Nowhere are braided rivers better developed than on the Canterbury plains of New Zealand's South Island. They include the Waimakariri, Ashburton, Rakaia (Figure 1) and Rangitata, and are characterised by wide braided floodplains, with beds and banks mainly composed of gravelly alluvium, in contrast to many gravel-bed channels elsewhere which have cohesive banks.

A major problem is river aggradation, which raises river bed levels above the surrounding floodplain, reducing flood discharge capacity and creating a very hazardous situation, which is often too expensive to maintain or to manage effectively. The Waiho river in Westland (South Island) is a good example of this (Figure 2). Here the river threatens a state highway bridge, a township and agricultural land. So far the river has cost $(NZ)1.2 million in river training works; destruction of the main highway bridge would add another $(NZ)1.0 million to costs. Although extreme, the Waiho situation is not unlike many management problems associated with braided rivers throughout New Zealand and elsewhere. The need for control works reflects the increasing pressure to develop the resources of braided rivers: e.g. water abstraction and hydropower require rivers to be trained around water intakes.

River control in New Zealand has a long history and most of it has been accomplished using good judgement



Figure 1 The lower reach of the Rakaia River, Canterbury. Although the river is confined at this point to a fairway just under 1500 m wide, old channels can clearly be seen in the surrounding farmland.

and rather primitive analytical techniques. River managers and engineers have adopted a range of techniques to investigate past and future impacts of control works and management practices. One possible method, hydraulic modelling, relies on establishing similarity between a model and prototype so that river behaviour can be reproduced to calculable scales. In braided river studies moveable bed models are frequently used to provide information on three-dimensional time-dependent problems related to channel behaviour. This strategy transfers the trial-and-error approach of prototype river engineering into the controlled environment of the laboratory where the consequences have no 'real' impact.

Hydraulic modelling of braided gravel-bed rivers is a relatively recent phenomena. The first serious attempts in New Zealand were initiated in the late 1970s by **Tim Davies** in what was then the Agricultural Engineering Department at Lincoln College. Activity at Lincoln University and the University of Canterbury continued steadily over the next two decades but never developed into a very large area of research. At first this may appear surprising, given the potential for modelling New Zealand braided rivers, yet considering the small academic community in New Zealand actively concerned with braided gravel-bed rivers, the lack of enthusiasm of the majority of engineers to adopt hydraulic modelling approaches and the small number of international institutes involved in scale modelling of braided gravel-bed rivers, the progress made in New Zealand is significant.

Recent advances in the hydraulic modelling of braided gravel-bed rivers are covered in a special issue of the *Journal of Hydrology (New Zealand)*, currently in preparation. There are to be seven papers covering aspects of 'Hydraulic Modelling of Braided Gravel-bed Rivers'. *A brief review of hydraulic modelling of braided gravel-bed rivers in New Zealand* (Warburton) describes the current state of play in braided river hydraulic modelling in New Zealand and identifies key research themes. Paper two discusses the *Principles and practice of hydraulic modelling of braided gravel-bed rivers* (Young and Warburton). This is followed by a short paper on the specific issue of *Surface tension in small hydraulic river models - the significance of the Weber number* (Peakall and Warburton). The next three papers examine specific braided river flume models and look at applications in key areas of research: *A physical model study of stage-discharge relationships in a braided river gorge* (Davies and Griffiths), is an applied study investigating the problems associated with establishing a stage-discharge relationship in the Waimakariri gravel-bed river gorge; *Sediment dispersion and duration of storage in model braided river beds* (Hoey) indicates a possible strategy for modelling sediment storage in braided gravel-bed rivers, while the third paper investigates the complex and somewhat controversial topic of *The influence of bed geometry on bed load transport and channel morphology in a model braided river* (Warburton). The volume concludes with a short paper on *Future prospects for the use of hydraulic models in the management of New Zealand braided gravel-bed rivers* (Davies, Griffiths, Hoey, Warburton and Young).



Figure 2 The Waiho river in Westland, an active, glacier-fed braided river with a history of severe aggradation and brief periods of down-cutting, is now very close to destroying a main bridge on State Highway 6, a very important tourist route on the scenic West Coast. The photograph taken in 1994 shows the river within 3 m of the bridge, which when originally constructed stood 20 m above a river gorge.

It is hoped that 'Hydraulic Modelling of Braided Gravel-bed Rivers' will be published in 1996. It will be of value to fluvial geomorphologists interested in sediment transport and mechanisms of channel change, to engineers interested in investigating engineering problems and solutions, and to river managers who have perhaps not considered the value of physical hydraulic models. One major hope is that this special volume will encourage the effective use of hydraulic models in investigating braided river processes and raise awareness of the New Zealand research into this important topic. It builds on a previous Special Issue of the *Journal of Hydrology (NZ)*: 'Bedload transport in gravel channels' (Carson and Griffiths, 1987) in attempting to provide further understanding of braided river processes.

In conclusion, although there has been considerable work on New Zealand's braided gravel-bed rivers, there are still considerable uncertainties about the nature of channel behaviour. Braided gravel-bed river models provide a useful tool for river management, but they are generally under-used in current engineering practice. This is unfortunate, because the method could be applied to most engineering problems, with the possible exception of those involving vegetation. I am grateful to BHS for providing Travel Grant assistance on my recent trip to New Zealand.

Jeff Warburton
University of Durham

Travel grants

Grants in the range £75-£100 are available to help members with the cost of attending meetings (see *Circulation 38*). The scheme is open to anyone, but is intended mainly to help students or younger members whose travelling expenses are not met by an employer.

Please apply to the Hon. Secretary (**Paul Younger**, Department of Civil Engineering, Cassie Building, University of Newcastle, Newcastle upon Tyne NE1 7RU, Tel. 0191 222 6000 ext. 7942, Fax 0191 222 6669, Email P.L.Younger@newcastle.ac.uk), including details of the meeting, whether a paper or discussion is to be presented, the total costs and benefits of attendance, brief details of your financial situation, your background and your 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, which may also be considered for *Circulation*.

Scale problems in hydrological modelling

BHS National Meeting
Birmingham University
23 June 1995

Scale has become an important area of research in hydrological modelling, partly because of the demand for hydrological models and theory that can be applied to regional or even global problems. This national meeting, attended by fifty delegates, addressed the problems encountered in hydrological modelling when dealing with processes and measurements at different scales. Sections covered groundwater problems, rainfall modelling and rainfall-runoff modelling from the plot scale up to the macroscale. A final paper completed the "journey up-scale" with a review of the representation of hydrology in global climate models.

The opening address was an "idiosyncratic view" of some current issues by **Keith Beven** (Lancaster University). Having noted that the vocabulary of the "scale problem" is still in a somewhat fluid state, Keith asked the question "How can we best make use of identifiable structures in space?"

One approach may be the concept of the "Representative Elementary Area" (REA) which suggests that at or above certain length scales, the functional spatial heterogeneity in a system may be adequately represented by its statistical distribution rather than by its spatial pattern. The use of this concept was illustrated with an idealised general distribution function model. This model disaggregates from the hydrograph to a set of parameter and process distributions within the catchment. However, Keith pointed out that most of the distribution functions within the model were probably unknowable, leading to a requirement for model calibration and, consequently, a degree of uncertainty in model predictions.

Turning to the opposite approach, aggregating point process theories up to larger scales, Keith argued that the incommensurability of variables at different scales means that process theories and their governing equations are scale-dependent. This uniqueness of scales may eventually force a disaggregation approach where functional model forms are conditioned on data measured at an appropriate scale (and with some treatment of predictive uncertainty). Under this approach, it will be important to focus on the functional patterns of hydrological responses in the landscape such that new measurement techniques will assume far more importance than the "holy grail" of a scaling theory.

In reply to a question from **Max Beran** (NERC TIGER Office) about the implications of the scale problem for research funding, Keith commented that if funding bodies were to become more critical of the "outrageous science" in some current modelling approaches, there was a danger that funding could be cut — this may already be happening in the USA. One way to mitigate this danger would be to develop methods for estimating model uncertainty scientifically.

The first of two groundwater modelling papers was given by **Rae Mackay** (University of Newcastle). Making pragmatic use of effective parameters in macroscopic process descriptions, Rae gave three examples of cases where the estimation of these parameters, and the predictions of physically representative models, were affected by changes in scale. Firstly, a method was described where stochastic microscale lithological characteristics were used to generated effective conductivities at scales of 10^2 or 10^3 metres for a regional flow model. This procedure involved sampling the small-scale conductivity distribution within the larger scale grid elements, adopting a strategy designed to represent any larger-scale trends in the field.

Secondly, the problem was extended to include transport processes in the larger-scale model. Rae described how effective dispersivities were calculated using a "quick upscaling rule" based on the comparison of contaminant plumes modelled at fine and coarse scales of spatial resolution. It was shown that the best effective dispersivity in the larger scale model varied as this scale was changed.

In the third example, the prediction of tracer breakthrough curves in fractured porous media was considered under changes in the scale of the modelled domain: changing the domain area could lead to large differences in the performance of the model. The recalibration required to achieve a good fit for a different domain area was shown to be partially a reflection of the scaling properties of the modelled fracture network.

Jacob Tompkins (Imperial College) continued the groundwater theme by investigating the scaling problem in stochastic flow and transport models. In this approach, rather than using effective parameters to describe the properties of the media, heterogeneous conductivity and fields may be created so as to reflect the statistical properties and actual values of observed data. Jacob described how numerical flow and transport simulations were carried out on multiple realisations of the stochastic field, with the resulting head and concentration predictions being compared to observed point data to identify a set of plausible scenarios. From this set, probabilistic simulations of a tracer plume can be obtained.

Scale-dependency appears in this approach because the discretisation of the conductivity field affects how well the true heterogeneity of the porous media can be represented. Also, the size of the tracer source area relative to the correlation length of the conductivity field was shown to be important in determining the possible forms of the simulated plume.

In the discussion that followed, there was a question about the use of fuzzy logic in groundwater modelling problems, such as the multiple transport scenarios described by Jacob Tompkins. Rae Mackay replied that some work had been done in Poland on this subject. The use of effective parameters originated from a desire to make models applicable to more than one study, rather than entirely dependent upon a given data set for calibration. Keith Beven pointed out the underlying scale problem in conditioning grid-based models on point measurements, but **James Bathurst** (Newcastle University) noted that in his experience point parameterisations could be used successfully in large-grid-scale models.

Christian Onof (Imperial College) described his work under the HYREX and TIGER projects on the disaggregation of GCM grid element rainfall predictions. The aim was to produce sub-grid-scale spatial and temporal distributions given only the simulated

rainfall depth for an entire GCM grid cell. By studying the properties of observed rainfall data, empirical relationships could be obtained to account for the autocorrelation in rainfall coverage as a function of the aggregated rainfall depth obtained from the GCM.

Rainfall could be simulated at the sub-grid scale using a distributed random process model, the results of which were compared with radar data. After first discussing the temporal scaling properties of observed rainfall data, Christian also noted that the spatial scaling problem is twofold, since there may be scaling both within wet areas and in the distribution of wet and dry areas.

The afternoon session, chaired by **Howard Wheater** (Imperial College), was opened by **Bob Moore** (Institute of Hydrology) who gave a talk on probability distributed rainfall-runoff modelling. Working from a simplified point process model, the distribution of storage capacity within a catchment could be expressed as a probability distribution function at any scale. Rainfall may be added to this storage capacity function, and, by integration, a total catchment storage calculated. Given a specified distribution of critical saturation storage capacities, runoff could also be calculated for a known rainfall. Bob showed results illustrating the different runoff predictions obtained for different storage capacity distribution functions.

As with the REA concept discussed earlier in the meeting, the probability distributed approach provides a means of scaling up from point process descriptions to larger scales, where the statistical distribution of spatial variability is more important than the geometrical distribution. However, Bob concluded by showing how the probability distributed approach may be extended to include spatial pattern by using a catchment digital terrain model to include the effects of topography (on runoff production and incident radiation) and channel routing, of which we were to hear more later.

Having heard several comments on the need for an emphasis on field data collection, it was instructive to hear **Nick Chappell** (Lancaster University) talk about the measurement of parameters for "mesoscale" problems such as hillslope contaminant transport or slope disturbance. It was noted that uncertainty in the estimation of sub-grid parameters is due to equifinality in calibration solutions and model structural errors. On the other hand, the aggregation of small-scale plot or point measurements is difficult because of the frequent disagreement between different techniques. Nick then showed results from tracer and bulk electrical resistivity experiments that he hoped could be used to obtain effective parameters at an appropriate scale.

