THE NEWSLETTER OF THE BRITISH HYDROLOGICAL SOCIETY

Circulation

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Salford Symposium, September 1997

The BHS National Hydrology Symposium takes place every other year. It is an occasion for members to present the results of their recent work and to discuss a wide range of related topics. The first five — Hull (1987), Sheffield (1989), Southampton (1991), Cardiff (1993) and Edinburgh (1995) — were all successful and enjoyed by those who attended. Next year's venue is the University of Salford, on a pleasant campus only a mile and a half from the city centre of Manchester, one of Britain's most vibrant and cosmopolitan cities.

Organising committee

Dr K A Tilford, *University of Salford* (Chairman)
Prof. I D Cluckie, *University of Salford*
Dr R J Griffith, *University of Salford*
Prof. M Hamlin, *BHS President*
Ms C Kirby, *Institute of Hydrology*
Dr L Kaar, *Environment Agency*
Dr R Mackay, *University of Newcastle-Upon-Tyne*
Mr J Tyson, *United Utilities*

Technical exhibition

There will be an exhibition area at the Symposium, which will provide businesses and industry the opportunity to exhibit their services, products and expertise to the members attending. All types of product related to hydrology and water resources are welcome.

It is hoped that all exhibitors will join in the symposium activities.

Call for papers

The Symposium will address a range of topical issues in hydrology and water resources. Contributions from younger members are especially welcome. Contributors are encouraged to concentrate on the following themes:

- *Hydrology in the urban environment*
- *Remote sensing in hydrology*
- *The impact of climate change on water resources/hydrology*
- *Water quality studies*
- *Hydrological modelling*
- *Hydrology of upland areas*

Abstracts of papers or posters should be submitted by ***15 February 1997***. Papers will be pre-published in the BHS National Hydrology Symposium volume, but it is also intended to post the abstracts on the BHS World Wide Web pages. Please see the Symposium flyer for all the details and the registration form.

The World Wide Web address is: http://www.salford.ac.uk/civils/BHS.

BHS Annual General Meeting

The AGM of the British Hydrological Society will be an integral part of the Symposium. We hope as many BHS members as possible will attend the AGM and the Symposium.

Community water supply in Uganda

A community-based well-digging programme in Uganda faces a few more problems than just where to find water and how to extract it. The Water and Sanitation Sector of the Busoga Diocese Multi-Sectoral Development Programme has a staff of ten: two expatriate engineers and eight Ugandan staff trained as water source constructors, health educators and maintenance technicians. The project area is roughly the size of Yorkshire and 460 water sources have been successfully completed so far.

Apart from the hydrological and engineering considerations of this programme, there are social, economic, political and cultural factors, quite often hidden from people in the UK.

Uganda is listed as the 8th poorest country in the world[1]. AIDS is rife and the life expectancy is 48 for men and 52 for women. The need for clean water is acute: it is an essential building block for good health, itself a necessity for alleviating poverty.

The Province of Busoga, in the south-east of the country, contains an estimated 2.3 million people. However, with growth rates of between 3 and 5% per annum[2] that is changing rapidly. Within this very fertile, agriculturally-rich area (which was formerly rain-forest) one of the main problems is water — quality rather than quantity.

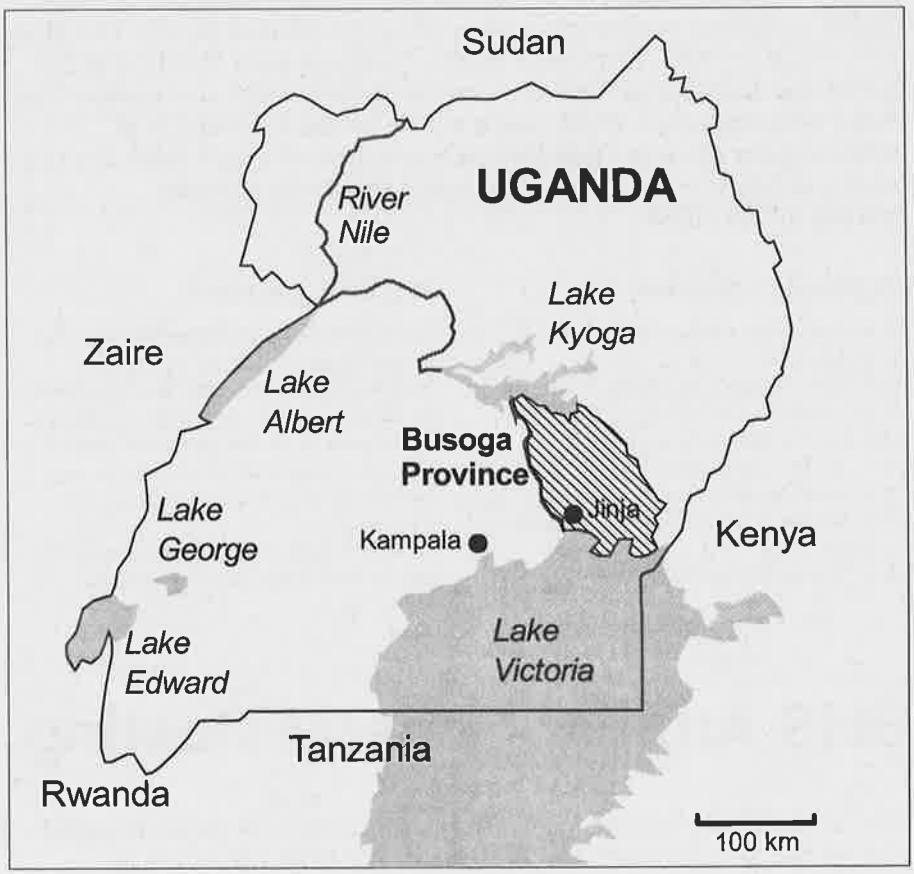
The mean annual rainfall for Busoga varies from 1000 to 1400 mm, with mean monthly figures as low as 25 mm in the dry seasons and up to 220 mm in the wet seasons. With Busoga's proximity to Lake Victoria, and the much smaller Lake Kyoga to its north, the dry seasons rarely produce severe drought conditions, and it is rare for a month in the dry seasons to have no rain at all. The rainfall is almost entirely the product of convectional systems and therefore tends to come as high intensity storms. From daily readings taken in Jinja (the biggest town in the region) in 1995, the highest recorded was 80 mm in a 3 to 4 hour storm, but this was exceptional: 30 mm is common for a heavy storm.

These conditions lend themselves to shallow well construction, since the water table is commonly 4 m or less in the low-lying areas and rarely falls more than 2 metres in dry seasons, allowing a perennial supply of very good quality water. Nitrates are not used on the soil and the only major potential source of pollution is faecal contamination from animals or human beings. Other technologies that have been used successfully by the programme are protected spring construction and rainwater catchment schemes on large tin-roofed buildings such as schools.

Boreholes are a necessity in many of the higher elevations, though they are expensive and costly to maintain. Gravity schemes are not appropriate, since there is little surface water above the lowland areas and the hills are quite small.

But there are some less obvious aspects of the work. Selecting a suitable site for a well is a serious consideration in itself. Not only must the site satisfy the needs of adequate water yield and suitable ground conditions for digging: it must also be where all the community can reach it (if on private land permission must be granted from the owner); in an area where water need is most acute; away from local judicial boundaries that could cause problems of ownership; in an area not too close to nor too far from other protected water sources for reasons of overuse, logistical problems of maintenance and difficulty in obtaining community participation in its construction. Another factor might be that the community *do not want* the water source. It is not uncommon for a community to refuse to participate in constructing a protected water source because they are unsure of its benefits, and they might need some convincing before accepting.

Once a suitable site has been located, the well is constructed by the Programme's technicians and local labour from the community. The work is almost entirely funded by the Programme but the community are expected to bring local building materials (sand, bricks and aggregate) to construct the well. This involvement with the community is crucial to ensure a lasting product: the community must take responsibility for its maintenance and each well has a Water Committee, comprising chairman, treasurer and secretary, who collect funds for breakdown repair and organise community members to look after their well.



The location of Busoga province in Uganda

[1] UNICEF-quoted data 1996
[2] Uganda Census 1991

In general these committees keep functioning and it is pleasing to visit a far off village, two hours from the tarmac road, to be greeted by a man in torn trousers, barely held-together shirt and no shoes, who proudly announces that he is the Chairman of the Well Committee. Committees make contact with the office in Jinja by various routes (such as stamped postcards) and a maintenance technician repairs the well's handpump (usually replacing a worn seal or piston rod connection). This system is soon to be replaced by locally-based handpump mechanics, each able to serve an area of about 500 km², or 50 or more pumps.

Complementing the water supply is a programme of education in sanitation, health and hygiene. This targets communities that already have a clean water source and the ones soon to receive one. Findings from studies last year showed that average faecal coliform counts in protected sources were 40/100ml, while average counts in samples of household water collected from protected water sources were 400/100ml. This deterioration in quality is attributed to poor hygiene practices, and proves that provision of clean water alone is not sufficient to tackle the water-borne and water-washed diseases prevalent in rural communities. Attempting to change such practices is very difficult, as many have their roots in ancient cultural beliefs. An extreme example is the belief that women using pit latrines while pregnant would lose their babies, but on the whole such beliefs are dying out. A common trait is that knowledge of good hygiene and sanitation is widespread, while the actual practice remains poor.

Hence overall health improvements need to be made by ensuring that sources of water-borne and water-based diseases are eradicated from the water supply to provide clean water for ingestion. And for the benefits to be felt fully they must be sustainable, the local communities must be involved and water sources must be able to be maintained. Avoidance of social considerations in such a programme can negate the effect of much of the good work of clean water provision.

Murray Dale
Jinja, Uganda

A shallow well being excavated in Uganda





A newly-completed water source (below), with the water technician, well committee chairman and other members of the community

President's Piece

Let me start by apologising for the omission of the questionnaire referred to in my Piece in the last edition of *Circulation*. Please complete the form enclosed this month. A contribution, however small, will assist young colleagues from developing countries to attend the International Conference at Exeter in 1998.

Members will be pleased to know that **Frank Law**, who has contributed so much to hydrology in general, and to the Society in particular, has been elected BHS President for the period 1997-9: he will serve as President-elect for 1996-7. We are fortunate too to have **Hilary Smithers** as Honorary Secretary for the next two years. The Society depends a great deal on its officers, but their job is made much more rewarding when members let them know in which direction they feel the Society should be moving and how the programme of events could be improved.

The President's Prize was presented to **Howard Wheater** at the AGM in September. Howard was a keen supporter of the establishment of BHS and has been a member of the National Committee since its inception. He has also played a leading role for many years in the affairs of the Southern Section of BHS. Now that Frank Law has become President-elect, Howard has agreed to convene the Scientific Programme Committee of the Exeter meeting.

In the past few weeks the Department of the Environment has published

its paper *"Water Resources and Supply: Agenda for Action"*. It is also likely that before you receive *Circulation* the Environment Committee of the House of Commons will have published the results of their inquiry into Water Conservation. These two papers have the potential to affect thinking on water conservation, resources and supply for the next five to ten years. The Committee is keen that BHS should comment on both these documents, on behalf of its members. In this connection I would appreciate any comments members would wish to have considered by those who will draw up the Society's response.

Elsewhere in this issue you will find a call for papers for the Sixth National Hydrology Symposium to be held in Salford in September 1997. The last meeting in Edinburgh was an outstanding success and I am sure the organisers at Salford are keen to maintain the standard set by Heriot-Watt in 1995.

Since the quality of the meeting depends significantly on the standard of the published papers, members are urged to support the event in Salford by submitting abstracts as quickly as possible.

M J Hamlin

New hydrology staff at Imperial College

Dr Matthew Lees has joined Imperial College as Lecturer in Hydrology/ Water Quality. Matthew has moved from the Department of Environmental Sciences at the University of Lancaster. His specialist interests are real-time forecasting and control of environmental systems, with application to flood forecasting, water resources management and water quality modelling.

Dr Paul Hardisty has been appointed a Visiting Lecturer in Environmental Hydrology. He is MD of Komex Clarke Bond in Bristol and Director of Komex International, Calgary, Canada. His research interests are groundwater contamination, waste management and remediation of contaminated land.

Dr Mike de Freitas has transferred within IC from the Geology Department to Civil Engineering as Reader in Engineering Hydrogeology.

Professor Cedo Maksimovic is visiting the Civil Engineering Department on a long-term secondment from the University of Belgrade. He is an international authority on urban water management and is lecturing at IC on GIS applications in hydrology.