The first of three papers on macroscale modelling was given by **Bill Sloane** (Newcastle University) who described the UP ("Upscaled Physically-based") system. This is designed to use an analysis of detailed, computationally expensive models in defining the transfers taking place between the stores of a simplified conceptual model. Surface runoff production and routing were treated by identifying runoff source areas and then using catchment topography to define a velocity field from which simple routing transfer functions can be identified. Upscaling is completed by combing a mosaic of UP elements, for instance as "patch" models to represent the land surface component in a GCM grid.

A more empirically-based macro-modelling approach was described by the organiser of the meeting, **Tim Jolley** (University of Westminster). The aim was to find an efficient large-scale land surface model with parameters that could be calibrated robustly. Tim described the scale problems encountered when aggregating the results of point SVATS (Soil Vegetation Atmosphere Transfer Schemes) up to the catchment or GCM grid scale. He also pointed out the scale problems in catchment boundary definition when working under an imposed coarse grid and in the spatial averaging of fluxes.

A simple water balance model had been applied to the Severn and Thames catchments. With the addition of a runoff routing model, discharges for the catchments as a whole could be simulated successfully. However, at the sub-catchment scale, systematic errors had been observed in runoff predictions and these had been related to an East-West drying trend. In order to resolve this problem, Tim adopted large-scale "water balance zones" allowing spatial corrections to be applied to his model. However, these corrections were purely empirical and so added to the calibration problem.

Continuing the macrohydrology theme, **Pam Naden** (Institute of Hydrology) presented a large-scale channel routing model based on simple physical principles and a distribution function representation of the channel network topology (the "network width function"). Potential scale problems affecting the method are the map scale from which the network width function is derived, the scale of modelled runoff production and the effects of catchment scale on the estimation of physically-derived parameters. The effect of map scale was easily resolved in Pam's example, while the problem of the scale of runoff production was dealt with by catchment subdivision. This procedure involves estimating the runoff input to the model by averaging runoff production per unit area from small sub-catchments, where routing effects are negligible. The subdivision could be on the basis of an arbitrary grid, or stratified according to soil/geological units that generate different amounts of runoff. The effects of scale on parameter estimation is the subject of further research.

Discussion of the afternoon session centred on the generality of macroscale models, following a question on the subject from **Terry Evans** (Mott MacDonald). Generality was discussed as an important consideration if such models are to be applied globally within GCM schemes. Of particular concern is whether models developed in humid regions would work well in arid areas of the world. Tim Jolley mentioned that his model for the Severn and Thames did not work as well when applied to the Nile, although this might be solved by recalibration.

The final paper of the meeting, given by **Peter Cox** (Hadley Centre), offered an "end-user" perspective on the upscaling of hydrological models. Peter described how hydrological and land surface processes are typically represented in GCMs and illustrated the sensitivity of climate models to these components. It was noted that scale may also be an important problem in modelling the CO_2 cycle. Having described the one-dimensional process equations used for land surface fluxes, Peter suggested that patch or mosaic models might be effective in representing the spatial variability of these fluxes at larger scales.

In the concluding discussion, Peter assured the audience that the land surface representation was receiving a high priority in GCM model development, although cloud dynamics were still seen as perhaps the most important area. Although spatial heterogeneity may affect moisture fluxes, one view was that the first aim of GCM modellers in incorporating land surface processes must be to capture all the essential feedbacks. From this point, heterogeneity and scaling could be considered more fully. Another point made was that the effect of human water resources policies should not be ignored in macroscale modelling. Abstractions for irrigation from the Nile were cited as an example.

With time running short, it was left to Howard Wheater to close this lively meeting with a vote of thanks to **Paul Webster** (Birmingham University) for organising the facilities and to Tim Jolley for arranging the speakers.

Robert Lamb
Lancaster University

BHS in the South West

The BHS South West Section has recently been revitalised by the creation of a new committee. Two series of presentations and a field trip have already been undertaken successfully, and a full programme of meetings and trips has been planned for the next two years to maintain the momentum. Committee members are mainly from the NRA so far, but it is hoped that people from outside the NRA will soon become involved.

Users' perspectives of hydrological modelling

The inaugural meeting of the revamped BHS South West Section on *20 January 1995* looked at the users' perspectives of hydrological modelling. The first speaker, **Bryony Howlett** (NRA South Western), considered at the River Tavy in Devon and the criteria behind selection and use of a hydrological model. The Tavy was a priority site for low flow investigations to determine the impact of abstractions on fisheries, the ecology and the hydrology. Bryony outlined how three criteria — time-scale, looped-system and a need for flow routing — resulted in the selection of ONDA from a shortlist. She described the prototype and network phases of the project, and explained how model structures were set up and how data preparation methods were tried out. The process of assessing inflows, system parameters, control rules, calibration and validation was discussed.

Bryony identified some key issues. The first was the learning curve to understand the hardware and software. Using a model still under development resulted in some difficulties, although the model itself was easy to run. The cost and the long lead time of obtaining data for good calibration and validation of model results was highlighted. The model did prove to be flexible, allowing scheme design of alleviation of low flow procedures.

Questions that followed raised the ability to run several scenarios of abstraction, the difficulties of data availability, especially when projects expand from their original purpose, and the use of different flow inputs.

The presentation by **Jennifer Taylor** (NRA South Western) considered her personal perspectives and experiences in the application of HYRROM, a rainfall runoff package. The problem she faced was that flows at the Lumburn gauging station on the River Tavy were known to be in error, but they were required for the Tavy low flow investigation. HYRROM was chosen because it was available, relatively simple and straightforward to use, the Lumburn catchment was relatively natural, the model's data requirements were satisfied and Jennifer had had experience of using HYRROM.

After describing the catchment characteristics and flow regimes, Jennifer outlined problems of using models in the real world: gaps in flow records limiting calibration periods, limited rainfall records making it difficult to arrive at areal averages and the lack of evaporation data. Given the constraints of data, Jennifer explained the selection of separate calibration and validation periods and illustrated project progression through to the final validation sequence.

She noted that HYRROM had been successful in producing improved hydrographs for the gauging station, making use of available data. In general HYRROM was easy to use and representative of natural, surface flow catchments. She did find that data preparation was lengthy and that poor data availability limited the package. Areal averaging of the rainfall data also highlighted the need for good data. Specific to the package, parameter values which could be adjusted tended to be hidden within a black box, resulting in some time being spent by the user getting a feel for the package.

This point was raised in questions, and Jennifer explained how difficult it was to relate model parameters directly to catchment characteristics. The value of high quality real data was stressed in relation to both presentations.

The final presentation by **Johnathon Larkin** (Rust) examined the process of model selection for groundwater modelling. He explained that a good model can save time but that there were many to chose from. The situation was placed in context by a quotation: "Models should solve problems, not create them". Johnathon outlined some issues facing the modeller. The physical system being modelled has to be understood, including technical issues. It must be clear whether modelling will help to clarify issues and an appreciation of what the model can tell us is necessary. As shown in the first two presentations there is a requirement for good data. Limitations affecting model use include the assumptions within a package, data availability, financial and time resources and the technical ability of the modeller.

Johnathon identified a number of factors affecting model selection: availability, confidence in the model, hardware and software requirements, project budget and resources and the project objective. He explained the use of an integrated model evaluation system, with 150 models on a database, allowing a process of objective selection to be used. Questions focused on whether lack of data led to inappropriate use of some packages, and on the relationship between the modeller and the client, which raised many points, including liability for results, accreditation of models and the education of clients in the capabilities of models.

Goss Moor field visit

Applied hydrology for conservation rehabilitation purposes was the central theme for BHS South West members who attended the field visit to Goss Moor near Bodmin on *22 March 1995*. This former wetland heath, covering the headwaters of the River Fal, has had a predominantly willow vegetative cover for the last fifty years. The heath's wetland status has declined almost completely since the underlying granite was first plundered for tin and then surface watercourses were canalised to aid in mine drainage.

Today the tin mines are derelict, but the heath is bordered to the south by china clay works and traversed to the north by the encroachment of the A30 Indian Queens by-pass. English Nature has set out to rehabilitate the wetland to improve the heath site's conservation value. The University of Plymouth was commissioned to examine how the heath's hydrological system works and so identify methods to reintroduce a wetland regime. The National Rivers Authority also joined the project, liaising with English Nature over the conservation rehabilitation programme.

Members were first presented with the hydrometric background to the current work on the heath. The central problem over the last 40 years has been the rather short residence time of the components of flow during dry conditions, both within the surface water courses and in the surrounding heathland. Monitoring of the water table in the area showed a relatively steep hydraulic gradient from the

heath's margins to the main tributaries of the Fal in the centre. The channels have deep symmetrical profiles and show very little sinuosity in plan.

Work was conducted to attempt to identify the relationship between the groundwater levels across the heath and the wetland status of the area. Studies then established the sensitivity of the wetland to hydrological perturbations. These elements of the work enabled the quantification of target groundwater heights and their distribution across the heath.

Recent work has assessed methods to increase the present groundwater level to the target height. The University of Plymouth modelled sites along the banks of surface watercourses where there is good hydraulic connection with the water table below the heath. Introducing granite block weirs to the channels was identified as an effective method to back-up water at these natural "off-takes." The increased up-stream depth at these points might then reduce the hydraulic gradient within the heath and so achieve the target groundwater levels: modelling work predicted just such an outcome.

The field visit included an examination of several block weirs; the programme for installing them is continuing. Hydrometric data collected over the next few years will clearly be of great interest. The return of a predominant wetland vegetative cover is being encouraged by English Nature, and the future recreational use of the heath is hoped to be increased with plans for public access similar to the nearby Camel Trail.

Thanks go to English Nature, the University of Plymouth and the National Rivers Authority for allowing access to the site and organising the speakers and material for the presentation.

Flooding in South West England

On *7 June 1995* the BHS South West Branch held the second afternoon of presentations this year. The three talks to the thirty-strong audience concerned flooding in the South West, all from officers of NRA South Western: **Dan Alsop** gave an engaging and wide-ranging presentation on flooding in the Somerset Levels & Moors, **Julian James** brought the audience up to date with the background and progress of plans to provide flood alleviation to the residents of Polperro, and **Steve Taylor** briefly described the current approach to flood warning used in the NRA South Western Region.

Dan gave a very entertaining tour through his experience as a flood warner and flood alleviator in the Somerset Levels & Moors. His talk included a demonstration of the virtues of using simple equipment when flood surveying, and emphasised the value of a historical appreciation of floods and their damage. Dan warned against too much office-based catchment experience via telemetry systems at the expense of field-based knowledge.

Members are strongly encouraged to look out for future talks by Dan: his experience of alleviating floods was evident from his dramatic aerial shots of a flooded Taunton High Street and coastal caravan parks submerged beneath several metres of water.

Julian James gave an account of the NRA's work to offer flood protection to the Cornish coastal tourist haven of Polperro at the mouth of the Pol river. The Pol follows an extreme gradient for much of its short length in flowing down to the village and sea (where its gradient is essentially flat). The village has suffered from two severe floods over the last twenty years — the most recent in December 1993 resulted in the greatest interest, but Julian showed how little is known of the 1976 flood: photographic evidence is rather limited and a sparse amount of hydrometric data was collected.

The 1993 flood was captured on film by the NRA and the media. Julian showed a video to set the scene, which with the photographic evidence demonstrated how the Pol flooded out of its channel to flow along the main road through the village. It was the analysis of flood marks on properties along this road that provided the severity calculation for the 1976 flood.

Prior to the 1993 flood, the incorrect interpretation of the 1976 event was that this level of water applied fully across the channel width. The 1993 evidence clearly showed how this false interpretation could have been made. It was concluded that the 1976 event was not as severe as the recent flood — indeed the damage caused by the 1993 event was worse. The construction of a large car-park just upstream of the village during the early 1980s (in perhaps the only part of the river valley with significant storage) is viewed as a major contributory factor to the increased vulnerability of the village to floods since 1976.