Obituaries

Dr George Edward Hollis (1947-1986)

After presenting a series of thought-provoking and challenging papers to the Fifth INTECOL International Wetlands Conference in Perth, Western Australia, Ted Hollis died of a heart attack on 28 September 1996 at the age of 49. He leaves a wife, Celia, and three daughters, Bryony, Sophie and Amy Victoria.

Ted started his academic career studying hydrological processes in urban areas, but found his true vocation when he discovered wetlands. For more than a decade, he was one of the vanguard that has changed the world view of wetlands from one of wastelands to one of social, environmental and economic importance and outstanding natural beauty. Ted created the Wetlands Research Unit at University College London, he was a founding member of the IUCN Wetlands Programme Advisory Committee and has provided technical support and policy advice to the other major wetland conservation organisations of the world including the Ramsar Convention, the International Wetlands Research Bureau (IWRB), the Asian Wetland Bureau and the Tour du Valat Research Station, to name but a few. His studies took him from the River Mekong in south-east Asia to the River Ver in Hertfordshire, from the North Kent Marshes to the Hadejia-Nguru wetlands in Nigeria and many wetlands of international importance in the Mediterranean.

As a hydrologist Ted brought a new dimension to a subject area which, in the early days, was largely dominated by ecologists. He imposed rigour through mathematical and computer modelling and promoted new concepts, such as sustainability and river basin management. Ted was often controversial and outspoken, but always argued logically and believed passionately in everything he said and did. He inspired his undergraduate and postgraduate students and his many friends and colleagues and commanded respect for his uncompromising appetite for hard work and new research projects. But despite his hectic schedule, Ted always had time for lively and humorous discussion over a beer and a sandwich, telling me about his family and asking me about mine. He will be missed by many in the British Hydrological Society throughout the world.

Mike Acreman
Institute of Hydrology

Peter Andrew Towlson BSc, MICE, MCIWEM

Peter died suddenly on 5th October, aged 50. He was Regional Hydrometric Services Officer for the Environment Agency in the North East and a member of the National Hydrometric Group. Bilbrough Parish Church (where he served as Churchwarden) overflowed with family, friends and colleagues who came to remember his achievements and mourn his untimely death. He leaves a widow, Margaret, two daughters and two granddaughters.

Peter joined the Yorkshire Rivers Authority in 1969 to work on the Derwent Development Scheme which led to the construction of the Barmby Tidal Barrage. It was here that he started his career in hydrometry, with the design and construction of low-cost gauging weirs in the Vale of Pickering. At the creation of the Regional Water Authority in 1974, Peter became responsible for abstraction licensing and water management, the start of a long involvement in resource planning in the region.

Several years later he returned to lead the hydrometric section in the implementation of plans for a network of flow measurement stations on the rivers of Yorkshire. He built gauges on most of the major rivers, using the relatively new and untried techniques of ultrasonic and electromagnetic gauges where conventional weirs could not be used. The advent of the NRA in 1989 saw Peter in charge of hydrometry and resource planning in Yorkshire, the completion of the hydrometric network and installation of new systems of telemetry and data collection. Colleagues will remember his dedication to the task, his attention to detail and his insistence on high standards.

His personal library and interest made him an authority on inland waterways and navigation and he enjoyed holidays cruising on the canals. Peter supported the Pennines Hydrological Group for many years, serving as a committee member and Chairman, and he was a founder member of BHS. His enthusiasm, kindness and consideration will be remembered by all those who enjoyed his friendship.

Richard Franklin
Wakefield, West Yorkshire

New Members

We welcome the following members to the Society:

Baillie, G.	Dougall Baillie Associates Ltd, East Kilbride
Cox, B.A.	Imperial College, London
Clapperton, T.	University College, Scarborough
Stewart, D.A.	Wakefield, West Yorkshire
Ferguson, H.L.	Northop, Cheshire
Gillham, A.T.	Imperial College, London
Grievson, O.J.	Fulham, London
Imamura, Y.	Cambridge
Lam, S.Y.M.	Imperial College, London
Lees, M.J.	Imperial College, London
MacLeod, C.	Imperial College, London
Noble, M.	Scottish Hydro Electric, Pitlochry
Tate, E.L.	Institute of Hydrology, Wallingford
Uppington, T.R.E.	Imperial College, London
Wallace, Dr J.S.	Institute of Hydrology, Wallingford
Wallis, R.P.	Alcan Smelting & Power UK, Fort William

Report of the 13th AGM of the British Hydrological Society

The 13th Annual General Meeting of the British Hydrological Society was held at Imperial College, London on *Tuesday 10 September 1996* at 2 p.m. BHS President **Professor Michael Hamlin** chaired the meeting, which was attended by 32 members.

Professor Hamlin welcomed those present, although he commented that the attendance was slightly disappointing, particularly as a mini-symposium was due to follow the meeting. A report of last year's AGM was noted, but it was not felt necessary to approve it as formal minutes.

The main part of the meeting started with the formal announcement that **Professor Jim Dooge** was to become an honorary member of BHS. Professor Hamlin was proud to have Professor Dooge as an honorary member and paid tribute to his career of great distinction. Professor Dooge said that he felt honoured to receive honorary membership and was particularly pleased to accept it at Imperial College.

The Honorary Secretary, **Dr Paul Younger**, then expanded on his written report. He highlighted several areas of particular interest beginning with the Internet. BHS should be proud of its home pages as they were regularly kept up-to-date and proving very effective. Paul said that 90% of correspondence, especially with younger members, was done over the Internet. Moving on to the post-graduate symposium, he said that the papers gave a vivid picture of what hydrology would be like over the next 10-15 years: the increasing diversity of hydrology became readily apparent with papers on hydroecology, information technology for manipulating data, water quality and chemistry. BHS should embrace the changing nature of hydrology and the main committee were always keen to receive new ideas.

Another area touched upon was the high quality meetings of the regional groups. The south-west region was singled out for particular praise for resurrecting the South West Section: they would be particularly active with the 1998 International Symposium. One slight problem area was the production of Occasional Papers based on national meetings. A couple of expected papers had not been produced, but it was hoped the situation would improve.

Paul Younger ended his term as Honorary Secretary by thanking his fellow committee members and the membership as a whole and extending his good wishes to **Hilary Smithers** who has taken over the role of Hon. Secretary.

Dr Richard Harpin, Honorary Treasurer, summarised his written report. A balanced budget was probable for the next two or three years and it was hoped that more funds would be made available for travel grants. Dr Harpin thanked **Mary McBride** and her team at the ICE for their excellent work in preparing the accounts.

Professor Peter Wolf reinforced the point that there should be increased reserves for travel grants and that special consideration should be given to young hydrologists.

Celia Kirby gave a report on publications, and *Circulation* in particular, on behalf of the editor, **John Griffin**. Members were thanked for their contributions to *Circulation*, as was John himself for editing *Circulation* so effectively. It was hoped that the book review section of the newsletter would be expanded: members could keep the books they review. Professor Hamlin added that the committee was considering producing a BHS house style for future publications, but he would first seek members' views via *Circulation* (as it could involve additional production costs).

The President's Prize was presented by Professor Hamlin to **Professor Howard Wheater** for his long and dedicated service to BHS. Professor Wheater had supported BHS behind the scenes in many ways, such as responding to government consultation papers and overseeing research and was a very worthy recipient of the prize. Professor Wheater, accepting the prize, said he had been pleased to see BHS grow and wished the society every success for the future.

The meeting ended with announcements of the changes to the committee for the coming year. **Frank Law** would become President-elect (taking over as President in September 1997), **Hilary Smithers** would take over as Hon. Secretary and **Chris Soulsby** would become a member of the main committee. Professor Hamlin thanked all the candidates for agreeing to stand.

Richard Howard, ICE
Secretary to the BHS Committee

Travel grants

A subcommittee has been set up to administer the interest from the Exeter Fund and other travel grants. Its four members are the President, the Hon. Treasurer, Dr David Collins (IAHS rep. on the BHS committee) and Dr Jim McCulloch.

Grants of up to £150 are available to help members with the cost of attending meetings (see *Circulation 38* to 47). Please provide details of the meeting, why you want to attend, the costs of attending and other sources of finance. Successful applicants are expected to produce a short report of their experiences in attending the meeting.

Any enquiries should be made to the Hon. Treasurer, Dr Richard Harpin *(tel/fax 01793 812479).*

Impact of hydrological change on catchment management

BHS Pennines Group AGM
University of Sheffield
15 May 1996

Seven interesting and highly informative papers accompanied the Pennines Hydrological Group AGM in this full-day meeting, chaired by *Professor Keith Beven* (University of Lancaster).

The AGM consisted of a short report by the Chairman, followed by a report from the Treasurer, **Rae Mackay** (University of Newcastle).

Brian Hodgson (Environment Agency, Welsh Region) presented a paper entitled "Fisheries management of the Welsh Dee — a regulated river". Many of the effects of regulating the Dee were unforeseen when the project was begun. Brian outlined the main objectives of regulation: to meet abstraction requirements, assist flood mitigation, supply waterways, safeguard fish populations, provide residual flows within tidal fisheries and meet the needs of water sports.

It was noted that the migration and spawning of salmon and trout are most sensitive to changes in the river flow regime. Game fish can move higher up the river system as a result of augmented summer flows, thus changing distribution patterns. Attenuation of the extreme high and low flows has been found to change habitats — an example was increased siltation, resulting in loss of spawning areas. Coarse fish have also been affected by falls in reproduction rates and juvenile growth. A shift in coarse species was seen towards those better suited to faster water. It was recommended that methods of flow regulation should be carefully scrutinised, improvements should be made to tributary spawning areas, habitats within the riparian zone should be enhanced and there should be selective fish stocking. These considerations were particularly important; the impact of water resource schemes should be better understood before they are implemented.

The second paper was by **Paul Boulton** (University of Newcastle) on effects of river management on bird distributions. It examined the effects of land-use change upon riparian bird populations and distributions. Modelling within a geographical information system (GIS) tried to predict the bird species distribution from habitat parameters, and then to assess potential effects of land-use change. Having simplified a very extensive dataset, principal component analysis was undertaken.

Information about water quality was also used, along with an indication of flow velocity given by the slope component. Good correlations were found between predicted and observed distributions for a number of bird species. However, some problems were experienced with species that have a very high or very low incidence.

The approach used did have some drawbacks related to the need to simplify and rescale the datasets. No account could be given to territorial behaviour or the impact of human activities.

Following the AGM and lunch, **Graham Bird** (Environment Agency, North East Region) gave a paper on the impact of the 1995 drought on the biological communities in the River Wharfe. The extreme lack of rainfall in the Yorkshire area, particularly in the west, had caused well-documented problems in 1995. The situation continued through the winter, and reservoir levels in the Pennines were still only about 50% of their maximum in May. The Wharfe had been considered as a source of water to alleviate shortfalls. Graham outlined some of the mitigating steps required to accompany a drought order: oxygenating the river, surveying invertebrate populations, examining possible effects of acidification on plant life and studies of protected species such as crayfish.

Possible impacts on invertebrates were increased siltation as a result of lower flow velocities, reduced dilution of sewage effluents, reduced habitat area, increased exposure to predation and greater susceptibility to temperature fluctuations. The Environment Agency's programme is studying invertebrate populations using kick sampling methods and identification down to species level.

Somewhat surprisingly, the in-stream fauna of the Wharfe was found to be richer, both in the number of individuals and in the variety of taxa present, compared to other years. These results have also shown up in surveys in early 1996 and would seem to show that the normal winter washing out of invertebrates has not taken place in the dry winter. Graham suggested that some of these faunal changes could persist for several years. Overall the biological communities of the Wharfe have withstood the 1995 drought extremely well.

Julie McNish (University of Huddersfield) gave a student paper entitled "An assessment of the spatial sensitivity to acidification of lotic waters in Yorkshire". Acidification of rivers involves a change in water chemistry, with increased numbers of hydrogen atoms. These can mobilise aluminium and other metals. Some acidification comes from the underlying geology or soil type, but industrial releases and drainage can contribute significantly.

Long-term remedial measures, including pan-European emissions reduction, have become more targeted on a regional scale with the development of critical load mapping. There has been a trend from the international scale towards a national basis, but even national policies may be at an inappropriate scale for local river management.

In the Yorkshire region 5% of the rivers are considered by the Environment Agency to be too acidic to support fish. This project aimed to develop a GIS (including surface soil type and solid geology) and to use this to create a regional sensitivity map. Then marginal areas susceptible to acidification could be identified, and an investigation at the tributary scale could lead to management plans related to the catchment's sensitivity.