Julian described the project plan designed to deliver to the people of Polperro an effective flood alleviation scheme. The project has identified a tunnelling solution to the problem in preference to headwater storage and channel protection banks. Polperro offers virtually no space for raised channel banks with the pretty white-washed cottages forming the path of the river, and storage reservoirs were dismissed on cost and site access grounds.

The tunnel solution includes the construction of an ingenious two-stage channel weir upstream of the village. Mean or low flows will continue to flow down the main channel, through the village and into the sea, but once a critical depth and velocity of flow is reached the water fully clears the weir and enters an off-take channel. This takes water down a tunnel blasted through the cliffs to discharge into the sea some hundreds of yards along the coast from Polperro. The tunnelling work has yet to begin: there were considerable problems in gaining planning permission from the local authority because of the blasting work timetable, but they have now been overcome. Julian's talk successfully communicated the message of problem comprehension and engineering design coupled with tight project management.

If you want to know more about BHS South West events or would like to get involved in the South West Section, please contact Graeme Boyce (01392 444000).

President's Piece

The time has come round for me to write my last President's Piece. It seems no time at all since Mike Lowing handed me a car boot full of Presidential files (he still has the other half!) and I wondered what I had taken on. On reflection BHS has moved a long way in the last two years.

I am particularly pleased that with the Main Committees help I have been able to set out a strategy for BHS's second decade. Whilst, this will be reviewed, I am sure, during the coming ten years, it is a useful marker to show what we felt were the main objectives and goals for the Society at the time it was written.

Already, we have achieved some of the targets in the Strategy and we have moved towards others. For example, membership totals are well on course for what we had hoped.

We have published four occasional papers in the last two years following a lull in publication activity. Our Research Strategy, published in March, has been well received and several organisations have responded by asking BHS to take further initiatives in this area. These will be reported on in future issues of Circulation. We have a programme of occasional papers planned for the coming few years which will keep our publications up to

target. Angela Gurnell is leading our marketing initiative and we are already reaping the rewards by way of increased income.

In international affairs, the standing of BHS continues to be enhanced in our relationships with UNESCO, WMO, IAHS and EGS. We continue our involvement in the International Convocation of Geophysical Societies. The international conference to be held in 1998 will further consolidate our position. Further opportunities for international collaboration will, I am sure, occur with BHS Member, John Rodda becoming President of IAHS and with a hydrologist, Georges Vauchaud, being President of EGS. A formal bilateral arrangement has been set up with the Hungarian Hydrological Society and good relations have been developed with several other overseas societies.

On the home front, we have continued to have joint meetings with UK organisations, notably the Hydrogeological Group of the Geological Society and ICE and (C)IWEM. Our own meetings have been well attended and it is good to see, in particular, that the South West section is vibrant once again. The post graduate symposium continues to be a success.

After many years of negotiation, we have taken over the Exeter travel fund from the Royal Society. We allocated grants to several members to allow them to travel to the IUGG Assembly in Boulder. We have also used other BHS travel grants to help support others of our members to attend overseas meetings.

Other new initiatives include the President's Prize and the Penman Lecture which are being inaugurated this year.

In order to keep our members fully in touch with Society activities, we have set up an electronic mailing list. Whilst this will not in the short term take over from the printed page, it will provide a useful additional mechanism for dissemination of information to and between members.

During the last two years, Education and Training issues continue to remain at the fore. Whilst there have been significant improvements in the prospects of BHS members seeking Chartered status, with opportunities now existing for hydrologists to become chartered via the Royal Met Soc, CIWEM and ICE, there is still much work to be done on the mechanics of the process.

Alongside the strategy for the future direction of the Society, I am grateful to the Hon Treasurer, Rod Hawnt, for establishing a Financial Plan for the Society. This is a key achievement and places the Society on a sound financial footing.

As my term of office closes, I would like to thank not only Rod for his help and support, but also Michael Hamlin, Paul Younger, Richard Harpin and all the committee members who have put in a large amount of time and effort into the activities of the Society. I would also like to thank Celia, John and colleagues at IH who continue to do sterling work on the Society's behalf.

Susan Walker

Water Resources in a Vulnerable Environment

Organisation for the international conference to be convened by BHS in 1998 is now well under way. The event will take place for 5-10 July at Exeter University. Chairman of the Conference Organising Committee will be Prof Des Walling who will be assisted by Frank Law who will lead the technical organisation and Bruce Webb who will chair the local organising committee. Michael Hamlin will also be closely involved in the organisation whilst he is BHS President.

International Convocation of Geophysical Societies

I attended the 2nd International Convocation of Geophysical Societies (ICGS) on 8 July. This was a follow up meeting to the one in Washington last year (see Circulation No. 43.). The opportunity was taken to gather together many of the Presidents of Geophysical Societies worldwide whilst they were in Boulder for the IUGG meeting.

This second meeting had less momentum than the first meeting and so was one of consolidation rather than new inspiration. We talked about many matters of mutual interest. Several common issues were apparent for geophysical societies worldwide, including:

- the need to increase the profile of geoscience with the public and government;
- the need to provide information to schools and the public at large on geophysical matters;
- concerns regarding accreditation and education and training;
- special problems of the new countries (eg Eastern Europe);
- the implications of electronic media for journals and other publications.

Many of these are relevant to hydrological societies in general and BHS in particular.

There were several ideas coming out of the meeting which we may wish to take forward in BHS. Last year a series of resolutions were passed. This year the only formal resolution related to guidelines relating to ethical standards for those carrying out research in countries other than our own. The Convocation agreed to promote this in Society newsletters. It is reprinted elsewhere in Circulation.

The next meeting of the Convocation will be in Brisbane next year. It is likely that further meetings may be held on either a regional basis (e.g. alongside the next EGS meeting) or a subject basis e.g. in conjunction with the IAHS meeting in Rabat in 1997. This is for the benefit of those societies who are unlikely to have representatives in Brisbane.

Sue Walker July 1995

New Members

We welcome the following members to the Society:

Adam, S.A. ..... Stoke-on-Trent, Staffordshire
Ballm, S. ..... Peterborough, Cambridgeshire
Browne, J.A. ..... Ruthvenfield, Perth, Scotland
Maxted, R.W. ..... NRA Northumbria & Yorkshire Region, Leeds
Milligan, K.J. ..... Ferguson & McIlveen, Belfast

Overseas hydrology: a world of engineering possibilities

Scottish Hydrological Group Meeting
Royal Society of Edinburgh
9 March 1995

This meeting and the preceding AGM were presided over by Paul Jowitt, the current chairman of the Scottish Hydrological Group, who introduced the speakers, Robin Wardlaw and Robert Walker. At the AGM, Andrew Black introduced newly elected members of the committee: Bayo Adeloye, Dick Johnson, Robert Walker and Robin Wardlaw.

The first presentation of the evening was given by **Robin Wardlaw** (Edinburgh University) who spoke of some of his experiences as a consultant overseas. Robin introduced his talk by listing some of the differences between hydrological practice overseas and in the UK:

- Water resources problems overseas are often of a different order, scale and magnitude;
- The order of importance of relevant hydrological processes tends to be different;
- Language and communication difficulties may arise overseas, particularly with local staff who speak little English;
- Hydrometeorological data are often in short supply overseas and those available may be of poor quality.

Robin considered the last factor to be the most difficult problem and his subsequent examples focused on it. For example if hydrological analysis is to go ahead at all, it must take much longer overseas than in the UK where data are more abundant and relatively good.

In spite of these problems, Robin did identify some challenges and advantages in practising hydrology overseas: for example, the possibility of having a wider brief on major water resources projects than would be feasible in the UK; the hydrologist's ability to develop a clearer overview of the project than many other team members, and the (non-hydrology) advantage of learning about other cultures and sharing in their aspirations.

To illustrate these issues Robin presented a case study of a major water resources project in Bangladesh. At the start of the project, there were very few streamflow data records to carry out resource assessment of ground and surface waters. Thus some form of catchment modelling was needed first to synthesise the needed data and (perhaps more importantly) to aid understanding of the hydrological interaction processes between surface and groundwater sources in the region.

It soon became clear that the rainfall-runoff relationship in the catchments studied was affected by other factors, in addition to the usual processes. Some of these unusual processes include: the superiority of vertical over lateral groundwater flow because of the generally gentle hydraulic gradient and the importance of capillary flux; significance of irrigation return flows on river discharge; sedimentation problems; backwater effects on river flows and rating curves, and bunded field storage effects.

None of the well-known catchment models — like the Stanford Watershed model — could be used without extensive modifications to incorporate these processes, so a model specific to Bangladesh was developed. It was impossible to calibrate the model against streamflow data (because none were available) and so calibration had to be against groundwater levels, an unusual feature for a catchment model.

The modelling results were used in national planning, specifically to quantify the impacts of major water resources projects. Although there might have been reservations about using the model in detailed design, it was a very useful planning tool.

The second speaker, **Robert Walker** (Babtie, Shaw & Morton) investigated the role of hydrology in the design of river diversion works for a hydropower project. In his example the optimum size of diversion works was less sensitive to errors in hydrological data than to the impact of potential downstream damage caused by diversion works failure. He reiterated the problem of the lack of adequate accurate streamflow data often faced by hydrologists on assignment overseas. This problem is sometimes exacerbated by old and damaged measuring equipment, often operating outside its range of validity. He stressed the importance for the hydrologist of always assessing the limitations of hydrological information received before using it.

Robert then described in detail the stages involved in cost-benefit analysis for sizing a diversion scheme for a hydropower project. The objective function was the minimisation of the total diversion cost, comprising the construction cost, the delay costs, and the costs associated with the quantified risk of damage during construction. These component costs are affected by the hydrology, particularly the validity of distribution hypothesis for describing flood flow frequency (model error), uncertainty in parameter estimates for the distribution (sampling error) and the error associated with the stage-discharge relationship (gauging error). However, the sensitivity analysis indicated that while the optimum size of the diversion scheme was sensitive to errors in the hydrological data, it was considerably more sensitive to the inclusion or exclusion of potential downstream damage in the optimisation process.

The discussion opened with an invited comment from **David Banks** (Babtie Group; ex-Chairman of the SHG) who spoke about the problems of flow measurements overseas. Often rainfall data are abundant, but are of no use without some discharge data. He illustrated this with a hydroelectric scheme in Malaysia, which was designed on practically no historical data. A common feature of overseas projects is the time constraint: emergency programmes of stream gauging, often using crude, approximate techniques, have to be carried out.

Paul Jowitt (Heriot-Watt University; Chairman of the SHG) asked Robin to comment on the time step used in the catchment modelling in Bangladesh, the number of parameters calibrated per sub-catchment and (perhaps more importantly) how the catchment sub-boundaries were identified. Robin replied that on the basis of the limited data available, the best time step that could be used was monthly. Six parameters were calibrated per sub-catchment. Delineating catchment boundaries was difficult: for most of the subcatchments, river banks or road embankments were used.

Chris Pratt (Coventry University) asked about the availability of satellite imagery in the area and how far this could go in alleviating some of the problems posed by the dearth of conventionally recorded data. Robin replied that satellite imagery archive in

Bangladesh is very extensive and offers good potential. The next question from **Bayo Adeloye** (H-W University) started from his experience as a hydrologist in data-limited situations. He asked whether, in spite of all the limitations, it was right to present results of such models to communities overseas as gospel truth for national planning. Robin replied that there are obvious limitations which should be stressed: always carry out sensitivity studies and state error bands.

Ronnie Falconer (Babtie Group) asked the two speakers what they considered the most significant recent contributions to the understanding and practice of hydrology. Robin felt the most significant advance is the flexibility/versatility offered by computing power and IT. For example nowadays, lap-top and notebook computers have replaced cases of books, with modems facilitating exchange of electronic information with remote stations. The best things to have happened to overseas hydrology practice, according to Robert, are cheap travel and the ability to work better with overseas teams, drawing on their ideas. Paul Jowitt then asked Robert whether or not he considered multiple failures in his risk analysis. The answer was no, since the probability of a second or higher failure was considered to be very low.