The GIS modelling showed that the Pennines and North York Moors had low buffering capacity. This was reinforced by tributary scale studies. The River Esk was chosen: a naturally acidic area subject to some acid deposition from power stations. Instrumentation installed for a paired catchment study had been run for about a year. The data still had to be analysed, but there were some results. When it did rain after an extended dry period, the pH dropped by 3 to 4 points, but then returned rapidly to the previous level. After a wet period, a rainfall event still produced a reduction

in pH but the level was suppressed for longer. The conclusion was that careful management of catchments and their land use was needed to protect against the harmful effects of acidification.

"Water transfers to the River Wear: more harm than good" was the title of the paper by **Chris Gibbins** (University of Northumbria). This was particularly interesting in the light of recent discussions about a national water grid. Chris described water transfers in other countries and the need for some type of system in the UK. However, little information had been collected about the ecological impacts of such schemes.

The Kielder Reservoir transfer to the River Wear was completed in 1984 and has been used to augment river flows on eight occasions. The releases were uniform, and the rapid discharge changes produced an angular hydrograph. Possible implications for riverine habitats included increased water velocity and reduced bed coverage by particulate organic materials.

Studies showed that there had not been any gross change in the variety or the number of invertebrate species as a result of these transfers. There was no evidence that the structure of invertebrate communities had altered, although individual species populations did fluctuate at some sites. PHABSIM was used to develop suitability indices for species groups. Whilst the ideal habitats were rarely present, the transfers did improve the situation very slightly. It was concluded that habitats were not significantly improved by river transfers, but are protected from the impacts of extreme low flows which would otherwise occur.

Marc Naura (Environment Agency, North West Region) presented the "Effects of flood defence management on river habitats". He used the River Habitat Survey methodology to classify the physical channel characteristics and wildlife suitability. His approach was to conduct field surveys, check the validity by using a network of reference sites, identify the key factors of river type, use benchmark parameters to calibrate the model and assess the quality of the predictions.

The main aim of flood defence works is to reduce channel friction and increase capacity. This is usually done by re-sectioning and reinforcing river channels, but as a result habitats will usually be lost. Some notable changes in channel features had occurred, with a shift towards smaller channel substrates — from gravel and cobbles to silt and sand. The flow type also moves from riffles and pools to smooth boundary turbulent flow, and there is an underlying reduction in the variety of flow types. The amount of shade covering channels was reduced by tree clearances, and so were the underwater roots, which are known habitats for fish fry.

Marc concluded that 22% of all rivers in England and Wales had been extensively re-sectioned, and 4% had been subjected to reinforcement work.

The final paper, by **Malcolm Newson** (University of Newcastle), was "River restoration — what does it mean?" He explained that the concept of restoration (from the geomorphologist's stance) is dominated by addition of features to the river channel. There are widely varied ideas about how to achieve this and what type of habitats should be created.

Malcolm illustrated some problems that could beset restoration schemes. The first was from the River Don, a tributary of the Tyne, which showed the compromises that must be made between the aesthetically desirable and the financially viable. Historical maps alone were used to design a more sinuous course for the straight channel. This had to be accomplished without reducing the level of flood protection available.

The River Skerne in Darlington was the second example, where a more meandering channel was designed using hydraulic equations. Areas of stiller water were incorporated into the design, allowing a variety of habitats to be created. The presence of a gas pipeline along one bank did, however, limit what was achievable.

The River Cole near Swindon is in a rural setting and so was less constrained in what could be attempted. A sinuous compound channel type was introduced, with a reduced capacity. Neighbouring fields were used as floodplain to take water during times of spate. This river has been returned to a dynamic system, with large amounts of erosion and deposition. Important issues were raised about the exact state to which rivers should be returned, as their form will naturally evolve, and the still limited understanding of the best methods of intervention.

Measuring the success of such projects is very difficult and tends to focus on changing the distribution of features to something more desirable. Some thought-provoking ideas were put forward, concluding with a question as to whether we should see this as an area for restoration, rehabilitation or enhancement.

This very interesting meeting closed with a vote of thanks to all the speakers by Prof. Keith Beven.

Doug Wilson
University of Huddersfield

Lake Lahore

Paul Webster went to Pakistan recently to present a Workshop at the Centre of Excellence in Water Resources Engineering of the University of Engineering and Technology in Lahore. This article describes the scenes on his arrival.

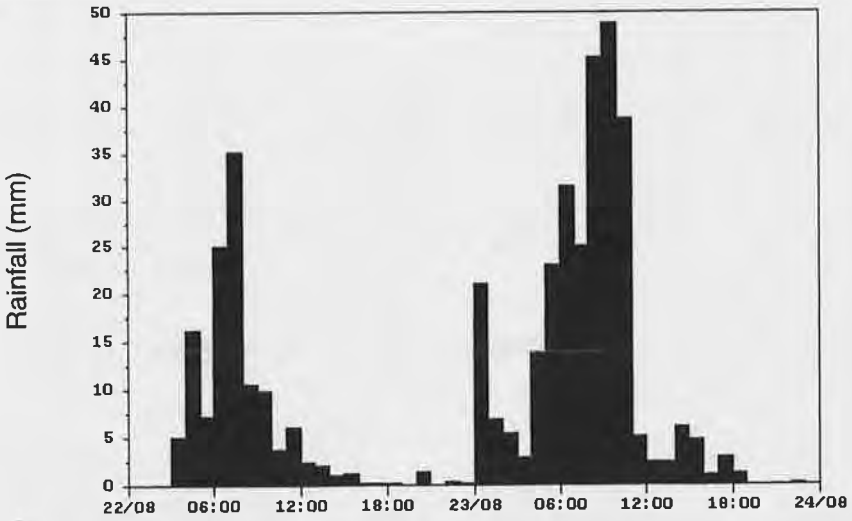
I suppose the pilot of the PIA Boeing 737 was lucky to be able to land at Lahore. We had emerged from the clouds minutes before our touchdown, but only a few seconds were needed to appreciate that all was not well in the city. Torrential rains had virtually transformed it into a lake, from which buildings, vehicles and the occasional brave soul protruded.

The pilot accomplished a smooth landing under very difficult conditions — I had never thought of Boeings aquaplaning until then. The rain beat down noisily on the fuselage as we taxied onto the apron. Soggy-looking ground staff did their best to deal with passengers who were ill-prepared for 10 cm of standing water at the foot of the aircraft steps.

In spite of the havoc outside, the terminal building provided a fairly dry refuge. That was until the sodden remnants of luggage began to appear: by this stage luggage labels were of limited value for anything but papier maché. By the time I was met by my hosts I had rescued my pocket camera, and I recalled what I had said to my wife while packing: "I won't take my [proper] camera. I will be too busy to go looking for scenes of hydrological interest". Now those scenes had come looking for me.

The rain was even heavier as the driver took us confidently away from the airport. He seemed to relish the challenge of weaving his minibus through the flooded streets. The few vehicles around kept close to the centre of the road, where the water was generally, though not always, shallowest. This strategy was made more tricky by abandoned and slow-moving vehicles and by the ubiquitous potholes.

The field hydrologist in me was of course much enthused at this manifestation of what I aspire to teach and research. I have always maintained



Hourly rainfall at Shah Jamal Tomb, Lahore, 22-23 August 1996 (from an Institute of Hydrology logger)

that it is important to get back to the cutting edge from time to time, and here it all was. And then I glanced down some of the side roads. Families were moving around in the flooded streets, the adults waist-deep in water, with small children clinging onto them. It didn't look much fun, and it can hardly have been a joyous experience waking up to find out what the flood waters had done to your home and your business.

It wasn't bad news for everyone: the children were enjoying playing in the rain, especially those who — inspired by the success of their national team — were playing a version of aqua cricket using an exposed pavement as a wicket. The 'posers' in their 4×4s seemed to be gaining some pleasure too, from racing through the streets, saturating poor souls less fortunate than themselves travelling by bicycle or on foot. It seemed vaguely reminiscent of the UK after a major snowfall. It all looks very interesting and is fun for a few folk, but for the majority it's anything from a severe nuisance to a disaster.

I would like to be given some credit for bringing these extreme monsoon rains to an end. Ever the enterprising hydrologist, I fashioned a crude rain-gauge from my toothmug, which I proudly installed on the roof of my lodgings. I measured a further 7 mm over the next hour, before the heavens relented. According to rainfall data loggers, installed by the Institute of Hydrology under an Urban Hydrology Project in Lahore, this veritable dribble brought the total over the 40 hours of continuous rain to 420 mm — not quite up to the 440 mm that drenched me in 30 hours during typhoon Brenda in Hong Kong in 1989, but close enough.

Video footage shown on the national TV network revealed how disastrous the flooding had been in other parts of the city. Some dwellers could be seen trying to recover possessions, wading virtually up to their necks in the streets. The home of one of the hostel staff had been flooded to a depth of 1 m inside the house. To add further agony, the level had receded by only 20 cm in the first 24 hours since the rain stopped. Whoever said urban flooding was of short duration?

Many of the 100 or so fatalities in the city were by electrocution, as flood waters swamped the electricity distribution and switching gear. For once, I was grateful for the lack of power at my hostel. It came as no surprise when the Municipal authorities declared an emergency in the city and called upon the Army for assistance. As the floods began to recede in the urban areas, the focus of attention moved to the larger catchments, with times of concentration of the order of 40 to 50 hours, where dangerous flooding was virtually guaranteed.

From the comfort of my lodgings, with power now restored after 30 hours' interruption, what can I reflect upon?

- Teachers, practitioners, researchers must get out and observe. I have often preached this sentiment and will continue to do so, in the hope that before we try and model anything, we must at least know vaguely what it looks like.
- Always, always take your full camera kit, even if, to quote a certain hydrologist, 'You will be too busy to go looking for scenes of hydrological interest'.
- Urban flooding is bad news. It seriously disrupts transport, business and residential life, particularly in extensive, flat sprawling cities like Lahore where the stormwater simply has nowhere to go.
- Urban flooding is particularly bad news for the urban poor, for it is they who live in the flat, low-lying, poorly-drained areas, and they themselves have nowhere to go.
- And what can be done about it? Well, if there was a simple solution, we would presumably have found it by now. Large capacity drains may offer a hydraulic solution, but are often impractical because of their cost, land take and the need for regular cleaning. The solution is surely better management, both of the stormwater itself and of people's activities in the area. The challenge is to make creative use of the space provided by roads, parks, car parks, etc. for temporary storage of stormwater and practical means of conveying water away from those areas. This would need some strong land-use management by the municipal authorities and planners, working in partnership with local communities, identifying needs, developing solutions and educating residents on issues such as refuse control — still not easy issues to address, let alone solve.

Paul Webster
Birmingham/Lahore

Paul's visit was part of an ODA-funded Academic Link with the Centre of Excellence in Water Resources Engineering, Lahore. The rainfall data were obtained from loggers installed under an ODA funded Urban Hydrology Project (see below). The views expressed in this article are those of an individual author and any recommendations therein do not necessarily commit the ODA or BC to any particular line of action or use of funds.

Lake Lahore again...

Paul Webster's article mentions the ODA-funded Urban Hydrology Project in Lahore, managed by John Packman of the Institute of Hydrology. This project developed through Paul's contacts and has measured rainfall and runoff in various sub-areas of Lahore over three monsoon seasons. Similar measurement programmes are under way in Kanpur (India) and Dhaka (Bangladesh). Unfortunately the Institute's man on site, **Ned Hewitt**, was in Kanpur when the Lahore storm occurred, and consequently we have no photographs of that either, but significant flooding has occurred in Lahore each year — the photograph is one of many taken in central Lahore in 1994.

I wholeheartedly support Paul's reflection that we must get out and observe what is going on before we model: too often high-tech models are used without checking their suitability.

Our project is working with local research organisations to collect data on urban runoff, and thus develop models appropriate to local conditions. The Lahore field programme is now over, but analysis is still in progress. In general we are finding lower runoff volumes than UK experience would suggest, mainly due to huge depression losses, drains blocked with garbage, and diversions into the foul sewers. The Lahoris are largely tolerant and prepared for flooding, although the inconvenience and health impacts (enteritis, malaria) are serious. There are no easy solutions, but refuse control would help, maybe with better storm-water management (as Paul describes), and perhaps with active stormwater control (improved pumping strategies).

Oh, and why do so many street cricketers come out in the rain? With the customers kept away, the workers will gleefully play.

John Packman
Institute of Hydrology



Flooding in central Lahore in 1994 (John Packman, Institute of Hydrology)

HYREX conference

Institution of Civil Engineers
6 November 1996

The HYdrological Radar EXperiment (HYREX) was funded by the Natural Environment Research Council (NERC) as a three-year special topic research programme, starting in 1993. This is a report of the final conference, sponsored by BHS, NERC and the Royal Meteorological Society.

The impetus for this special topic came from the NERC Steering Committee on the Hydrological Applications of Weather Radar, which later evolved into the Interagency Committee on the Hydrological Use of Weather Radar. HYREX received full support from the Environment Agency (EA), the Meteorological Office (Met Office), Ministry of Agriculture, Fisheries and Food (MAFF), North West Water Ltd and the Rutherford Appleton Laboratory (RAL), and NERC granted £ 700 000 to the programme.

The infrastructure provided comprised a dense raingauge network and river flow data from the Brue catchment in Somerset (EA), radar data from Wardon Hill and Cobbacombe, radiosondes and C130 flights (Met Office), a HYREX community database at the Institute of Hydrology (MAFF funded), a Vertically-pointing Radar (VPR) operated by the University of Salford (funded by North West Water), Doppler dual-polarisation radar data from the Chilbolton radar (RAL), an automatic weather station (from the NERC Equipment Pool), and a soil water station plus disdrometer (provided by IH).

In his opening presentation, **Professor Brian Wilkinson** (Director of the NERC Centre for Ecology and Hydrology) described the milestones from the early days of weather radar in 1966 to the present day. He also described the six scientific questions that the HYREX Programme was established to answer:

- What are the structures in rainfall systems and can the parameterization of mesoscale and cloud physics models be improved by using radar?
- What is the spatial structure of rainfall fields and can this be established by comparisons of point and spatial estimates of rainfall using dense raingauge networks and radar?
- Which is the most effective radar system for the discrimination of precipitation (rain, snow, hail, graupel) and for the subsequent use of precipitation estimation in hydrological forecasting?
- Can the outputs from global satellite-based rainfall measurements be improved by using radar/rainfall networks for calibration?
- Do improved spatial rainfall estimates from radar lead to better estimates of runoff and is there any scale dependency?
- Can integrated atmospheric/hydrological models for rainfall and flow forecasting be developed with the support of weather radar?

Professor Mike Hall (Chairman of the HYREX Steering Committee) explained how a community had been established through workshops and Intensive Observation Periods (IOPs) in the Brue catchment. Mike explained that the Brue catchment in Somerset (132 km^2)

was chosen because it had good radar coverage, from the Cobbacombe, Wardon Hill and Chilbolton radar installations. A vital part of the programme was the 49-raingauge network provided and maintained by the EA. With the Automatic Weather and Soil Station data, plus a disdrometer, some unique datasets were available to the HYREX community.

The first scientific presentation was by **Dr Sean Wood** (IH) on the design of radar/raingauge networks for hydrological use. The aim was to review the requirements for rainfall field estimates in hydrology and to establish how they can best be met using networks of radars and raingauges. Statistical analysis and interpretation of raingauge and radar accuracy has enabled the accuracy of different sensors to measure rainfall, in isolation or in combination, to be quantified. Variation of accuracy with rainfall intensity, for different time and space scales, over different storm conditions, was now much better understood. Future work will examine the sensitivity of catchment flow models to this rainfall uncertainty and variability, and the results will give valuable guidance on the raingauge network density needed for hydrological use with a weather radar.

In his paper on verification of polarisation radar techniques for improving estimates of rainfall, **Dr Anthony Illingworth** (Reading University) described the six areas where polarisation techniques can improve on rainfall estimates by radars, which measure only reflectance:

- Use of rapid scan radars,
- Absolute calibration of a radar system,
- Use of the lowest beam from the radar,
- Estimation of the attenuation of a radar beam in heavy rainfall,
- Measuring precipitation due to rain, as compared to hail,
- Identifying the level at which snow melts into rain and a technique to correct the reflectivity of the radar image at this level.

Professor Ian Cluckie (Salford University) gave a presentation on radar hydrometeorology using a vertically pointing radar (VPR), using the latest in microchip technology. Using a PC screen show, Ian showed the development of the VPR at Salford University and results from their VPR in the Brue catchment and in Manchester. Results gained from this project have improved the understanding of the characteristics of "Bright Band" in weather radar data. The expertise and theory established will allow the application of VPR measurements to on-line correction of scanning weather radar data for the adverse effects of Bright Band.

After lunch **Professor Howard Wheater** (Imperial College) described the results from the collaborative project with University College London and Nuffield College Oxford on spatial-temporal rainfall fields: modelling and statistical aspects. This project:

- Examined the basic spatial properties of the raingauge data from the unique datasets from the HYREX raingauge network.
- Developed spatial/temporal models to provide a succinct summary of the data and to be a primary means of generalisation for hydrological applications.
- Considered the implications of spatial rainfall distribution for large-scale hydrological modelling, and focused on some of the problems of disaggregation which can arise.
- Considered, in a preliminary way, the potential of a new family of design methods for hydrological application, through the application of stochastic simulation methods.

Continuing the theme of stochastic modelling, **Professor Enda O'Connell** (Newcastle University) described a stochastic space-time rainfall forecasting system for real-time flow forecasting. The Newcastle team has developed this new technique, based on the Modified Turning Bands method, which provides an ensemble of rainfall field forecasts suitable for real-time application. Used with a catchment model, ensemble flow forecasts were obtained indicating the range in uncertainty of flow estimates.

The last presentation was by **Dr Mike Pedder** (Joint Centre for Mesoscale Meteorology, JCMM) and **Dr Vicky Bell** (IH) on methods of short-period precipitation and flow forecasting incorporating radar data. An important goal of flood hydrology is to forecast catchment scale precipitation and the associated runoff response accurately, in support of flood warning and control. While the resolution of the mesoscale model at JCMM is probably not sufficient for hydrological purposes in a small (<100 km^2) catchment, it could provide information of value in high resolution storm models for short-term forecasting.

Vicky described the use of radar and mesoscale model data in a simple storm model. Results showed that information on rain, contained in the multi-scan radar data, can lead to better rainfall forecasts than those obtained using simpler advection and persistence schemes. These forecasts have been coupled with the PDM rainfall-runoff model and demonstrate the improvement in forecasting flood runoff from the Brue catchment.

Discussion

Discussion centred on the degree to which the HYREX Programme had answered the six scientific questions posed at the beginning of the conference. Apart from the satellite calibration question, which lay outside the scope of the funded projects, it was agreed that significant progress had been made towards answering each question. But, as in all scientific research programmes, it was impossible to explore in depth within the time frame all the issues associated with weather radar. It was hoped that the community established through HYREX would continue its research and development aimed at improving the application of weather radar in hydrology.

Anne Roberts
Institute of Hydrology

BHS Committee news

Dr Hilary Smithers

Hilary has been an ordinary member of the committee and now takes over from Dr Paul Younger as Hon. Secretary.

Currently Hydrological Systems Manager for the Environment Agency North West Region, Hilary has experience of working in several parts of the UK, for both regulator and water company.

She continues to be heavily involved in operational aspects of drought and assessing the implications for water resource planning. Her other main interests include decision-support tools, putting hydrological theory into practice in the real world, and training for hydrologists.

Dr Chris Soulsby

New committee member Chris Soulsby worked as a hydrologist for the NRA for two years. He is now a lecturer at the University of Aberdeen, with teaching interests in hydrology and water resource management. His main research interests focus upon catchment hydrochemistry, aquifer-river interactions and management of rivers and wetlands for conservation purposes.

Dr David Collins

Dr David Collins has moved from Manchester University to the School of Geography, University of Oxford, Mansfield Road, Oxford, OX1 3TB.

Hydrogeology congress in Beijing

International Association of Hydrogeologists Congress at the 30th International Geological Congress 4-14 August 1996 Beijing, China

The 30th International Geological Congress (IGC) attracted a record number of participants, more than 6000. The first IGC was held in France in 1878, and more recently it has become known as the "geological Olympics", being held every four years and attended by earth scientists from around the world. It provides an opportunity to share new geoscientific data and theories and contribute to the development of earth sciences and sustainable development. The scientific programmes of the 30th IGC focused on continental geology, with particular attention paid to interdisciplinary issues. It was fully supported by the Chinese government, with maximum media coverage and an opening speech by Chinese Premier Li Peng.

The International Association of Hydrogeologists (IAH) Congress took place within the framework of the 30th IGC. Symposium No. 16, "Hydrogeology", contained twelve sub-themes, but four topics received my special attention because of my research interests:

- Theme 16-2: Problems of aquifer development / overexploitation and their control;
- Theme 16-4: Hydrogeology of low-permeability strata;
- Theme 16-5: Protection of groundwater resources from pollution;
- Theme 16-9: Conjunctive management of surface water and groundwater; artificial recharge.

About 80% of the presentations in Theme 16-2 came from China and other developing countries including India, Bangladesh and Sri Lanka. They concentrated on environmental problems caused by groundwater overexploitation, particularly in China, where excessive abstraction has led to a consistent decline in groundwater levels and yield in urban areas, subsidence and land collapse in karst areas, and intrusion of sea water in coastal areas — more than 40 major cities in China have polluted groundwater.

In Theme 16-4, W. Zhou and M. J. Apted discussed a potential use of numerical modelling for safety assessment when selecting the underground repository for high-level nuclear waste in fractured and low-permeability rocks in Yucca Mountain, Nevada, USA. The other papers described tracer tests and fractal models in determining hydraulic properties of low-permeability rocks.

Subjects of papers in Theme 16-5 included contaminant transport modelling, heavy metal pollution, acid mine pollution, salt-water intrusion, capture zone delineation and groundwater vulnerability mapping. W. Zhu, A. James & David Lerner (UK) gave an interesting paper on remediation of Dense Non-Aqueous Phase Liquid (DNAPL), such as coal tar, from contaminated land. New computer code, ModGA, which couples flow and transport simulation codes MODFLOW and MT3D with genetic algorithms for optimization of groundwater remediation designs under certainty, was presented by C. Zheng and P. Wang (USA).

Theme 16-9 emphasised quantitative and qualitative understanding of groundwater-surface interactions, and the need for collaboration between hydrogeologists and surface-water hydrologists. Presentations included aquifer pollution by large volumes of waste discharge in an effluent stream in USA, urgent needs for management of surface and groundwater in Beijing, China, and geochemical mixing models in quantifying groundwater-surface interactions.

In general, the hydrogeology themes showed a widespread use of computer and mathematical models in different aspects of environmental hydrogeology. There is no doubt that increasing use of computer models will be required to solve ever more complex hydrogeological problems. The most widely used computer models are USGS MODFLOW and MT3D (S.S. Papadopulos & Associates, Inc.). It is important, however, that interest in modelling does not detract from the continuing need for field work.

The organisers offered warm and friendly hospitality throughout the IGC. The highlights were the welcome reception in the Great Hall of the People at the heart of Tiananmen Square and the farewell party. The organisers also arranged sightseeing to the most magnificent tourists' hot spots such as the Forbidden City, the Ming Tomb and the Great Wall. The 31st IGC will be held in Brazil in 2001, where I am sure the hospitality will be equally good.

Finally I would like to thank the British Hydrological Society for their travel grant of £150 to cover part of the costs of attending this congress.

M. Chen
Aberdeen University

Entries sought for the 1997 BHS Register of Consultants

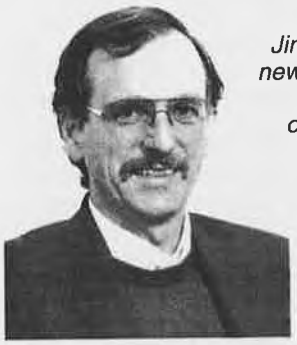
The 1997 version of the *BHS Register of Consultants in Hydrology* is now being compiled, ready for dissemination in the New Year. The register is sent out to all members for inclusion in the BHS handbook and is aimed at both independent consultants and consultancy firms with a hydrological practice. The register provides a shop window for your services and is available through the members to their companies.

Like last year, entries for independent consultants cover a half-page each, with a fixed format:: name, title and letters, telephone, fax and e-mail, address, year of birth, summaries of previous employment and expertise, examples of recent jobs, countries of work and foreign language skills. The charge is unchanged from last year at £15. It would help if new entries were sent on disk.

Consultancy firms are given a full page to advertise their services. The format is free and printing is in black and white. Consultancy firms entries are also entered onto the BHS World Wide Web pages on the Internet (note that a separate format suitable for WWW pages can be submitted). The charge is £100 per entry and camera-ready copy is required.