Bayo Adeloye asked whether Robert's finding that hydrological data was not crucial to his design was tantamount to saying that hydrological data have no value and should therefore not be collected: such a claim would contradict the numerous studies which have found that the value of data generally exceeds the cost of collection. Robert was clear: data do have value and he supported data collection. However, it just happened that data were not crucial for the particular diversion works analysed. Most people do not understand or appreciate the value of data and hence the need to invest in the maintenance and operation of gauging facilities. He referred the meeting to the December 1994 issue of *Circulation* which described the deplorable state of hydrometric networks in a part of Indonesia after barely fifteen years of establishment. Contributing to the discussion on the value of data, David Banks felt that Robert's findings might be true for the particular scheme analysed, being concerned with high flows, but it was wrong to think that data are not valuable. Obviously, the same may not be true for a hydroelectric scheme. Robert agreed that low flows data are more important than high flows because of the problems of locating the former on the stage-discharge curve and hence the higher error involved.

The final question came from **Steve Wallis** (Heriot-Watt University) who wanted to know why Robert limited damage risk to overtopping without considering other possibilities such as scouring for example. Robert replied that other risks could also be important but they were not considered significant in diversion schemes; they might be significant in other schemes, such as the design of cofferdams.

The meeting closed with a vote of thanks from Paul Jowitt to the two speakers for their interesting presentations.

Bayo Adeloye
Heriot-Watt University

CIWEM Liaison

A Memorandum of Understanding has been signed with CIWEM which identifies those areas in which mutual cooperation would be of benefit to both BHS and CIWEM. This formalises arrangements which already exist to cooperate regarding joint meetings, etc, where appropriate. The BHS President is now a member of the CIWEM Water Resources Panel and CIWEM send an occasional visitor (currently Cliff Dobson) to BHS Main Committee meetings.

MEMORANDUM OF UNDERSTANDING

1995

The Parties

1. The Chartered Institution of Water and Environmental Management

2. The British Hydrological Society

The Understanding

The Parties have a long association and realise the advantages which may be gained for their respective professional bodies continuing to work closely together.

Accordingly the two organisations agree:

1 to work together in the public interest,
2 to hold joint conferences or meetings where appropirate, locally or nationally,
3. to publish joint publications where appropriate,
4. to maintain good communications,
5. to encourage close working between CIWEM's Water Resources Panel and British Hydroligcal Society,
6. to encourage members of each organisation to be members of the other, where appropriate.

This Memorandum is not intended to create legally binding obligations but to record some of the commonly held intentions which are based on that mutual respect which is appropriate between professional bodies.

SIGNED on behalf of CIWEM by

C J A Binnie (President)

SIGNED on behlaf of BHS by

Susan Walker (President)

Water in the Middle East

BHS Southern Section Meeting
Imperial College, London
8th March 1995

The meeting was opened by *Professor Howard Wheater* (Head of Hydrology in the Civil Engineering Department, Imperial College). He introduced *Ron Manley*, a hydrological consultant who had recently participated in the Middle-East talks on the creation of a shared Palestinian, Jordanian and Israeli water data bank. The second speaker was *Professor Tony Allen* (School of Oriental and African Studies, University Of London), who spoke about the politics and economics of water in the Middle-East.

The subject of **Ron Manley**'s talk was the hydrology of the Iraqi marshes, a study commissioned by the 'Amar appeal', a charity which specialises in health care to the Marsh Arabs. The Iraqi marshes are at the confluence of the Tigris and Euphrates, which both rise in Turkey (Figure 1). The study was broad based, covering the hydrology, wildlife and socio-economic aspects of the area. Immediate problems were due to diversion works (whose legitimate aim was unclear) constructed in the area of marshes, and there was some dispute about the long-term impact of works upstream in Turkey on the marsh area, and the impact of local drainage.

Data availability

Ron Manley outlined the data collection phase of the study. Rainfall and flow data were needed, both historic and recent, as well as information on artificial influences such as dams, reservoirs and irrigation. Fortunately, excellent monthly rainfall data from the 1930s were available from Turkey and Iraq. The Met Office were very helpful in providing data for recent and earlier years, and good river flow data were available from Mike Mansell-Moullin's work in the 1950s, but it was more difficult to obtain recent data. The Global Data Runoff Centre in Germany was able to provide some more up-to-date flow data.

The Tigris and Euphrates are well developed in terms of dams and reservoirs: 24 major reservoirs (capacity >1 billion m^3) are built or planned on the Euphrates (the total number of reservoirs is three to four times this number): the largest dam on the Tigris is the Saddam dam. There are also natural reservoirs, and canals that join the two rivers. Three large natural depressions are used for flood storage upstream of the marshes and a number of barrages are used to divert flow for irrigation. The main source of information on demand in the area were two Iraqi PhD theses which gave information on the operation of dams, storage capacity, etc. A fairly good model of past and present demands was built up with the data obtained.

The marshes are called 'Haur' in Arabic and are generally a few metres deep. They act as very shallow lakes, with marked seasonal fluctuations. They are *Haur Dalmaj* (350 km^2), used to store water from the outflow, *Haur Qurnah* (2500-9200 km^2, 1.2-11.6 billion m^3), *Haur Huwaizah* (650-3500 km^2, 0.2-2.4 billion m^3) and *Haur Hammar* (600-2900 km^2, 0.5-1.8 billion m^3).

The areas that fluctuate are fringed by semi-aquatic plants. As they expand the submerged vegetation provides a rich source of food for aquatic and semi aquatic life and a fine hydro-ecological balance then develops.

Data summary and analysis

In Turkey, a large proportion of runoff is from snow melt and there is marked gradient in precipitation from 480 mm a^{-1} at Erzurum to 400 mm a^{-1} in Northern Iraq (Mosul) and 170 mm a^{-1} in Southern Iraq (Basra).

Flows upstream of the marshes are 21.2 billion m^3 in the Tigris at Mosul (area 54,900 km^2) and 32.6 billion m^3 in the Euphrates at Hit (area 264,100 km^2).

The streamflow data were not as comprehensive as the rainfall data. Although data were obtained from the 1930s, some of the records were not available and the data obtained for Iraq only extended up to 1975. The data for artificial influences were reasonable, but not fully comprehensive.

As the stream flow records were incomplete, it was first necessary to do some data infilling. For rainfall, cross-correlation methods were used, and for streamflow a seasonal regression model was used which had to take account of the lag due to snowmelt.

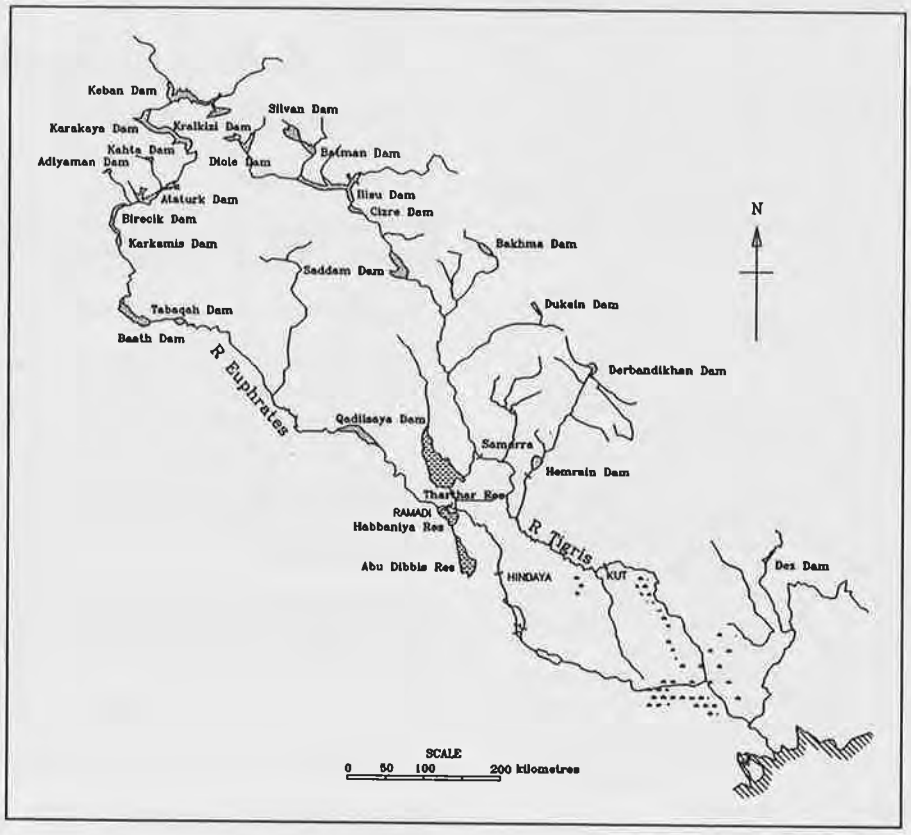


Figure 1 The Tigris and Euphrates basin

Simulation of river basin

Three separate models were used: two simulated the river system (the Euphrates at Hit and the Tigris at Mosul), while the third model simulated the operation of reservoirs and the marshes, taking account of inflows, storage and discharges. However there were complications: the power capabilities of the turbines were known, but there was no accurate measure of actual demand and therefore this was estimated; this was also the case for water demands for irrigation and an estimate of actual demand was made.

Simulation of the main river system was carried out using four scenarios:

The *Traditional* scenario simulated how the rivers would have behaved, had no dams been constructed; the *Historic* scenario simulated the development that has occurred from 1930 to the present day, taking into account the different dams which have come into operation and the change in irrigation demands during this period; in the *Present* simulation the present level of development in the river basin was modelled, and the *Future* scenario simulated the reservoir system incorporating all the future developments proposed in the river basin. In this simulation evaluating future demand was a problem: the publicly available information on development plans of the major water users suggested that they tended to exaggerate the future level of demand that they required.

A difference of views was noted. The Turks view the Tigris and Euphrates as one river basin, and therefore consider their share as a proportion of both. However, if they were considered as separate basins (the view of Syria and Iraq), then since Turkey's potential from the Tigris is small, they would not be able to take any more from the Euphrates. If considered as one basin, Turkey could take its share of the Tigris out of the Euphrates instead.

Simulation of the marshes

Two scenarios were looked at: *Traditional*: no major engineering works in the marshes, and *Drainage*: influence of a drainage scheme, which has been under development since the 1950s.

Iraq built the drainage scheme to take highly saline water from the end of the irrigation system in the marshes directly to the sea. This was perceived by the western world as a ploy by Saddam to drain the marshes to destroy the habitat of the marsh Arabs, but there are technical reasons for the scheme. The scheme does drain the marshes somewhat, but not to a serious extent.

The model looked at the operation of natural reservoirs and irrigation schemes, considering three main marshes. In the model it was assumed that past abstraction rates would continue. There was no detailed information on the variability of the marsh areas. There was satellite imagery available which would have given a good picture of the seasonal development and recession of the marshes, but the cost was prohibitive. First, the normal variation of the marshes was looked at.

Three main losses were considered: evaporation, infiltration and the initial wetting loss caused by flooding of dry land at the margin of the marshes (a significant factor).

Findings of study

At Qadisiyah, upstream of the marshes, the flow is already reduced to about half its previous discharge. It was found that the operation of reservoirs for hydro-electric power was causing a dampening effect on the discharge in the Euphrates which could completely alter the character of the marshes. As there is less development on the Tigris the effect on the flows was much less. If no development took place, there was a large seasonal fluctuation in area of both *Haur Qurnah* and *Haur Hammar*.

With the present level of development it was found that at *Haur Qurnah* the area and the seasonal fluctuation of the marsh is significantly reduced, while local works had little effect on the marsh area. With the model it was shown that if the proposed future engineering works upstream of the marsh areas took place there would be serious damage to the marshes, which could lead to their destruction in the next twenty years.

In discussion it was asked why a five-year moving average was used to plot the data. Ron Manley said that this technique was used in an attempt to identify trends in the data. The question of water quality was brought up: Turkey says that it is keeping water at the top end at 1000 ppm salinity, and while this is acceptable for irrigation, by the time it reaches the bottom end, the salinity could be dangerously high. There is also a potential danger from saline groundwater intrusion as the marshes dry out.

Water quality was not studied in this survey and it is recommended that this should be the subject of future work.

The last question concerned the loss rates used in the analysis associated with evapotranspiration and infiltration, which were found to be in the order of 2m a^{-1}.

Political and economic aspects of water in the Middle-East

The second speaker was **Professor Tony Allen** (School of Oriental and African Studies, University of London), whose talk centred on the political and economic aspects of water in the Middle-East.