If you would like to subscribe for the coming year, please send the information requested, together with your cheque payable to the *British Hydrological Society*, to Dr Richard Harpin, Hon. Treasurer, BHS, c/o ICE, 1-7 Great George Street, London SW1P 3AA before **20 December 1996**.

New Director at IH



Jim Wallace – new Director of the Institute of Hydrology

The Institute of Hydrology's new Director is **Dr Jim Wallace**, previously head of the Institute's Hydrological Processes Division. We welcome Jim to his new post at IH, and to BHS, and hope that he will be an active member and vigorous champion of the Society.

Tony Debney, Acting Director for the past two years, has retired after a career spanning 28 years at the Institute, during which time it has grown from some 20 staff to over 200. In his retirement Tony hopes to write scientific articles for a wider readership.



Tony Debney – retiring after 28 years at IH

Improved methods of snowmelt forecasting

Environment Agency Seminar
Institute of Hydrology
26 September 1996

This seminar presented the results of a research project on "Development of Improved Methods of Snowmelt Forecasting". Those who attended were from the Environment Agency (EA), Institute of Hydrology (IH), universities, the Scottish Office, SEPA and three consultants.

In his welcome, **Tony Debney** (Director, IH) noted that the drive for this research at the Institute of Hydrology came from the parallel development and requirements of new flow forecasting systems. It was funded jointly by the EA and MAFF, who have (respectively) operational and strategic responsibilities for flood warning. The Scottish Office were funding a new phase of the project using the IH experimental catchment at Balquhidder.

Vic Brown (Project Leader, EA) welcomed everyone on behalf of the Environment Agency, which had inherited the NRA's R&D programme, including this snowmelt project. The enlargement of the EA's responsibilities to include dissemination of flood warnings has led to their requirement for effective flood forecasting systems.

Bob Moore (IH) introduced the project, pointing out its emphasis on the operational use of snowmelt models in flow forecasting systems. The River Flow Forecasting System (RFFS) for the Northumbria and Yorkshire Region of the EA illustrated the scale of such forecasting systems, with over 200 points requiring forecasts, as well as the need for adequate models and data to cope with snowmelt in the headwater catchments. The results of the three-year project are presented in a large report entitled "Development of Improved Methods of Snowmelt Forecasting"*, as well as at this seminar. He introduced the three sessions of the seminar, to be concluded by looking at future opportunities for research.

The snowmelt process

Richard Harding (IH) outlined the background work that had gone into ensuring a good and appropriate physical basis for snowmelt modelling:

Yearly plots of the number of days of snowfall and lying snow at two sites illustrate climatic variability from year to year, and the dependence of snow cover on altitude. Snow at Edgbaston (lowland) is highly variable and there has been little in recent years. Snow on Moel Cynedd (~300m) is also variable, but with 40-50 days of lying snow in some years.

Many historical floods have snowmelt components, tending to be in January and February in the UK. Snowmelt has contributed to the maximum recorded flood at 16% of gauging stations in England and Wales, and 27% in Scotland. Major floods on the Trent include some that were entirely snow (Feb 1897), entirely rain (Oct 1875) and others of mixed origin (Mar 1947). In contrast to the seasonal snowmelt pattern in Scandinavia, snowmelt in the UK is only an occasional component of floods. Unlike isolated storms, melt can happen over long periods and large areas, producing large amounts of water, even if the peaks are not particularly high.

A forecast hydrograph from the River Soar shows a 24-hour error in the peak arising from inadequate snowmelt modelling: this is why we need to understand and represent the melt process better.

Richard described the energy balance associated with snowmelt. The latent heat of melting is balanced by the net radiation, the sensible heat transfer from the air, the latent heat of moisture evaporating from or condensing on to the snow, the heat content of rain water, and the heat flux to or from the ground.

Radiation tends to be hard to estimate, with up to 85% of solar radiation reflected, and longwave radiation tending to balance, giving a small net value from the difference of four large values. Sensible heat flux is very important, and is usually estimated via an aerodynamic resistance which multiplies temperature and wind velocity, giving a heat flux equivalent to a melt of 0.78 mm/h for a wind speed of 5 m/s at a temperature of 5°C. Evaporation and condensation, although small in mass terms, can give

*NRA R&D Note 402, available from the Foundation for Water Research, Liston Road, Marlow, Bucks SL7 1FD

a significant loss or gain of energy. Rainfall input energy is small, as is ground heat. The rapid melt often attributed to rain is actually due to the associated warm windy airstream and the fact that the rain is held in the snow until the pack becomes saturated, when it can flow out suddenly.

Equations for estimating melt range from the empirical and widely used degree-day (temperature-index) methods, to full energy balances. An extended temperature-index method, developed for this project, combines a wind speed term with the degree-day approach. The usefulness of this approach can be seen in the AWS data from a snowmelt event on the Trout Beck in the Upper Tees, Northumbria. Net energy fluxes from radiation, rain and soil were negligible, whilst the sensible and latent heat fluxes were substantial due to the high temperatures (up to 10°C), high wind speed (>5m s^{-1}) and condensation from the cloud of warm, saturated air. These and other data illustrate that the major determinants of snow melt in the UK are the fluxes of sensible and latent heat, in contrast to Alpine snowmelt, where radiation is the main factor.

The results suggest that a snowmelt model based on temperature and wind speed alone is likely to be suitable for operational use in the UK, being easier to transfer between catchments than the degree-day method, and not requiring the radiometer data necessary for the full energy budget model. The major problems for distributed snowmelt modelling lie in determining the distribution of snow cover and meteorological conditions over a catchment.

Tim Ettrick (EA) asked whether snow pack depth affected melt calculations, and whether melt occurred faster for shallower packs.

The answer was that depth did not affect melt, but was important because the pack holds the liquid water, deep packs holding more water, and depth could also delay the movement of water through the pack. There were also small thermal inertia effects dependent on depth.

Steve Anderton (Newcastle University) asked if the effects of trees on interception and atmospheric fluxes had been considered. They had not, but there were data from the Plynlimon experimental catchments that would be interesting to look at, and an interception model was under development for a separate project.

Vic Brown (EA) asked how access to the snow database would be provided, and **David Price** (IH) asked what data were held. Bob Moore (IH) said the data were held on a relational database at IH, but the form for dissemination had yet to be decided. Only the cost of supply would have to be recovered. Types of data included 15-minute river levels and flows, hourly AWS data (including albedo and ground heat measurements from some enhanced instruments), hourly data from an experimental snow pillow, and daily snow survey data. These data came from the project catchments at Plynlimon and on the Tame, Aire and Upper Tees, and covered at least the three years of the project. In an extension of the project, data were being gathered from Scotland, and from the Dove, which (unlike the nearby Tame) had actually had some snow in recent years. The data and database were detailed more fully in an appendix to the report.

Ian Pearse (EA) asked whether, in addition to wind speed, wind direction and humidity had been considered as factors in the degree-day method.

Richard Harding replied that temperature was the most important factor determining snowmelt, then wind speed, and then perhaps humidity, although this would be hard to measure in sub-zero conditions. Wind direction was unlikely to be important. Realistic models had to be able to operate with a variety of observed inputs. Another factor was that wind speed would vary over areas, giving another point-to-area extrapolation problem.

Use of spatial data

Vicky Bell (IH) described the use of the IH DTM for feature extraction and snow cover prediction. The IHDTM records five types of data on a 50 m grid covering the UK: elevation, inflow direction(s), outflow direction, surface type (land/water) and contributing area. From these it is possible to derive surface slope, aspect and curvature, in order to deduce where snow patches are likely to accumulate in the study catchments.

The inflow and outflow directions can be used to compute flow paths to the catchment outlet. Together with a flow velocity inferred from the surface slope at each point, this gives a time of travel to the outlet. By summing the areas between isochrones (lines of equal travel time) a time-area diagram can be constructed for the catchment. This can be thought of as a unit hydrograph with diffusion effects removed.

The DTM can also be used to derive the hypsometric curve: the proportion of the catchment area below a given altitude. Combined with a lapse rate (or other simple model for inferring freezing level from temperature), this can give the proportion of catchment precipitation falling as snow.

Areal observations of snow cover can be used to examine the controls on patchiness of snow, and to validate predictions based on DTM data. Landsat provides images approximately every 16 days at 28 m resolution: only one suitable image was available in support of the study. The image over the Upper Tees catchments was classified into six types of land cover (including snow) and downgraded to 50 m to match the resolution of the DTM. These observations of snow cover were compared with the distributions predicted by several variations on Bloschl's index for snow water equivalent.

The Bloschl index, derived from work in the Austrian Alps, predicts greater depth of snow on higher relief, shallower slopes and more concave features. Reformulated as an index of snow presence, it predicts snow cover at points satisfying a minimum elevation, a maximum slope and a maximum convexity (the last two have empirically fixed values). For evaluation, the minimum elevation value was taken from the Landsat image and the distribution of the index was then compared with the observed pattern. The match was poor for the original index, but a modified index, incorporating a minimum as well as a maximum slope, gave better agreement. Further images would be required to develop this work further.

Steve Anderton asked how temporal variation of the critical slope and elevation might be incorporated. Bob Moore said that adjustments to these values could be made as data became available in real time, but this was work for the future.

David Collins (then Manchester University, but now at Oxford) asked whether a trade-off could be made between spatial resolution and frequency of data, by using lower resolution data that might be available more frequently than the Landsat data. Vicky Bell said this would have been difficult for the small catchments used. Bob Moore added that this work using satellite data would probably lead to a methodology for extrapolating point measurements, rather than a scheme for using satellite data operationally.

David Cooper (IH) asked if the effects of wind on snow distribution could be included, but Bob thought this would be difficult, as there the dynamics of blown snow was not well understood. He hoped that curvature would be an important control. Tracking the speed and direction of wind through a storm would also be difficult.

David Collins asked what elevation might be chosen for the separation of rain and snow. The 1°C surface was commonly used, but there was a fuzzy area between about 0°C and 2°C.

Snowmelt models and evaluation

Bob Moore described the PACK model, a pragmatic snowmelt model designed for operational use in the Institute of Hydrology's River Flow Forecasting System (RFFS).

The original focus of this model (in the days before DTMs) was a

representation of processes occurring at a point. Snow falling on to a dry pack melts (according to a temperature excess rule) into the wet pack, which is treated as a reservoir with two orifices, which in turn drain into the catchment runoff model. Rainfall enters the wet pack directly. Drainage from the lower orifice of the wet pack is slow, but there is rapid drainage from the second orifice when a critical capacity is reached; this critical capacity in turn depends on the overall water content of dry and wet packs.

The point model can also be used as a lumped model for the snow-covered area of a catchment, or an elevation zone within a catchment. In the former case an areal depletion curve is used to relate the snow-covered area to the modelled snow depth.

Updating using snow observations (typically daily) can be achieved by running two models in parallel: a point model for the survey site and a lumped model for the catchment. Correction factors are found to adjust the point model to match ground truth, and these are then applied to update the pack storages in the catchment model.

This original PACK model was implemented as part of flow forecasting systems in Yorkshire and Lincoln areas, but without data for calibration it had to be delivered uncalibrated.

Even with snow survey and raingauge data available, calibration is difficult, since raingauges cannot measure snowfall. A screened optimisation process is therefore used: model stores are updated from snow observations when new snow has fallen, and model predictions are compared with snow observations only when no new snow has fallen.

Several variations on the PACK model were also explored during the study. These included allowing a proportion of rain to bypass the wet pack; enhancing the temperature-index melt equation to include wind-speed and rain terms; using a full energy budget melt formulation, based on the one used in the IH Distributed Model (IHDM), and the use of DTM-derived elevation zones with independent snow water accounting.

A sensitivity analysis using the energy budget melt model for idealised hillslopes in upland Britain suggested a strong sensitivity to the aerodynamic roughness length of the pack (controlling convective heat loss) but little sensitivity to slope aspect and angle (controlling radiation melt).

The PACK model and its variants were used in combination with either a lumped or a distributed catchment runoff model. The Probability Distributed Moisture (PDM) model is a simple lumped conceptual model in which soil moisture stores have a distribution of depths. The proportion of stores that are saturated thus defines a variable contributing area for surface runoff production, whilst total soil moisture contributes to a slow groundwater recharge. Parallel storage functions control translation of runoff and groundwater to the basin outlet. The Simple Distributed Model employs isochrones, derived from the DTM, to configure a kinematic wave flow routing scheme receiving distributed inputs from saturation excess controlled moisture stores. Both catchment models were configured to receive inputs from snowmelt models covering either the entire catchment, or multiple elevation zones within the catchment.

The study also addressed other problems: the need to use empirical snowmelt and storage time constants, often determined from daily observation data, in operational models running at a 15-minute time-step; model updating procedures that make use of snow depth observations alone (without water equivalent); and improvements in the transfer of updating information from the point to the catchment scale.

Models were evaluated using data from the four study catchments with significant snowfall over the study period: Harwood Beck and Trout Beck on the Upper Tees, the Wye at Cefn Brwyn, and the Aire at Kildwick. Catchment models were calibrated on no-snow periods, and snowmelt models were fitted to snow measurements. The combined models were judged with respect to snow water equivalent and (primarily) flow data.

Using the basic PACK model over the entire catchment, the lumped (PDM) runoff model performed better in the Tees catchment, and the distributed model was better for the Wye, but both performed poorly for the Aire at Kildwick. The wind-speed and rainfall terms in the enhanced melt equation added little benefit — more data are needed to explore this further. Poor performance for the Aire at Kildwick was felt to be due largely to the unrepresentative nature of the gauge.

The use of different elevation zones gave a small improvement on the Wye, but negligible or inconsistent effects for the Tees catchments, for both lumped and distributed catchment models.

Results from the full energy budget model confirmed that, under the study conditions, radiation terms were negligible during the main melt phase leading to flood flows, and consequently use of this melt model had little impact on performance.

The hourly data from the snow pillow in the Trout Beck catchment allowed more frequent updating of the snow model, which led to a small improvement in flow forecasts.

The conclusions from the project were:

(1) Model results, supported by data, demonstrated the importance of convective heat transfer (and hence aerodynamic roughness) and latent heat generated by condensation on to the pack, and the relatively minor role of radiation and soil heat flux.
(2) The DTM was invaluable for automatic topographic feature extraction in support of model parameterisation and snow cover prediction.
(3) Melt equations more sophisticated than a simple temperature-index method gave only slightly better performance on the limited data examined, although more modelling studies and data were required.
(4) Neither lumped nor distributed catchment models proved consistently better, while the use of elevation zones for snowmelt provided improved results for the Wye, but did not seem to help in the other catchments.

Opportunities for future work included:

(1) Coupling the energy budget melt model with the simple distributed model, together with improvements supported by DTM data.
(2) Development of a probability-distributed melt model, linking temperature to elevation, again supported by DTM data.
(3) Use of a topographic-index predictor of snow cover to extrapolate snow measurements.
(4) Use of weather radar for spatial estimation of snowfall, and exploitation of new satellite sensors to support modelling.
(5) Further evaluation and development of models using more events, and including catchments in lowland Britain.

Discussion

Rob Lamb (IH) asked why the use of elevation zones might be important for the Wye. Bob Moore did not know the reason for this, but the elevation ranges of the Wye and Tees catchments were similar.

James Bathurst (Newcastle University) said that experience with the SHE (Système Hydrologique Européen) distributed model was consistent with the project findings, showing only a slight benefit from using an energy budget melt model, and with some sensitivity to the value of the aerodynamic transfer parameter. He asked whether the PACK model was sensitive to the division between dry and wet pack. Bob noted that the energy budget and temperature-index variants of the PACK melt equation had the same number of parameters, so over-parameterisation was not an argument against the energy budget approach. The distinction between dry and wet pack was important, as storage within the pack was a key feature. The growing 'ripeness' of the pack during melt primed it to release water to the catchment.

Richard Harding added that although sensitivity tests on the model had not been carried out, observations

of deep pack showed that visible melt is delayed several days beyond the predictions of an energy budget model without storage. He also noted that aerodynamic roughness varies with the state of snow and topography and hence is not really a physical constant.

Alistair Kirkbride (University of Lancaster) asked what happened at the edges of snow patches. Richard felt this was an interesting problem. Melt was enhanced at the edges, where air was a bit warmer. There had been Canadian work on snow patches making use of fractals. Advective effects at the pack edge were probably most important for the present application. Steve Anderton said that this should be most significant when there was high radiation, heating bare areas next to snow patches. He asked how areal depletion curves had been used within elevation zones.

Bob Moore replied that the purpose of the depletion curve was to calculate, for shallow snowpacks, the bare area of the zone over which rain would go directly to the catchment model. Richard Harding said there was scope for improving the formulation of depletion curves using data from remote imagery.

Tim Ettrick (EA) asked if there were any data since 1993 to verify the model. Bob said that extending the project would allow more data to be gathered, and the evaluation of new datasets.

Steve Anderton asked if there was evidence that ground frost affected runoff response, through an influence or infiltration. Bob replied that the project had not addressed modelling at this level. It had tried to construct operational models using historical data, rather than process studies. However, there were ground temperature and heat flux data to support such an investigation in future. Richard Harding added that since rainfall-runoff model parameters optimised for summer data worked well in winter, this was probably not important, or else the soil had not frozen during these events.

Tim Harrison (EA) asked whether heated raingauges had been used. The only such gauges were in the Severn-Trent region where no snow had fallen. A heated gauge (provided by Severn-Trent Region) for installation in the upper Aire catchment had not been installed for technical reasons. Tim Harrison said that EA experience had shown that the heating element was not up to the job, with only a trickle getting through. Bob noted that there was a need for a low cost snow sensor, as instruments such as LED optical sensors were very expensive.

James Bathurst (Newcastle University) noted that the height of vegetation was often comparable with the depth of snow, creating a micro-climate for the snow, and asked whether this was important in the UK.

Richard Harding replied that this was an interesting problem, and also included snow within deeper vegetation such as heather or forest. Vegetation could affect both aero-dynamic roughness and radiation characteristics. There were no good measurements for such messy conditions, which could involve tens of mm of snow water equivalent.

Conclusion

Vic Brown thanked MAFF and the Scottish Office for supporting the project. Bob Moore thanked the speakers and the Environment Agency, and in particular Vic Brown and Bogus Zaba for the idea of sponsoring a seminar to assist dissemination of these project results.

Roger Austin
Institute of Hydrology

Editor's note

This issue of *Circulation* has been severely delayed, and is therefore dated December rather than November, for which I apologise. I hope members will be able to read it and the enclosed information over their Christmas break.

There are some rather long reports in this issue, which make interesting reading for members who did not attend the meeting, but it has been suggested that reports should be more concise in future, with highlights from the discussion and perhaps details from one topical paper, but referring the reader to the authors or published papers for full details.

John Griffin

Books

Guide to private water supplies

Rick Brassington, *Finding Water — A guide to the construction and maintenance of private water supplies* 2nd edn (1995). John Wiley & Sons, Chichester, £16.95. ISBN 0 471 95711 9

This is a practical manual for those wishing to use rainfall, springs, rivers or boreholes to provide water requirements. It covers all aspects of small water supply schemes, including measurement of available water, assessing demand, building and maintaining infrastructure, water quality, treatment and law. This second edition contains more detail than the first, and is clearly intended for a wider audience around the world.

The sections on the hydrological cycle and water measurement are basic, but too much detail in such a broad manual would be inappropriate. This could be overcome by reference to other publications, e.g. for the siting of rain gauges or weirs (backwater effects and non-uniform flow are not mentioned). The links between measuring rainfall, river flow and groundwater, its variability, assessing available resources and the impact of abstraction on other users and the environment could be clearer, and for the layman the costs of each type of scheme could have been compared. Water demand assessment could be simplified by the use of tables including peak demands, losses, evaporation, seasonality, etc.

The guide covers construction of tanks, reservoirs, pumps, pipes and planning a layout, whilst the chapter on maintaining a system resolves problems of quantity and quality. The text makes building a system appear fairly simple, although reference to the section on water abstraction and reservoir safety would have been useful. Water quality and treatment includes recent EC standards and UV treatment methodologies. Water law has been updated to include the Water Resources Act 1991, but curiously reservoir safety refers to the 1930, rather than the 1975 Act.

Other revisions include an appendix on safe working practices, an updated reading list and a revised glossary. Most of the diagrams have been redrawn, with significant improvements to the descriptive text. However, the guide often leaves the reader knowing that further information is required, but not where to find it. Unfortunately the list of useful UK addresses in the first edition has been removed, probably in an attempt to bring the text to an international audience.

However this is a useful practical manual for assessing and building small water supply schemes, both in the UK and overseas. It should prove invaluable for small-scale users, farmers and country dwellers as well as consultants, students and perhaps one or two of the water companies. It is basic in parts, but covers a broad area with some success. Those with the first edition need not consider this new version — there are few material changes apart from text relating to other countries, aiming at a wider market.

Paul Garrad
Guildford

Analysing gauging network data

W O Thomas, Jr (1994), An overview of selected techniques for analysing surface-water data networks. WMO

Operational Hydrology Report No 41, WMO-No 806, 30pp.

The issue of this WMO report is timely for hydrometricians in the UK. It describes and reviews methods for assessing surface-water gauging networks in terms of assessing station locations, data type and frequency, and optimum record length. In a climate of increasing emphasis on the justification of resource expenditure, it therefore provides useful reading.

An early chapter focuses on data requirements: who wants what data, why, to what accuracy, how often, how long for and when? A point-rating scheme is presented which allows the network manager to assess the value of data being generated at any site, although this is subjective. One thoughtful inclusion is an assessment of the economic value of water in a watercourse, which feeds through into an assessment of the value of the data.

Some alternative methods of providing streamflow data are considered, extending beyond normal UK practices, e.g. crest-stage 'stations' maintained only in order to measure the stage of the annual maximum flood. Flow-routing, regression techniques and catchment models are all discussed as options which should always be explored as alternatives to the costly process of collecting data in the field. For networks which are considered to be appropriate for future needs, a 'travelling hydrographer' program is described. This allows the available gauging effort to be directed at minimising uncertainty in the network data, using uncertainty functions, travel and station running costs.

By far the most rigorous chapter is 'Analysing the regional hydrology network'. Using examples from Canada and the US, and drawing on his own experience, the author considers the lengths of record necessary to define at-station flow parameters to a given accuracy, and the regional gauging densities necessary to limit sampling errors in relation to future information needs at ungauged sites. By introducing station operation costs in a mathematical framework, the value of individual sites in reducing sampling error, over given planning horizons, can be assessed.

The report makes the important distinction between stations operated for water resource management purposes and those operated as part of a regional information-gathering system. In practice this distinction is often blurred but, nonetheless, network managers must strive to maximise the information value of their monitoring activities. The report provides some useful tools to aid that process, particularly in devising gauging strategies and assessing the theoretical sampling error-reduction benefit of continued station operation. However, it is of limited value for application to networks where real-time or recent data are drawn from many stations, often for a range of resource management functions. It also fails to recognise the importance of ongoing data collection where climate or land-use change may markedly alter future streamflow characteristics.

Andrew Black
University of Dundee

Ecology and the Colorado dams

"Colorado River Ecology and Dam Management". Proceedings of a symposium in May 1990, Santa Fe, New Mexico. National Academic Press, Washington DC. ISBN 0 309 04535 5.

As the title implies, this is a collection of papers by leading scientists studying the impact of dam management and operation on the ecology of the Colorado river. The papers cover the full range from hydrology to the law and politics of dam operation to the changing numbers of endemic fauna in the basin.

Increasing water temperature, changing chemical composition, sediment load reduction and flow regime alterations have all contributed to continuing ecosystem changes in the Colorado river. Most of these changes are irreversible, but because ecosystem components are linked to one another it is possible to manipulate and manage the flows in the river to protect the environment as much as possible. Because the full effect of any change in the operation of the dams is not fully understood, extensive monitoring is called for and corrections made as the system becomes better known. Most of the dams are multipurpose and economic issues are very important. Increasing demand for domestic and agricultural water as well as hydroelectric power have to be considered when contemplating the environmental aspects of a catchment management plan.

It is broadly acknowledged that the environmental impact studies carried out prior to construction of the various dams on the Colorado river and its tributaries were inadequate. The eleven papers presented at the symposium and collated in this book discuss the impacts the dams have on the ecology of the river and possible measures which would halt the degradation and preserve native species despite increasing demands on the reservoirs.

While the climatology, geomorphology and sheer size of the Colorado basin is clearly different from any catchment in the UK, this report provides interesting background reading on water management and environmental issues in another country.