The Arab regions are some of the driest in the world. In these areas the only main surface water resources are the rivers Nile, Tigris, Euphrates and Jordan. In most parts of the Middle-East there is a great shortage of water. The present demand for water is twice as much as there is available, and it is thought that in 40 to 50 years the demand will rise to four times the available yield.

However, the available yield is adequate to meet the demand for water for domestic and industrial use, both now and in the foreseeable future. The main problem concerns agricultural use. A key point is that water used for food is accessed via world trade, and this will continue to be the case. The concept of virtual water was used to describe the trade of water for food. To produce one tonne of grain takes 1000 tonnes of water, therefore to import a tonne of grain is equivalent to importing "virtual water".

With respect to political economies in the Middle-East, Prof. Allen outlined how economies operate in 'problemsheds' not just watersheds, and added that problems of living in watersheds can be resolved. He then went on to point out that the economics of water are subordinate to those of the political economy of global food production and trade. The main Policy priorities are to achieve a higher level of economic development.

With respect to changing patterns of water use, Tony Allen pointed to the experience of Israel, where rapid expansion of water demand occurred in the 1980s, but two droughts then forced recognition of the need to reduce consumption. It was noted that 97% of Israel's GDP was from the industrial sector of the economy, yet agriculture is the main water user. Hence there was a recognition that agriculture should reduce its water consumption.

More generally in the Middle East, 80% of water consumption is by agriculture, which produces less than 20% of the GDP and employs less than 10% of the workforce. It is therefore apparent that more effective use of water resources is needed, and that consumption by agriculture should be reduced.

Egypt is an example of a country which has reached the limit of its use of available water resources, and moved towards large imports of food and hence "Virtual water". Currently 83% of GDP is industrial, 17% agriculture. This displacement had been increasingly recognised in the study of political economy in 1990s.

It is evident that the Middle East is a vulnerable region due to the scarcity of water, and is dependent on the capacity and stability of the world trade in food. Policy makers and those allocating resources should focus on evaluating

global food production. However in Prof. Allen's opinion, there would be no water wars in the Middle East, as there will be adequate access to virtual water via world trade.

After a general discussion, Prof. Wheater thanked both speakers for what had been two stimulating, informative and thought-provoking presentations on a topic of major contemporary importance.

Jason Small
Imperial College

HYREX — the Hydrological Radar Experiment

BHS and Royal Meteorological Society joint meeting Imperial College, London 26th April 1995

HYREX (the HYdrological Radar EXperiment) is an initiative set up by the Natural Environment Research Council (NERC) to investigate the measurement of precipitation using radar and to assess ways of using these radar measurements to study precipitation fields. This joint BHS and Royal Meteorological Society meeting was organised by Professor Howard Wheater so that research teams from several institutions could present six talks on different aspects of the experiment.

Professor John Harries was in the chair. **Professor Mike Hall** (IHE Delft) began with an overview of the history of HYREX. The initial impetus came from the NERC Steering Committee on Hydrological Applications of Weather Radar (which later became the Inter-agency Committee on the Hydrological use of Weather Radar), and the project grew into a NERC special topic with support from the UK Met Office, the National Rivers Authority, North West Water plc, the Engineering and Physical Sciences Research Council and the Ministry of Agriculture, Fisheries and Food. The experiment was planned to run from September 1993 to September 1995, although research teams began their work at different times.

One of the aims of the project was to develop a multidisciplinary collaborative research community: to this end, at this midway point in the programme, three workshops have been held for teams to present and discuss progress and future directions and exchange ideas. A further aim is to collect an extensive data archive (stored at the Institute of Hydrology) accessible by all members of the HYREX community. In particular, data are available for a number of 24-hour Intensive Observation Periods (IOPs), for which data from radar stations and raingauges are combined with data from aircraft flights and radiosondes to produce a very detailed picture of the atmospheric conditions. Five of these IOPs have taken place to date; more are planned for the summer of 1995.

Bob Moore (Institute of Hydrology) began with a talk entitled *Design of radar/raingauge networks for hydrological use*, a review of the requirements for rainfall field estimates in the hydrological sciences, aiming to establish how these can best be met using networks of radars and raingauges. Bob focused on the installation of a dense network of data-gathering devices across the catchment of the River Brue in Somerset, and on the question of how well radar and raingauge measurements actually reflect true rainfall intensity.

The River Brue, chosen as the focus of HYREX, drains a catchment of 132km^2. Three radars scan the area: Cobbacombe Cross to the West, Wardon Hill to the South, and Chilbolton to the East. A dense network of 51 0.2mm tipping-bucket raingauges has been installed across the catchment. The HYREX database also includes data from an optical disdrometer (for measuring drop sizes, hence examining the relationship between radar reflectivity and rain rate), an automatic weather station, a soil moisture station, and a river gauging station (at Lovington on the Brue).

The raingauge network was designed by a team from the Institute of Hydrology, University College London, Nuffield College Oxford and the NRA. The catchment was divided into thirty 2km grid squares, coinciding with those of the Wardon Hill radar station: 21 of the squares contain a single gauge; a further seven contain two gauges, and the remaining pair (one in a 'low-relief' and one in a 'high-relief' area) contain dense networks of eight gauges each. The configuration within these eight-gauge squares — a 'diamond•within a square' pattern — will minimise the expected squared estimation error of areal average rainfall over the square.

Bob described preliminary empirical assessments of the rainfall sensor accuracy. Raingauge quality control is carried out monthly by examining cumulative rainfall totals for each gauge: outliers can thus be detected easily. Error logs giving details of any problems are also received regularly from Allwater Technology, who maintain the gauges.. The effect of a single suspect gauge on estimates of the rainfall field was graphically illustrated by comparing two contour plots, one derived from all the gauges and the other from all but one, which was known to contain a mouse nest. Small animals, it would appear, can have a dramatic effect on the climate!

The accuracy of radar measurements can be assessed by comparison with operational gauge measurements. The results for the Brue were: that the Wardon Hill radar is underestimating rainfall intensities by around 50%, although the accuracy decreases with increasing rain rate. It did seem, however, that in the low-relief area of the catchment, the radar was performing much more reliably than in the high-relief area. It was suggested that orographic enhancement of the rainfall beneath the radar beam could be responsible for this. The Cobbacombe radar estimates of rainfall over the Brue are rather worse than those from Wardon Hill; this is due to the greater distance from the catchment to the Cobbacombe radar.

The talk concluded with some indications of future directions. A more detailed investigation of the sensor accuracy is being undertaken, to quantify the effects of relief and rainfall intensity. Another important issue is the sensitivity of modelled runoff response to errors in the recorded rainfall.

During questions, Paul Hardacre mentioned that similar archives of raingauge data existed from experiments in the United States in the

1970's, and asked if the HYREX programme was merely duplicating this work. Bob said that the availability of new technology allowed greater scope for detailed study. John Goddard asked if the disdrometer data had been compared with that of a nearby raingauge to assess raingauge variability; Bob replied that this had not yet been done, but that it would be investigated in the future. Finally, Stuart Bradley questioned the smoothness of the estimated rainfall fields derived from raingauge data using a multiquadric interpolation technique, and suggested that the effect of such smoothing upon, for example, water balance closures should be investigated. Bob agreed and indicated that this was an area for future study.

The second talk was by **John Goddard** (Rutherford Appleton Laboratory) and **Anthony Illingworth** (Department of Meteorology, University of Reading). Entitled *Verification of polarisation techniques for improving radar estimates of rainfall*, the subject was quantifying the improvement to radar estimates obtained by using radar techniques which rely on comparing the phase and intensity of vertically and horizontally polarised radar returns. The primary data source is the high-resolution multiparameter radar at Chilbolton, an experimental S-band radar with a narrow beam width. Radar accuracy is assessed by comparing radar data with those from three rapid-response raingauges, and *in situ* validation is provided by the Meteorological Office C-130 aircraft during Intense Observation Periods.

Polarisation techniques can measure the oblateness of raindrops, allowing a more accurate estimation of their size than by conventional methods, which assume that raindrops are spherical. This can help to improve the parameterisation of the relationship between radar reflectivity and rainfall rate. Results from an event on the 13th-14th September 1994 gave excellent agreement (to within 10%) between radar estimates of 60-second rainfall totals by this technique and measurements at a rapid response gauge beneath the radar beam (measurements at shorter time periods are affected by the unrepresentative nature of the gauge).

Another use of these techniques is in detecting hail, which typically gives very high reflectivity. Because hailstones tumble as they fall, they appear to the radar far more spherical than raindrops and can thus be identified. A correction can then be applied to the reflectivity/rain rate calibration.

Finally, cross-polar methods can be used to detect the height of the 0°C isotherm in the atmosphere. This is useful in correcting for the 'bright-band' effect in radar data, where reflectivity is dramatically increased by the presence of large melting ice crystals. The melting snow/ice gives a large cross-polar return, whereas embedded convection in the atmosphere (which will also give a high reflectivity, as it generates a lot of rain) does not, allowing the two to be distinguished.

Further information on this work can be obtained via a World Wide Web site at the Rutherford Appleton Laboratory. The address is http://rcrul.te.rl.ac.uk/.

In the discussion **Keith Browning** mentioned that other techniques could be used equally well to distinguish between bright band and embedded convection (for example, radar scans at different levels in the atmosphere will show embedded convection at all levels, whereas the bright band will only show up at one level). **Paul Hardacre** pointed out that intense hail is a potentially serious problem which should be studied in its own right, not just as a nuisance factor in the measuring rainfall. It was generally agreed that this issue had been neglected by the research community.

The third talk, *Vertical radar reflectivity profiles through storms*, was given by **Ian Cluckie** (Department of Civil Engineering, University of Salford). Knowledge gained from this study of the vertical structure of the atmosphere will assist in the detection of the bright band effect, as well as providing insight into the effects of orography on rainfall rate. A pair of mobile vertically-pointing radars (VPRs) is being used, each operating at 3cm (X-band) wavelength and providing high-resolution data (7.5m) through a column of the atmosphere every 2-4 seconds. Such vertical sections through the atmosphere are termed *vertical reflectivity profiles*. The second of the radars was built and funded entirely through HYREX.

To investigate the bright-band effect, experiments have been carried out in the north-west of England. By studying the time series of vertical reflectivity profiles at a site, it is possible to assess variations in bright-band height and hence to develop algorithms for correcting normal radar data for the effect. Findings indicate that when a bright band is present, its height is fairly uniform over space and, to a lesser extent, over time given consistent meteorological conditions. Algorithms have been developed to detect the presence of a bright band automatically, and hence its height and thickness: the results can then correct conventional radar estimates for the bright band effect over the scale of an urban area (in this case, Manchester).

To study the effect of orographic enhancement, VPR measurements have been made over transects across the Pennines, an area where enhancement is known to occur. This allows the spatial variability of vertical reflectivity profiles to be assessed, and will address the question of how well a single vertical reflectivity profile can be expected to represent the profile over an area. In addition to the work in the Pennines, future work will bring one of the VPRs down to the Brue, where it will complement the existing network of rainfall sensors.

At the end of the talk, **John Goddard** asked if Ian had any feeling for how well the calibration procedure was performing, when applied to data from the Hambledon Hill radar (which overlooks Manchester): Ian was confident in the results at altitudes above 700m, but said that more work was needed on the reflectivity profiles at lower heights. Paul Hardacre asked if wind drift beneath the radar beam was cause for concern with high-resolution data — the answer was yes. Keith Browning asked what spatial scale of measurements were required, from the point of view of flood forecasting and control (since for small urban catchments, it is very often highly localised and intense rainfall which gives rise to problems, where there tends to be no bright band problem anyway). Ian's reply was that this work is geared towards large urban drainage areas, where the focus of study is not so much on extreme behaviour as on 'average' events. £13 billion is to be invested in urban drainage infrastructure over the next decade, and high quality radar data is required over the entire area to assess requirements accurately. Such a scheme will produce a 16-20% return on investment in the long run, it is anticipated.

The second half of the meeting turned towards the use of precipitation data in studying rainfall fields. The first talk, *Analysis and modelling of spatial-temporal rainfall fields*, was by **Richard Chandler** (Department of Civil Engineering, Imperial College). After briefly reviewing the hydrological uses of weather data, Richard focused on two problems: the development and fitting of stochastic spatial-temporal models of rainfall, and the disaggregation of the output from meteorological General Circulation Models (GCMs) to produce realistic rainfall patterns 'on the ground'.