None of the papers presents novel ideas or scientific breakthroughs in the quest for non-damaging reservoirs, but rather a catalogue of trends in river ecology since the construction of the dams on the Colorado. The expectation is that a better understanding of the cause and effect relationship will result in better dam management and operation regulations in the future.

Barney Austin
Institute of Hydrology

Statistical models in hydrology

R T Clarke (1994), Statistical modelling in hydrology, John Wiley & Sons, Chichester, 412pp.

Statistical modelling in hydrology presents a selective description and critique of a range of statistical models which are used to describe and extrapolate hydrological data. The text presupposes a high degree of prior statistical knowledge and familiarity with statistical notation. For example, readers must be prepared to encounter and comprehend terms such as 'maximum-likelihood estimation' or 'moments' by the second chapter!

Because a substantial proportion of the book is devoted to the presentation of code and output from the GENSTAT statistical package its appeal may also be limited to those familiar with or prepared to use the software. The book would provide a useful primer for students or practitioners alike.

The book begins with simple statistical models for analysing characteristics of river flow such as flood frequencies, and goes on to discuss linear and non-linear approaches to ungauged catchments and rainfall-runoff modelling. Concluding chapters deal with hydrological applications of General Linear Models and the analysis of spatial variability in hydrological data.

The main strength of the text is the depth and rigour with which the selected techniques are discussed. Reference to real hydrological data from a variety of contrasting physical environments also provides practical demonstrations of the methods and interest for the less numerate reader. The author has also provided some useful insights into the analysis of hydrological data using graphical and statistical methods, both of which are an essential prerequisite to model building. Although the chapter discussing rainfall runoff modelling presented a succinct discussion of the construction and limitations of conceptual models, it sat uneasily with the rest of the book.

There are also a number of significant omissions, in particular time series analysis. The argument that the

stationarity assumptions inherent in these methods are inappropriate for hydrology is not convincing: the same limitations may equally be applied to most of the models in the book. Other omissions include the emergence of fractals and neural networks within statistical hydrology, the potential applications of new data sources arising from remote sensing, and the opportunities provided by digital terrain models. Although reference was made to the 'trans-scientific' nature of the hydrological discipline, greater discussion of the philosophical issues surrounding statistical hydrology would also have been welcome.

Equally the value of the exercises at the end of chapters 2 to 8 would have been enhanced by the provision of solutions.

In summary, the text provides a specialised critique of selected statistical models which will be of particular interest to students, engineers and hydrological practitioners with a working knowledge of GENSTAT. However, the absence of chapters on time-series analysis and the highly mathematical style will reduce the book's appeal to wider audiences.

Robert Wilby
University of Derby

WMO intercomparison of models

Simulated real-time intercomparison of hydrological models, Operational Hydrology Report No. 38, World Meteorological Organization (1992), 241pp.

WMO Operational Hydrology Report No. 38 is a summary of the 1987 Vancouver Workshop on the Real-Time Intercomparison of Hydrological Models. This international project followed earlier intercomparisons of rainfall-runoff models in 1974 and snowmelt-runoff models in 1984. The most recent exercise was conducted under the auspices of the WMO and the results are now presented within the context of the International Decade for Natural Disaster Reduction (UN General Assembly, 1990).

The report briefly introduces the aims and implementation of the project, followed by a summary of the 14 models submitted. A succinct description and comparison of the different approaches to real-time updating procedures then precedes details of the project implementation. This includes a clear exposition of the intercomparison 'rules' and of the numerical criteria for model comparison. Concluding sections provide a summary of the main logistical problems encountered and recommendations for future exercises. The remaining 200+ pages are devoted to annexes which document essential details of the models, the data employed and intercomparison results. Graphical results are presented for each model for seven forecast storm events in three catchments, namely: Bird Creek, USA (2344 km^2); Illecillewaet, Canada (1100 km^2); and Orgeval, France (100 km^2). In each case real-time flow forecasts are given for lead times of up to 9 hours (Orgeval), 4 days (Bird Creek) and 20 days (Illecillewaet). Tables provide the Root Mean Square Error associated with each models' flow forecast.

The report is well structured and provides a succinct account of the intercomparison exercise, the models employed and the key findings. However, the authors are at pains not to identify the most proficient model and the reader must assimilate a considerable number of tables and hydrographs to reach his or her own conclusions. The report would be a useful reference document for those involved in both applied research and operational hydrology if only as a datum against which future real-time flood forecasting models may be compared. The report would also provide a useful template for those considering designing similar intercomparison exercises. However, the specifics of the report will primarily appeal to those directly involved in the exercise, to those conducting ongoing research with the models listed, or to those studying any of the chosen experimental catchments.

Robert Wilby
University of Derby

Stormwater textbook — with disk

Martin P. Wanielista and Yousef A. Yousef. ***Stormwater management*** **(1993). ISBN 0-471-57135-0. John Wiley & Sons, Inc. 579 pages, hardback, with a 3½" medium-density disk. Price when published £45.50 (in UK), but £75.00 was quoted by a London shop in 1996. The University of Central Florida bookshop charges 'about US$80' or roughly £50.**

The authors are a Dean and a Professor at the University of Central Florida *(Internet site: http://www.ucf.edu/)*. Both have spent much time on research and in monitoring the performance of completed works and their experiences are well reflected in the work.

Following the authors' preface, there are eleven chapters, each with references, and eight appendixes — 'Notation', 'Metric units with English equivalents', 'Nondimensional rainfall and frequency-intensity-duration curves', 'Statistical tables', 'Computer programs, descriptions and example outputs', 'Description of common stormwater management practices' and 'Solutions to selected case studies' (35 pages). The work ends with a reasonably serviceable index.

The disk supplied in a pocket inside the back cover offers these programs: SMADA 4.0 (a stormwater management and design aid), RETEN (pollutant loading and management practice design), OPSEW (minimum cost pipe system optimization), Pearson Distribution (parameters by moments and 'estimates of likelihood'), Error Estimation (residuals, standard error and randomness tests), Linear Programming (minimizes/maximizes an objective function) and Linear (bivariate linear regression).

All the software is DOS-based and adequately fulfils the requirements. Updated versions of SMADA, RETEN and OPSEW, with additional examples, are available from the University of Central Florida Bookstore for US$82.55 plus US$4.95 Florida tax (residents in other States are exempt); the charge for postage and handling is US$2.50.

The emphasis is on practice in the USA which, regrettably, includes the mixing of imperial and metric units!

On page 9 there appears the comment 'Sometimes sites are picked for infiltration ponds based on published general soil data without a site investigation to estimate the rate of infiltration. This practice of using generalized data can lead to false results'. Indeed it can, and it is quite courageous of the authors to include this comment since not many writers would wish to publicly highlight the situation.

Page 94 includes a reference to '*Biological* oxygen demand', which should read '*Biochemical* oxygen demand', although this is a common imperfection in technical literature.

'Dry' ponds are often in recreation areas: there is nothing in the book to explain whether the sediment left from floodwater can occasionally be toxic to children or pets.

Throughout the work there are useful examples and calculations. Each chapter ends with a brief summary and most also have 'Problems' and 'Computer-assisted Problems'. There is a solutions manual, and Prof. Yousef told me that the publishers will supply a copy 'when 10 books are ordered'.

Spelling errors were discovered, but they have little effect on the contents of the book. No check was undertaken on the mathematics or on the various formulae. A list of corrections is being prepared, but it is unclear why it has been so long delayed.

'The book is decidedly different from others in the sense that it includes extensive coverage of water quality issues' (Preface). There can be little argument with this statement: moreover, there is good coverage of infiltration drainage, a subject which is receiving long overdue attention in the UK.

The preface declares that 'All eleven chapters are usually taught to fourth-

year undergraduate and first-year graduate engineering and science students or advanced-level graduate students of different academic backgrounds', but if the authors intended the target audience to be students, they have overshot their objective — they have succeeded in producing a work which is of very considerable interest to a far wider readership. Many disciplines will find much of value in this book, and it is confidently recommended to professionals in the broad spectrum of skills embraced within its pages.

John G Evans
Lichfield

Forgotten flows?

This is the first in a series of questions and answers from hydrological history, excavated by Frank Law, Head of the Information Hydrology Division at the Institute of Hydrology.

Q: When and where was the first river flow measurement in Yorkshire?

A: In late 1851 in the Ouse at York, when Prof. Phillips discovered (long before a credible successor) that there were "no published experiments to show how much water is discharged in a year by the rivers, or indeed any one river" he set about gauging.

With the assistance of Mr William Hill, he measured "the river which washes the walls of York, and obtained for a period of seven months, commencing 1st November 1851, the quantity of water in cubic feet per day". When spate effects were absent and only springs and drains were supplying the river, he noted a baseflow (but not using that term) of "about 15 000 cfm", i.e. 610 Mld^{-1}. The PC software package MicroLowFlows puts that as a 98-percentile flow on the current natural flow duration curve — which seems possible. Phillips reckoned the York catchment to be "about 1268 square miles", i.e. 3334 km^2: this compares with 3332 km^2 from MicroLowFlows.

The source of this snippet of environmental history was the Fourteenth Annual Report of the Inspectors of Salmon Fisheries (England and Wales), printed in 1875 and covering the previous year.

F M Law

Aquifer properties

BHS / Geological Society joint meeting
10 July 1996
University of Newcastle-upon-Tyne

In spite of its distinctly hydrogeological title, surface water — its effects on aquifer properties, and its interaction with groundwater — were recurring themes in this joint meeting. Knowledge of aquifer properties is essential for proactive planning and problem solving: understanding physical properties helps to predict the effects of droughts, floods and groundwater abstractions, while chemical properties affect the migration and dispersion of pollutants.

Choosing Newcastle as the venue was a success: it increased the participation of northerners, but was still accessible from the south. **Paul Younger** (University of Newcastle-upon-Tyne) and **John Ferry** (Gerraghty and Miller International Inc) convened the meeting. There were nine talks of 20-30 minutes each, with speakers from universities, the Environment Agency (EA), the British Geological Survey (BGS) and consultants.

The major UK aquifers are lithologically variable and fractured, with differing degrees of fracture interconnection. The anisotropy/heterogeneity of the real, "highly complex" aquifers was emphasised again and again: by Bob Jefferies regarding the Sellafield site, by Beatrice Gibbs in connection with the entire Permo-Trias, and by John Barker regarding aquifer transport properties. Scale-dependence of aquifer properties was emphasised. Regional-scale properties, such as aquifer geometry and boundaries, are important for flow and transport modelling.

Vin Robinson (EA, Thames Region) began with a keynote lecture "The physical properties of major aquifers in the UK — A review of the EA/BGS project". His co-author, **Dave Allen** (BGS, Wallingford) is also joint editor with Vin of "The physical properties of major aquifers in England and Wales", a manual including a CD-ROM with data and maps, to be published in 1997. The knowledge and information about physical parameters in the manual will be of value for all those involved in understanding and predicting groundwater flow. Vin addressed the availability, type and quality of data which may be used in groundwater flow models.

Andy Spink and **Philip Hayes** (Civil Engineering Dept, Birmingham University) gave a presentation on "Assessing aquifer properties through numerical models". Andy concentrated on vertical flow in unconfined aquifers, considering that it is necessary to understand a "simple" aquifer before trying to understand a "complex" one. Using results from radial flow modelling, he showed diagrammatically how drawdown and release of stored water varies with time and radial distance from a pumped borehole. At any point, the response reflects the aquifer properties being sampled by the edge of the cone of depression. As this cone expands, the area of aquifer sampled moves. Andy noted that, when modelling unconfined aquifers, incorrect horizontal permeabilities can be compensated for by changing the specific yield. It is important to understand and distinguish these two properties.

After Andy's introduction to the "simple" intergranular flow in unconfined aquifers, Philip Hayes described a flow model of a "complex" confined chalk aquifer near Ipswich, with increased transmissivities in the valley. This approach was used to best represent the differential direction-dependent drawdowns resulting from pumping. A slight increase in valley-chalk fissure width was proposed as the cause of the elevated transmissivities. Overburden removal in the valley, and correspondingly less cover over the chalk, allows the fissures there to be more open. In unconfined chalk, solution enhancement of fissures is thought to give rise to the pattern of higher transmissivities in valleys compared to interfluves. This is discussed in the aquifer properties manual referred to above.

Bob Jefferies (Golder Associates) presented "Flow testing and patterns in the Sherwood Sandstone Group, Sellafield" on behalf of **Mike Streetly** (Entec), **C Chakrabarty** (Golder Associates) and **R McLeod** (UK Nirex Ltd). Bob discussed how two-dimensional radial flow modelling of the Sellafield area has been used to speculate about the role of faults as vertical boundaries and described, analysed and interpreted a series of long-duration pumping tests at various horizons. The characterisation of Sellafield's suitability for deep disposal of radioactive waste requires a comprehensive understanding of aquifer properties and boundaries. When modelling the results of the Sellafield pumping tests analytically, three different approaches were used to assess deviations from the standard "Theis" type curves: a partial penetration model, boundary analysis and a generalised radial flow model all successfully reproduced the deviations. Although they gave consistent results for the standard aquifer parameters, it was not clear which sort of model was most appropriate. This ambiguity about the cause of response is a common feature of Permo-Triassic sandstones.

An ample lunch preceded the second keynote speech, "Aquifer transport properties: from models to tracer tests" by **John Barker** (University College, London & BGS, Wallingford). John explained how the effects of the variability of aquifer properties on groundwater flow tend to average out. This means that average properties such as transmissivity suffice for flow modelling. In contrast, the effects of heterogeneities on pollutant transport tend to be additive, causing growing uncertainty in prediction as distance of travel increases. John introduced the BGS/EA Tracers Project, which aims to produce a protocol, a tracer test practice manual, a bibliography and a listing of past tests. He urged people to carry out more tracer tests, as they are the only method of deducing large-scale transport properties. They cut across the complexities of the processes involved and aquifer heterogeneity. John stressed the importance of determining aquifer pollutant transport behaviour for the improvement of transport models. Better transport prediction would reduce the need for excessive caution, and this could have economic implications.

Steve Fletcher (EA, Central Region) gave an amusing presentation "The time-drawdown response of faulted aquifers: a cautionary tale from the Triassic Sandstones". Steve's cautionary tale of a borehole in a fault-bounded block of Triassic Sandstone showed an aquifer with "bucket" properties, where impermeable faults allowed no lateral groundwater flow to replace the abstraction. It had been assumed that faulting increased groundwater flow, but here it prevented flow entirely. In fact the three-month pumping test was abandoned two-thirds of the way through with water levels still declining linearly with time, and no hint of any equilibrium. Adjacent spring-fed pools dried up too and it took a remarkable seven years for water levels to recover and spring flows to resume.

Mike Streetly (Entec) described "Aquifer testing and analysis for an artificial recharge study in Northern Qatar". Mike used surface water arguments to explain part of the rationale for investigating artificial groundwater recharge in arid northern Qatar. Because the topography is everywhere between 0 and 40 m above sea level, there is no space available for surface water storage. Gaining detailed knowledge of aquifer parameters was an essential component of the feasibility study, and injection/reabstraction field testing at four sites preceded the modelling. The parameters affect how efficiently the recharged water can be recovered. "Recovery efficiency" also depends on how much water is put in, how fast and through how many boreholes. When quizzed about the source of recharge water, "strategic imports" was his adroit reply.

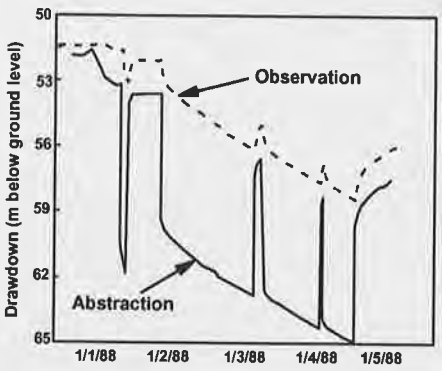
Grant Richardson (Department of Civil Engineering, University of Newcastle) discussed "Geochemical aquifer properties: a basis for future landfill planning and design". He presented new results and reviewed existing geochemical techniques, work he had done for his PhD. Grant argued that geochemical aquifer properties should be taken into account when planning and designing landfills. This would enable the intrinsic attenuation properties of the host strata to be exploited. He advocated a return towards a "dilute and attenuate" philosophy for landfill design, a view not shared by all of the EA representatives in the audience.

The final paper "Permo-Triassic properties — regional ramifications" was by Beatrice Gibbs, Susan Wagstaff and Dave Allen (BGS, Wallingford). In a synthesis of Chapter 7 of the EA/BGS Aquifer Properties Manual, Beatrice compared and contrasted Permo-Triassic sandstone aquifer properties within and between regions. Beatrice illustrated unusually high transmissivities (from pumping test analysis) in the Permo-Triassic Sandstones of the Fylde Plain. Although they reflect the significance of fracture flow in the area, they may also be, in part, illusory. Low drawdowns close to good river-aquifer hydraulic connectivity can be misinterpreted as resulting from high transmissivities. Model values are intermediate between the low core-scale hydraulic conductivities and the high pumping test values, because fractures are not connected regionally. Conversely, storage coefficients are time-scale dependent. On a diurnal scale, piezometric barometric efficiencies have low "confined" values. Delayed drainage in response to pumping persists for many months, giving rise to intermediate "semi-confined" values. On an annual basis, water table fluctuations indicate high "unconfined" values. Lithological variations are a ubiquitous feature of the deposits. Beatrice considered that the associated anisotropy and layered heterogeneity alone are usually enough to explain the hydraulic response. Faults and rivers can have a superimposed effect.

It was, by common consent, a most successful meeting. The public speaking was of a high standard; well-presented arguments and case studies were accompanied by clear diagrams. Ironically, most speakers studiously avoided using mathematical formulae, despite the fundamental importance of analytical and numerical techniques in determining aquifer parameters.

Authors were asked to submit their papers to a special "Aquifer Properties" edition of the *Quarterly Journal of Engineering Geology*.

Beatrice Gibbs (BGS, Wallingford)
Paul Younger (University of Newcastle-upon-Tyne)



Drawdown increasing linearly with time during a pumping test of a borehole in a Triassic sandstone block bounded by impermeable faults (Environment Agency Midlands Region)

Meetings

Fifth Symposium on the BIOGEOCHEMISTRY OF WETLANDS
16-19 September 1997
Royal Holloway campus, Surrey

This Symposium is sponsored by the OECD and two American University Institutes. It will be held at the Royal Holloway campus of Royal Holloway and Bedford New College at Egham, on the western margin of London.

A workshop on *The effect of projected sea level rise on the stability of coastal wetlands* will also be held, consisting of about ten invited papers in two general sessions.

If you would like to present a paper, please state whether poster or oral presentation and indicate the proposed title **by 31st January 1997.** The Symposium will address a broad range of subject areas, but particularly welcome are papers on:

- Functional assessment of wetland ecosystems
- Nutrient cycling in saltmarshes
- Plant-soil interactions of wetlands
- Modelling wetland biogeochemical processes
- Toxic chemicals in wetlands
- European wetlands
- Tropical wetland ecosystems
- Water quality
- Freshwater biogeochemistry
- Effects of climate change on wetlands
- The role of wetlands in global nutrient cycles
- Carbon dynamics
- Land-use and wetland conflicts
- Wetland biodiversity

For further information, please contact: 5th Symposium on the Biogeochemistry of Wetlands, Royal Holloway Institute for Environmental Research, Royal Holloway, University of London, Huntersdale, Callow Hill, Virginia Water, Surrey, GU25 4LN
Telephone +44 (0)1784 477404
Fax +44 (0)1784 477427
e-mail rhier@rhbnc.ac.uk

Diary

18th December 1996
BHS Southern Section meeting
"Gardening under global warming"
Venue: Dept of Civil Engineering, Imperial College, London SW7
Time: 5.30 p.m., tea from 5.00 p.m.
Contact: Dr A P Butler, Dept of Civil Engineering, Imperial College, London SW7 2BU *(Tel: 0171 594 6122)*

9th January 1997
Welsh Hydrological Group meeting
"Flood alleviation and highway development on the River Towy"
Peter Wade (Howard Humphreys)
Venue: Conf. Room 2, Welsh Water, Phoenix Way, Llansamlet, Swansea
Time: 5.30 p.m. for 6.00 p.m.
Contact: Simon Griffiths, 14 Cathedral Road, Cardiff, CF1 9LJ
(Tel 01222 388777, Fax: 01222 384888)

14th January 1997
Scottish Hydrological Group AGM
"Flood risk assessment" — Dr James Curran (Scottish Environment Protection Agency) *(preceded by AGM)*
Venue: Room K314, John Anderson Building, University of Strathclyde
Time: 6.30 p.m.; tea from 6.00 p.m.
Contact: Dr Andrew Black, Geography Dept, Dundee University, DD1 4HN
(E-mail A.Z.Black@dundee.ac.uk, Fax 01382 344434, Tel 01382 344433)

22nd January 1997
BHS Southern Section meeting
"Water resources management for arid & semi-arid regions"
Venue: ICE, 1-7 Gt George St, London
Time: 5.30 p.m., tea from 5.00 p.m.
Contact: Dr A P Butler *(address above)*

12th February 1997
BHS National Meeting
"Low Flow Solutions"
Venue: Environment Agency HQ, Rio House, Almondsbury, Bristol
Time: 1.30 - 5.30 p.m.
Contact: Graeme Boyce, Environment Agency South West Region, Manley House, Kestrel Way, Exeter, EX2 7LQ
Tel: 01392 444000

19th February 1997
BHS Pennines Section meeting
"Frequency Analysis"
Venue: University of Lancaster
Contact: Dr Keith Beven, University of Lancaster *(Tel: 01524 593892)*

26th February 1997
BHS Southern Section meeting
"Estuary management for the Thames"
Time: 5.30 p.m., tea from 5.00 p.m.
Venue: Dept of Civil Engineering, Imperial College, London SW7
Contact: Dr A P Butler *(address above)*

5th March 1997
BHS Midlands Section meeting
"Movements of sediments from hillslope to estuary"
Venue: University of Birmingham
Time: 13.40 - 17.25 p.m.
Contact: Prof. Angela Gurnell, School of Geography, University of Birmingham B15 2TT *(Tel: 0121 414 5526)*

19th March 1997
Scottish Hydrological Group meeting
"The snow resources of Scotland"
Venue: Royal Hotel, Bridge of Allan
Time: 10.00 - 16.30 *(Lunch provided)*
Cost: £40 (£22 student/unwaged)
Booking/information: Dr A R Black, Dept of Geography, University of Dundee, Dundee, DD1 4HN *(Tel: 01382 344433, Fax: 01382 344434, email: A.Z.Black@ dundee.ac.uk)* — make cheques out to the *Institution of Civil Engineers* — see also Scottish Hydrol. Group Internet pages: http://www.dundee.ac.uk/~azblack/SHG.htm

15th-17th April 1997
BHS Postgraduate Symposium
Venue: Imperial College, London
Contact: Prof. H S Wheater, Dept of Civil Engineering, Imperial College, London SW7 2BU *(Tel: 0171 594 6066)*

10th April 1997
BHS Midlands Section / Welsh Hydrological Group joint meeting
"The Shropshire Groundwater Scheme"
Field visit: 2.00 - 4.00 p.m.
Presentation: 4.15 - 4.45 p.m.
Venue: Shrewsbury
Contact: Simon Griffiths *(address above)*

30th April 1997
BHS Southern Section meeting
"GIS Applications in Hydrology"
Time: 5.30 p.m., tea from 5.00 p.m.
Venue: Dept of Civil Engineering, Imperial College, London SW7
Contact: Dr A P Butler *(address above)*

21st May 1997
BHS Pennines Group AGM
"Flood defence modelling"
Venue: University of Salford
Contact: Dr K A Tilford, Dept. of Civil Eng., University of Salford, M5 4WT
(Tel: 0161 7455000, Fax: 0161 7455060, E-mail k.a.tilford@civils.salford.ac.uk)

28th May 1997
BHS National meeting — jointly with the British Soil Water Physics Group
"Soil physics and macropore flow"
Time: 2.00 p.m. - 5.00 p.m.
Venue: Dept of Civil Engineering, Imperial College, London SW7
Contact: Dr A P Butler *(address above)*

15th - 18th September 1997
Sixth National Hydrology Symposium
Venue: University of Salford
Contact: Dr K A Tilford *(address above)*

Copy deadline for *Circulation* No. 53 15th January 1997

Circulation is the quarterly newsletter of the British Hydrological Society. It is issued free to members, but is also available on an annual subscription of £20. All enquiries concerning membership should be made to Richard Howard, Institution of Civil Engineers, 1-7 Great George Street, London SW1P 3AA. Telephone 0171 839 9836. Please address all other correspondence to the Editor, John Griffin, Institute of Hydrology, Wallingford, OX10 8BB. Telephone: 01491 692395. Fax: 01491 692424. Email b.h.s@ua.nwl.ac.uk.
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