The spatial-temporal rainfall models being developed are intended for use in hydrological applications such as design rainfall, where the primary aim is to simulate rainfall fields on a computer, over long periods of time. The output can then be run through models of surface processes to improve our understanding of surface hydrology. The models being considered are of the stochastic/mechanistic type, and aim to incorporate some broad physical knowledge about the behaviour of rainfall, while keeping the underlying mathematics relatively simple. Such an

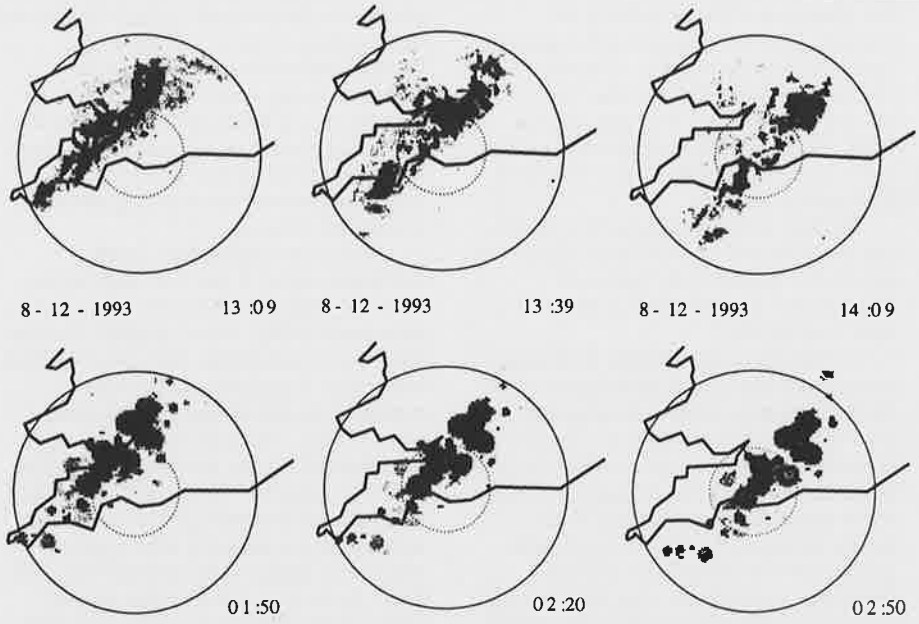


Figure 1 Sequences of actual (top) and simulated (bottom) images from the Wardon Hill radar station

approach has some advantages: the models have few parameters; each parameter has a physical interpretation; the incorporation of stochastic elements allows a single model to generate many different scenarios. By way of illustration, Figure 1 shows a sequence of 'real' data from the Wardon Hill radar station, together with a sequence of simulated data from one of these models. The simulation was produced by randomly scattering circular 'rain cells' about a moving 'storm origin'; each cell has a random intensity, size and temporal lifetime, and moves with the storm. The simulated rainfall intensity at a point equals the sum of contributions from all cells hitting that point. In this case, the cells were scattered over a long narrow ellipse to simulate the appearance of a rainband. By varying the ellipse parameters it is possible to produce rain more uniformly spread across the area.

Estimating model parameters from data is a difficult problem because of the complex dependencies in both data and models. The conventional approach is to select a set of 'primary features' in the data (such as mean rainfall intensity, variance, low-order autocorrelations, probability that a region is dry), and to choose parameters which reproduce these features, in some sense, as closely as possible. This has the disadvantage of being highly subjective: parameter estimates are sensitive to the choice of features used in the fitting. An alternative method now being developed, is to take the Fourier transform of the data: the Fourier coefficients thus obtained turn out to be approximately independent, so conventional statistical techniques such as Maximum Likelihood estimation can be used. The necessary theoretical work has been done for a wide class of models, and a large programme of data analysis using the technique is under way.

The rainfall disaggregation problem was then discussed. The issue here is that GCMs provide output over a coarse spatial grid (typically 200km^2) and the GCM output is used to update the surface hydrology. However, rainfall is spatially variable and allowance must be made for this. Existing techniques (as used by the UK Meteorological Office for example) consist of deciding on a proportion of the grid square which is wet (the *coverage*), and then, at each 'wet' pixel, allocating a rainfall depth according to an exponential distribution, independently of what has gone before and of neighbouring pixels. The main points to be addressed are: given a grid square is 'wet', the coverage depends on the size of the square; some spatial and temporal memory also needs to be incorporated to make the procedure more realistic. Initial work shows that the time series of coverage is highly correlated with that of mean rainfall depths over the grid square, and this can be used to generate realistic coverage sequences from the GCM output. Future directions include the incorporation of spatial dependence into the scheme (techniques from the field of statistical image processing are being investigated) and validation of results across extensive datasets.

During questions, **Anthony Holt** asked how the quality of the radar data would affect the results from the spatial-temporal model fitting — the response was that work is restricted to a small number of storms where the data are known to be of good quality. Keith Browning suggested that to quantify the effect of data error models should be fitted using different windows of data: some close to the radar station where the quality is good, others further away where the quality is known to be worse. He went on to ask what time period is being used for fitting models — the answer was that models are being fitted to individual rain events, and the time period could be anything from 4 to 12 hours. **Stuart Bradley** wanted to know how to decide on the number of Fourier coefficients to calculate in the model fitting procedure — since the data are discrete, only a finite number of coefficients are available, so all of them are calculated. Finally, **Anthony Illingworth** pointed out that for the disaggregation problem, the results obtained are likely to be highly dependent on weather type. Richard agreed, and said that work is in progress to develop an objective scheme to classify weather types for this very purpose. **Professor Harries** commented that the kinds of models discussed in this talk could, in principle, be applied equally well to cloud systems.

Next to speak was **Dale Mellor** (Department of Civil Engineering, Newcastle University), who presented *A stochastic space-time rainfall forecasting system for real-time flow forecasts*. The forecasting system being developed here uses the Modified Turning Bands (MTB) model to generate equally likely short-period forecast scenarios of a rainfall field: as in the previous talk, incorporating stochastic elements allows generation of an ensemble of different forecasts. The model is designed for use within a single rain event, and has a hierarchical structure (Figure 2): underlying the model is a random 'potential function', generated by superimposing a deterministic sinusoid onto two sets of parallel, randomly distributed parabola-based prisms. This potential function is then used to generate raincells according to an inhomogeneous Poisson point process: where the potential function is greater, more raincells are likely to occur. The raincells themselves are described as inverted parabolas of revolution, with each cell having a peak which grows and decays quadratically over its lifetime. The reasoning behind this is that the parallel prisms generate clusters of raincells where they intersect, and the sinusoid superimposes a 'rainband' effect.

The main difficulty with this model, as with those described previously, is in the fitting procedure. The methodology has now been developed so that the model can be fitted to data from either a raingauge network or a radar station. Broadly speaking, the fitting procedure identifies the rainbands in the data 'by eye', and then fits cells individually. The cell fitting is done by subtracting contributions from individual cells until no more data remain. The result is a scenario where,

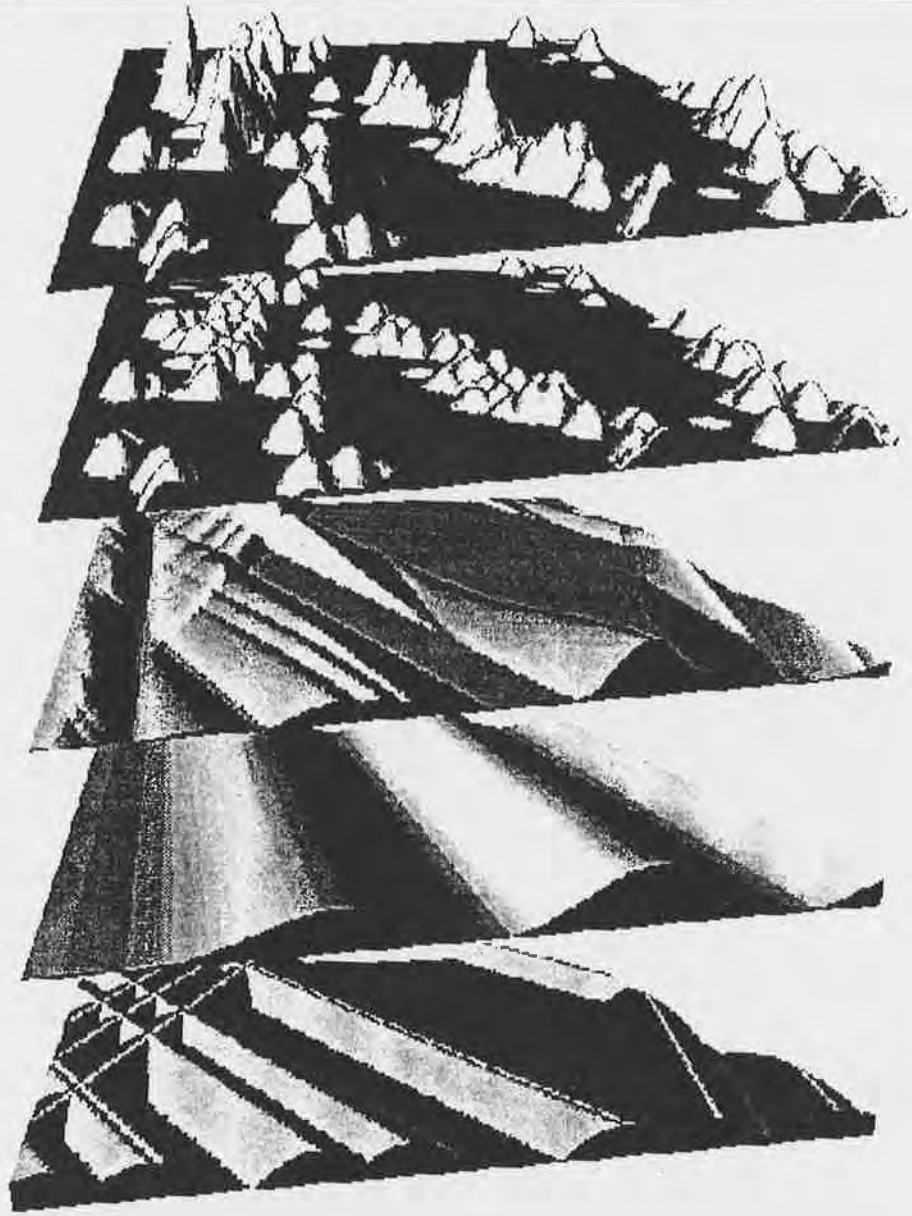


Figure 2 Construction of the MTB model: from bottom to top, the placing of two sets of parallel prisms, the deterministic sinusoid, the resulting potential function for raincells, a distribution of raincells, and the final rainfall field summing the contributions of all the raincells

at any point in time, the locations and times of birth of all active raincells can be calculated from data: forecasts can then be produced by extrapolating forwards. The stochastic nature of the forecast arises because, in the extrapolation procedure, new cells will appear at random within the structure of the fitted rainfall field.

Some results of 5-, 15- and 30-minute ahead forecast sequences, based on Wardon Hill radar data, were shown and compared with the actual sequences. The talk concluded with some indications of future directions: the next major phase was to use the forecasts as input to catchment runoff-response models.

Questions came from Anthony Illingworth, who pointed out that the images produced by the MTB model were much more grainy than the real data, and wondered how much of a problem this was likely to be. The answer was that there is some uncertainty in this area but that a better picture would emerge when the model has been used with catchment runoff models. Keith Browning asked whether the extra complexity of this model over that described by the previous speaker was justified: Dale said it was, as the MTB model explains all the data that are appropriate for the purposes of forecasting. Anthony Holt questioned the uniqueness of the inversion procedure used to fit the raincells to data: Dale was fairly adamant that, although the fit is certainly not unique, this is not a cause for practical concern.

The final talk of the day, also dealing with forecasting, was by **Mike Pedder** (JCMM, University of Reading) and **Vicky Bell** (Institute of Hydrology) on *Methods for short-period precipitation and flow forecasting incorporating radar data*. The approach to the short-period forecasting problem was deterministic in this case, the objective being to obtain and verify forecasts at the catchment scale and to develop an understanding of the processes affecting small-scale variability.

The methodology was to use the Meteorological Office mesoscale model to describe the mesoscale moisture budget associated with frontal rainband passage. This model provides precipitation forecasts directly, as well as other meteorological variables that can be used as input to the other forecasting applications. The mesoscale model forecast is used as an initial step to provide 'sensible' data on components of the atmospheric water balance, and is complemented by analysis of data from some of the HYREX Intensive Observation Periods, giving detailed information about the moisture budget on a finer spatial scale. A method for short-period forecasting, incorporating an analysis of the moisture budget, has been developed and successfully tested, and this work will be extended as data from more IOPs become available. An extension to the model is the ability to assimilate radar data at different levels in the atmosphere, in order to track a storm as it moves across a region.

In the concluding discussion, Professor Harries gave credit to NERC for instigating such a wide-ranging and comprehensive research topic. Keith Browning asked what was the vision for the future, both for HYREX and for the research community which it has established. Mike Hall pointed out that the project is still at a 'mid-term' stage, and future directions are perhaps not yet clear. Most of the research teams are about to embark on an extensive programme of data analysis over the next few months, after which the way ahead will become more focused. It was stressed that there is enormous potential for going much further with this kind of collaborative effort: the UK has many strengths in this area which are perhaps not always appreciated and there is considerable export potential for this kind of expertise. Finally, Peter Walsh commended the way the project had bridged the meteorology/hydrology divide, and hoped that the future would bring much more of the same.

Richard Chandler
Imperial College, London

Guidelines for visitors conducting research in other countries

At the 1994 International Convocation of Geophysical Societies (ICGS) it was agreed that guidelines be developed, especially for young scientists to indicate the ethical behaviour which should be expected of those carrying out research in countries other than their own. The guidelines are particularly relevant to work in developing countries. The guidelines were prepared by Ian Dalziel on behalf of the ICGS and were agreed by ICGS in Boulder in July 1995. I have adapted the guidelines to the hydrological context. They are set out below:

- The visiting hydrologist is working in a foreign country that is the home and principal study area of other hydrologists. He or she has an obligation to plan and conduct research with that firmly in mind.
- A visiting hydrologist must respect not only the sovereignty, laws and environment of the country in which he or she conducts research, but also the dignity and intellectual rights or its scientists, and indeed the well-being of all its inhabitants.
- The goals for interaction with scientists of the host country should be unselfish co-operation in research and enhancement of that country's science base.

Such research places obligations on the visiting scientist:

(a) Official

Many countries have strict legal requirements for foreign scientists seeking permission to conduct research in their territory. Shipborne research in territorial waters generally requires direct government to government agreement. There may also be limitations on the importation of electronic and other instruments, and on the exportation of field specimens. Copies of data and field note books may need to be retained by the host country. The science attache at the embassy or consulate of the country in question should be consulted at an early stage in planning.

(b) Unofficial

The onus in on the intending visitor to determine whether or not someone is already studying the problem, geographic area, or topic of interest. This can be done either through personal contacts, or through an organisation such as a hydrological society or national academy of sciences. Whether or not someone is already involved in an overlapping study, and especially if that is the case, every effort should be taken to establish a collaborative programme with one or more scientists in the host country. True collaboration involves intellectual exchange, acknowledgement or previous work and help by others, attendance at local congresses and symposia, joint publication and help with the training of local students. It is also desirable to arrange transfer of equipment, maps etc to local universities or schools upon completion of the project.

(Adapted from ICGS Resolution of July 1995).

Sue Walker July 1995

News from Members

New chair

Dr Angela Gurnell **has been awarded a personal chair at Birmingham University, as from 1st July 1995.**

Stephen Rice **takes up a Lectureship in Physical Geography at Loughborough University of Technology in October 1995. Stephen is currently completing his PhD in fluvial geomorphology at the University of British Columbia in Vancouver. His interests are in gravel-bed river dynamics.**

No ballot

At the last Main Committee meeting, the Hon Sec. reported that there would not be an election before the AGM in September for incoming Committee members as regrettably only single nominations had been received for each of the vacancies. We shall nevertheless be delighted to welcome on board **Richard Harpin** (Hon. Treasurer) and **Mike Acreman** and **Bob Sargent** as Ordinary Committee Members.

Secretaries leaving ICE

Best wishes to the **Louise Picton,** who has decided not to return to ICE after her maternity leave. **Anna Hotowska,** who has been an admirable temporary Secretary to BHS, is also unfortunately leaving ICE to spend more time with her family, so we are temporarily rudderless.

Honorary Member

The Main Committee is delighted to announce that Dr John Rodda has agreed to become an Honorary Member of the Society. John is a founder member of BHS and has always been an enthusiastic participant in its activities. He was until recently Director of Hydrology and Water Resources at WMO. The timing of John becoming an Honorary Member of BHS is particularly opportune, since in July he became President of the International Association of Hydrological Sciences (see report elsewhere in this issue).

President's Prize

The Main Committee is delighted to announce that Prof Des Walling will be the first recipient of the Society's President's Prize. The new prize has been inaugurated to be awarded in recognition of services to hydrology. Des was closely involved in the formation of BHS following the Exeter General Assembly of IAHS in 1982. Since that time, he has continued tomake significant contributions to the Society, most notably in increasing the Society's status and profile with the Royal Society and in international affairs. Until June, Des was Chairman of the UK Committee for IAHS which BHS organises on behalf of the Royal Society. In this role, Des has been a coopted member of the Main Committee for many years. Des is also extremely well known in the technical arena for his contribution to process hydrology, in particular his work on sediments.

OU PhD

Charles Eeles, now a consultant, but for a long time at the Institute of Hydrology, has been awarded his PhD from the Open University. His thesis title is *Probable maximum flooding using quantitative weather radar.*

International hydrology and BHS

The holding of the XXI General Assembly of the International Union of Geodesy and Geophysics (IUGG) at Boulder, Colorado, U.S.A. between 2 - 14 July 1995 marked the end of another four-year cycle of events for the international hydrological community under the umbrella of the International Association of Hydrological Sciences (IAHS), one of the seven associations which make up the IUGG. The lush campus of the University of Colorado, backed by the flatirons of the steep east flank of the Rocky Mountains, provided a beautiful setting for the Assembly, on the occasion of the 75th anniversary of IUGG. General Assemblies of IUGG have been held since 1922. In recent years, these have been convened at four-yearly intervals, in Hamburg in 1983, Vancouver in 1987 and in Vienna in 1991.

The Boulder Assembly

During the two weeks of the Assembly, Boulder basked beneath blue skies with temperatures between 30 and 40o C, and it was hardly surprising that, by Wednesday of the second week, more than 4500 registrations placed Boulder as having the highest attendance ever at a General Assembly. Conditions were perfect for enjoyment of North American barbecue culture, in addition to the scientific fare.

Scientifically, IAHS itself arranged six symposia, each with a pre-published 'redbook'. The topics were effects of scale on the interpretation and management of sediment and water quality, models for assessing and monitoring groundwater quality, biogeochemistry of seasonally snow-covered catchments, comparison of tracer technologies for hydrological systems, man's influence on freshwater ecosystems and water use, and modelling and management of sustainable basin-scale water resource systems. Additionally, there were four IAHS workshops, on information systems in hydrology, predictability uncertainty and prejudice in hydrology, hydrology in developing countries, and quality assurance in hydrological measurements. IAHS was also jointly involved with other IUGG associations in joint symposia and workshops, notably remote sensing of hydrological properties of the land surface, large-scale modelling in mountain catchments, global water balance, and sea level and ice-sheet volume changes.

A large contingent of British hydrologists took part in the sessions organised wholly or partly by IAHS. Inevitable parallel timetabling of sessions dictated selective participation or rapid movements between themes. UK participants in general were prominent as symposia convenors and co-convenors, session chairs and as authors of both oral and poster presentations across the full range of the IAHS scientific activities.

Elections of officers to the Bureau of IAHS and constituent commissions and committees

Administrative matters of IAHS and the six commissions and three committees of the Association are also conducted during a General Assembly. At Boulder, the new procedure of slates of candidates being recommended by nomination panels from amongst names put forward by national committees and existing Bureau was introduced, with the aim of producing Bureau which are balanced over all disciplines and regions. A further change is that whilst the Bureau changes at the General Assembly at which elections take place, the presidents of IAHS and the commissions and committees now take office two years after the Assembly at which they are made presidents-elect. In this staggered system, former presidents remain on the Bureau for two years until the next General Assembly, making eight years in total. Transition to the new system allows for a president to serve in 1995-1997, and a president-elect to serve from 1997 to 2001, or for a president to serve for the period 1995-2001. Mike Hamlin as chair of the IAHS Nominat ion Panel was instrumental, together with the Nomination Groups of Commissions/ Committees, in drawing up the slates of candidates.

Twelve British hydrologists were nominated by the UK Committee for IAHS and/or the existing Bureau of the Association or Commissions, and six were elected at Boulder. an honorary member of BHS, was elected President of IAHS, to serve from 1995 to 2001. He has wide experience of IAHS, gained as Secretary-General between 1979 and 1987. Head of Data Acquisition at the Water Data Unit, Department of the Environment at Reading from 1972-1982 and then Assistant Director of the Institute of Hydrology from 1982-1988, John has recently retired as Director of the Hydrology & Water Resources Department of the WMO in Geneva and become an Honorary Professor at the University of Wales, Aberystwyth.

Elizabeth Morris, Head of the Ice and Climate Division of the British Antarctic Survey was elected President of the International Commission on Snow and Ice (ICSI), also for six years, having served as a Vice-President since 1991. **Bruce Webb** (University of Exeter), a former National Secretary of BHS, was elected Secretary of the International Commission on Water Quality (ICWQ). There are three Vice-Presidents from the U.K.: Eric Barrett (University of Bristol), Alan Gustard and Jim Wallace (both Institute of Hydrology) elected for the International Committee on Remote Sensing and Data Transmission (ICRST), International Commission on Surface Water (ICSW), and International Committee on Atmosphere-soil-vegetation relations (ICASVR) respectively.

U.K. Committee for IAHS

Official contact with IAHS is through so called National Committees, the Chair being the National Representative to IAHS. In the UK, the BHS UK Committee for IAHS performs this role. Each IAHS Commission and Committee is also linked to countries through National Representatives, who are also members of the Committee. Any U.K. officers of the Association (such as Terence O'Donnell as IAHS Editor) and the BHS President are also members of the U.K. Committee. Des Walling (University of Exeter) has been the U.K. IAHS National Representative and Chair for nearly six years, and now hands on the baton to David Collins (University of Manchester), who has been Deputy Chair since 1991. At a meeting of the U.K. Committee on June 9, it was agreed that the term of office of the National Representative to IAHS would be four years, in harness with the IUGG cycle. The following National Representatives were proposed for 1995-1999:

IAHS Dr D N Collins
ICSW Dr A T Newman

ICGW Dr S S D Foster
ICWQ Prof J B Ellis
ICCE Prof D E Walling
ICSI Dr D N Collins
ICWRS Prof E O'Connell
ICRST Prof I Cluckie
ICT Dr C Neal
ICASVR Dr J S Wallace

Commumication between IAHS and the Commissions and National Committees and IAHS members was debated at most plenary sessions in Boulder. Clearly the Internet and World Wide Web suggest new routes for dissemination of information. Home pages for Commissions will probably now be forthcoming and information exchange to members will undoubtedly become easier in those countries which have good access to the net.

Future IAHS events

The next IAHS event in the U.K. is the International Symposium on Erosion and Sediment Yield: Global and Regional Perspectives, convened by Des Walling and Bruce Webb, which will be held at Exeter between 15-19 July 1996.

In the IAHS cycle, the Fifth Scientific Assembly of IAHS wil be held in Rabat, Morocco, 23 April - 3 May 1997, the first circular probably appearing in the autumn.

Birmingham 1999

The Royal Society had issued a formal invitation to IUGG to stage the XXII General Assembly in the U.K. in 1999, at the University of Birmingham. This invitation was accepted during the Boulder Assembly. British hydrology and BHS will therefore be in the spotlight and U.K. hydrologists can look forward to having high profiles internationally during the next four years in the hard work necessary for the preparation of the Birmingham meeting.

David N Collins
University of Manchester

Hydrology on the Internet

It's taken me a while to get to the stage where I can make the Internet professionally useful (although it has been good fun getting there). I hope that the following selection will give you a head start and enable you to find the resources that you personally find **useful.** Net addresses need to be exactly right, and I've tried to avoid one source of error by not putting "normal" punctuation after an address, but please let me know if you find problems accessing them.

1. Mail-lists

To join the BHS mail-list send a request to bhs-hydrology-request@mailbase.ac.uk

2. Newsgroups

Try sci.geo.hydrol for some interesting chat as well as very useful postings.

3. Library resources

You can e-mail the Civils library at library@ice.org.uk, but if you want top-class access to all kinds of library resources (and newspapers etc) then use Telnet to connect to the NISS Gateway. This can be found at niss.ac.uk and is highly recommended.

4. Websites

Try our very own at http://www.salford.ac.uk/docs/depts/civils/BHS/BHS _ Homepage.html or the Water Resource Systems Research Unit Newcastle page at http://wrsu7.ncl.ac.uk which is an excellent setting off point.

The best page that I have come across is the Northwest Pacific Laboratory page at http://terrasa.pnl.gov.2080/EESC/resourcelist/hydrology.html which gives a marvellous set of links to resources, lists, groups, mail-lists, societies and a variety of organisations world-wide. This is a real "must".

More excellent information on web sites can be found in the sci.geo.hydrology newsgroup in two very comprehensive postings called "Using the Web for Geoscience Resources (FAQ)" Parts I and 2.

5. Satellite weather maps

Lots of sites provide both contemporary and archieved satellite images from Meteosat, NOAA etc. The University of Illinois Weather Machine is recommended and can be accessed by gopher at gopher.wx.atmos.uiuc.edu and I'm sure it will also have a web page somewhere. More local images can be downloaded using ftp from Edinburgh University at ftp.met.ed.ac.uk using an anonymous login or from their Web page at http://src.doc.ic.ac.uk:80/public/weather/images/uk/uk.gif which gives images in gif format.

6. Topo maps

What every hydrologist needs when working overseas - good maps! You can get into the CIA map base by ftp to relay.cs.toronto.edu; using anonymous login and changing directory to doc/geography/CIA_World_Map. Or you could telnet to glis.cr.usgs.gov for access to a lot of USGS map and satellite data, which are also on the web site http://edcwww.cr.usgs.gov/glis/glis.html)..

Last, but not least, relax with http://www.infi.net/cool.html or http://wired.com/ or http://www.misty.com/laughweb/

I've tried all of these myself successfully, but Internet addresses frequently change, so I hope the information is still accurate by the time it's printed. If not, you can flame me on

rob@bebop.demon.co.uk

Happy surfing!

Rob Drayton

Invited Lecture Series

Following the request for suggestions for a name for the newly inaugurated BHS Invited Lecture Series, the Main Committee are delighted that the family of the late H L Penman have agreed to the naming of the lecture series in honour of the eminent hydrometeorologist and hydrologist.

The first lecture in the series is planned to take place at the Heriot Watt Symposium, when Prof Uri Shamir of Haifa, Israel and until July the President of IAHS, will present a lecture on water resource management issues associated with the Middle East peace process.

Pennines Hydrological Group

Kevin Tilford (Salford University) has taken over from Tony Lewis as the Pennines representative on the BHS Main Committee. Tony has been on the Main Committee for a number of years and has worked hard for the Society as the Pennines rep. and previously as Hon. Treasurer.

Rainfall modelling

BHS Pennines Hydrological Group AGM
University Of Lancaster
May 17th, 1995

The Pennines Hydrological Group annual general meeting was chaired by Professor Peter Young (Lancaster University) on behalf of the PHG chairman Keith Beven. Over 40 members and guests attended, and after an excellent buffet meal, there was a brief run through the Chairman's report and a statement of accounts by the Treasurer. This was followed by the election of new committee members, and then the afternoon's papers began.

Paul Cowpertwait (University of Newcastle) presented the first paper, "A spatial-temporal model of rainfall based on a clustered point process", describing a relatively simple stochastic spatial-temporal rainfall model. Rainfall cells are represented in the form of disks, each having a random radius, where the location of the disk centres is given by a two-dimensional Poisson process. Once defined, the rainfall intensity represented by each cell remains constant throughout its life, controlled by an exponential random variable.

The model uses two types of cell: heavy, convective cells of short duration, and lighter, longer duration stratiform rain. Research has concentrated on hourly data in two catchments, one in the UK, the other in Italy. Assessments have been made by comparing observed multi-site extreme rainfall with those simulated by the spatial-temporal model. Paul reported that parameter estimates for the two cell types have agreed reasonably with other studies on physical features in precipitative fields.

Christian Onof and Peter Northrop (Imperial College) followed a similar line of investigation. "Stochastic modelling of point and spatial rainfall for flood design" seeks to reproduce spatial-temporal rainfall. The application of Poisson cluster processes was described in the development of both point and spatial rainfall modelling. Here, ellipses have been used to represent the formation and development of storm cells, governed by stochastic modelling. In practice, model performance comparisons have been made with radar images from the Warden Hill device. These have been made available from the NERC Hydrological Radar Experiment (HYREX). Leading on from this, the work has been applied in the generation of stochastic storm sequences for flood design in the Thames region.

Martin Lord (University of Lancaster) presented work on the "Limitations of rainfall estimates made by conventional weather radar". After outlining the advantages of radar in spatial coverage, speed of data access and resolution, Martin went on to discuss the problems of using radar rainfall estimates in hydrological modelling. Here accuracy of the precipitation input, from calibrated radar data, acts as a limiting factor when forecasting the runoff process. The original Collier-Larke calibration, using a small network of ground-based gauges, has been found to be prone to errors, particularly during periods when the radar is affected by severe rainfall measurement problems. Martin has therefore developed a system to address radar and calibration anomalies.

The system consists of two stages: image processing followed by calibration. The initial processing section seeks to address problems in the radar image caused by interference with ground-based objects and various forms of anomalous reflection. Following this, an optimized raingauge network is used to calibrate the radar data with reference to "ground truth". Work is now being carried out to apply the calibrated data to rainfall-runoff modelling, and is reported to be producing promising results.

Next Patrick Arnaud gave a paper discussing the contribution of hyetograph simulation to the knowledge of extreme rainfall. This work concentrates on the use of a stochastic model to generate hourly hyetographs, the results being applied to operational hydrology. Patrick outlined the aims of his research, discussing the event hydrograph in terms of dry periods and storm periods. Initial analysis has been used to gather statistics such as storm duration and mean intensity. The rainfall process is then described by method of moments, in order to define a model for synthetic storm generation.

Comparison using mean and standard deviation has shown good agreement between observed and simulated hyetographs. This prompted Patrick to recommend that the technique might be of use in return period analysis as well as in hyetograph generation.

The subject of "Rainfall forecasting using a simple advected cloud model with weather radar, satellite infra-red and surface weather observations" was presented by Vicky Bell (Institute of Hydrology). The use of simple advective rainfall forecasts, based on radar information in real time, is now well established. However these methods are less effective during development of the rainfall field in intensity or extent, or when storm direction changes. These drawbacks are particularly important when attempting to use rainfall quantitatively in forecasting runoff production. In answer to these problems, the French and Krajewski two-dimensional rainfall forecasting model has been applied. This system, known as the Iowa model, combines an advective scheme with a component representing mass concentration in a vertical cloud column. This should allow operational rainfall forecasting for grids of the order of a few kilometres, several hours ahead. After modification for use in the United Kingdom, the Iowa model has been applied to Warden Hill radar data. The model has been found to work most effectively in frontal conditions, and research continues to improve forecast accuracy in more challenging cumulative events.

The final paper was presented by Tom Spijkers and entitled "Infilling sub-daily rainfall series: the needs of continuous rainfall runoff modelling for flood estimation". One of the most frequently-used forms of flood hydrograph estimation is the Flood Studies Report method. This has the drawback of being event-based, relying on almost arbitrary selection of design rainfall, catchment wetness and base flow. Tom discussed the development of continuous simulation rainfall-runoff models for flood estimation, avoiding such arbitrary starting conditions. In the long term, this depends on generating long sequences of consistent rainfall; in the short term it requires the assessment of suitable models, calibration and generalisation of model parameters. Shorter continuous records of measured, sub-daily rainfall are required. Such records are limited in their availability by the number of gauges and their reliability, which may lead to gaps in data continuity. In response to this Tom outlined the method for infilling chosen records, discussing reliability and shortcomings in the context of rainfall-runoff modelling.

Dr Owen Wedgwood
NRA North West

FORTHCOMING EVENTS

Fifth National Hydrology Symposium

Edinburgh, 4th-7th September 1995

STILL TIME TO REGISTER - JUST !

The ***Fifth National Hydrology Symposium*** will begin with the BHS AGM on Monday evening. This will be followed by an invited lecture on *The Water of Life*, and there will be some practical experiments on the same subject. Afterwards there will be an informal buffet in the University Restaurant.



Technical sessions begin on the Tuesday morning, culminating in the late afternoon with an invited lecture, hosted jointly by BHS and IWEM Scotland, on the new Scottish Environmental Protection Agency. In the evening there will be the President's reception and a buffet supper, in the Great Hall, Royal Museum of Scotland

The Symposium Dinner (and the famous hydrological games) will be preceded by a Reception hosted by the Lord Provost of Edinburgh.

Further technical sessions will follow on Thursday morning and early afternoon.

A variety of accommodation is available on the University campus, ranging from single study-bedrooms (with hand-basin and sharing other facilities) to executive rooms (with *en suite* WC, shower, TV, telephone and tea/coffee-making facilities). Costs vary, in the range £255-400 for the full Symposium package, depending on accommodation type.

Further details from: Kathy Patterson, Heriot-Watt University,, Edinburgh, EH14 4AS. *(Tel: 0131 451 3295; Fax: 0131 451 3170).*

Diary

4th – 8th September 1995
5th National Hydrology Symposium,
Heriot-Watt University, Edinburgh
(see revised leaflet and booking form)

11th – 15th September 1995
XXVIth IAHR Congress: HYDraulics **R**esearch and its **A**pplication next century — *HYDRA 2000*
Venue: ICE, Gt George Street, London
Contact: Dr W R White, HR Wallingford, Oxon OX10 8BA
(Tel 01491 835811)

18th October 1995
BHS Midlands Section
Young Persons' Meeting
Venue: School of Civil Engineering, Birmingham University
Contact: Paul Webster, *address above*

1st November 1995
BHS Pennines Section
"Soil Modelling"
Venue: Newcastle University
Contact: Prof Keith Beven, CRESS, Lancaster University, LA1 4YQ *(Tel 01524 593892, Fax 01524 843854)*

16th November 1995
NERC / BHS / The Geological Society
"Pollutant Transport in Soils and Rocks"
Venue: Inst. of Civil Engineers, London
Contact: Anne Roberts, Institute of Hydrology, Wallingford OX10 8BB *(Tel 01491 692363, Fax 01491 692424 E-mail amr@uk.ac.nwl.ua)*

22nd November 1995
BHS Midlands Section
"Extreme hydrological events in the Midlands"
Venue: *to be decided*
Contact: Paul Webster, *address above*

4th December 1995
BHS National Meeting
"Palaæohydrology"
Venue: Inst. of Civil Engineers, London
Contacts: Dr P L Younger, University of Newcastle; Max Beran, Institute of Hydrology, *addresses above*

21st February 1996
BHS National/Pennines Meeting
"Practical application of quality standards in hydrometry & hydrology"
Venue: Salford University
Contact: Liz Kaar, NRA North West Region, P.O. Box 12, Knutsford Road, Warrington, Cheshire WA4 1HG *(Tel.: 01925 653999, ext. 2131)*

27th – 28th March 1996
CIWEM, ICE & BHS Conference
"Water Environment '96: Supply & demand — a fragile balance"
Venue: ICE, Gt George Street, London
Contact: Lavinia Gittins, CIWEM Conferences *(Tel 0171 831 3110, Fax 0171 405 4967)*

June 1996 (date to be confirmed)
BHS National Meeting with the British Dams Society
"Rainfall and flood forecasting in reservoir design"
Venue: ICE, London
Contact: Dr Hilary Smithers, NRA North West Region, P.O. Box 12, Knutsford Road, Warrington, Cheshire WA4 1HG *(Tel.: 01925 653999, Fax: 01925 415961)*

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