THE NEWSLETTER OFTHE BRITISH HYDROLOGICAL SOCIETY

Circulation

No. 49 February 1996

Floods and sheep — is there a link?

In the Dales area of the Northumbria and Yorkshire Region of the National Rivers Authority, four major floods have been recorded in the last thirteen years. These floods caused serious erosion of the banks of many of the rivers in the area. Over the same period the numbers of sheep in the area have increased by nearly 40 per cent. Is it possible that these two observations are connected?

Heavy floods are an obvious cause of river bank erosion and there are two principal theories about the cause of the apparent increase in their frequency: climate change and change of land use. It has been suggested that climatic changes have had a major effect on the magnitude and frequency of floods, but the evidence is sparse because accurate records do not go back very far.

Furthermore, most of the studies of the relationship between climate change and floods and erosion have been carried out on catchments — or parts of catchments — that have already been extensively modified by man, so that it is impossible to disentangle the effects of climate from the effects of changes in land use. Britain has had an essentially maritime climate for thousands of years and the average rainfall is known to have fluctuated widely. However, it is not simply the quantity of rain that is important for erosion, but the rate at which the water runs off the land. Land use is the major factor that determines the rate at which water runs off the land, and this determines the susceptibility of the British landscape to erosion.

It is generally accepted that the 'wildwood' climax vegetation which covered Britain almost completely 7000-8000 years ago would have been highly resistant to erosion, while today's intensively farmed arable land is the most sensitive to erosion. During the wildwood period, forests dominated the British landscape and the tree roots helped to bind the soils of the hills and floodplains together. Since this period, the landscape of Britain has gradually been deforested, until today it is largely agricultural — as a result of human activities.

These changes in land use, which have taken place over thousands of years, have also changed the character of our rivers. General hydrological principles indicate that during the

Symposium helps young members travel

The Fifth National Hydrology Symposium at Edinburgh was judged a great success, not only because of the full programme of lectures, papers, posters and exhibits, and the wide-ranging discussions, but also because of the financial return. The surplus from this event will go a long way to help young members of the Society to go a long way — it is to be used to help fund travel for younger BHS members — and will keep costs down at the Post-graduate Symposium at Newcastle in early April (see page 11).

More travel grants

Grants of up to £100 are available to help members with the cost of attending meetings (see *Circulation 38* to *47*). Successful applicants are expected to produce a short report of their experiences in attending the meeting.

Money from the Exeter Fund is available to help members travelling to the IAHS 5th Scientific Assembly in Rabat, Morocco, April/May 1997. Please apply to the Hon. Treasurer, **Richard Harpin** (tel/fax 01793 812479).

'wildwood' period the forests would have intercepted up to 30% of the rainfall, which would then have evaporated before reaching the ground. In the summer transpiration from the trees would have 'diverted' enormous quantities of moisture from the wooded wetlands into the atmosphere, and the upland mires and bogs would have retained water during both wet and dry periods. The recharge of groundwater reservoirs was also likely to have been greater, with more water being absorbed into the permeable, organic soils and thence into the aquifers. As a result of these processes it is likely that less rainwater reached the rivers during the wildwood period than today. Surface runoff volumes and velocities would have been much slower and infiltration rates would have been greater, so that the rivers flowed more constantly, winter and summer, with less erosive power than they have today.

In contrast, less than 10% of Britain is now covered with trees, while over 80% is agricultural land, and 95% of Britain's wetlands have been drained, most of them since 1945. In general, larger volumes of water now reach the rivers faster now, and as a result it has become necessary to 'engineer' the rivers to contain the increased volumes. Human influence has continued to increase, with other activities such as upland drainage, urban development and road building, all tending to increase local runoff rates still further.

More water is therefore entering our rivers faster than ever before. Because of its increased energy and the increased load of sediment it can carry, its erosive power is also considerably greater.

River banks are eroded when soil and subsoil are washed away after the protective layer of vegetation has been weakened, damaged or removed. The erosive power of water — and particularly the power of a river in flood — is formidable. However, we should not underestimate the ability of healthy, well-managed vegetation (grassland, scrub or trees) to withstand these forces.

In a survey of river widths, Hydraulics Research (HR Wallingford) found that tree-lined rivers were on average 30% narrower than similar rivers from which the bankside trees had been removed. Well-managed trees can reduce river bank erosion by as much as 85-90%. Tree roots help to bind the bank materials together, whether they are loamy, silty soils, or boulders and cobbles. Trees have a remarkable capacity for surviving on and stabilising what can, in times of flood, be a very hostile environment.

Healthy soil-covering vegetation is also vital. Long grass is good, not only because of its greater root depth, but also because in a flood the long grass is laid flat by the force of the water, the roughness of the channel is thereby decreased and the surface of the soil is protected. Any damage to that protective layer of grass exposes the soil and makes erosion more likely.

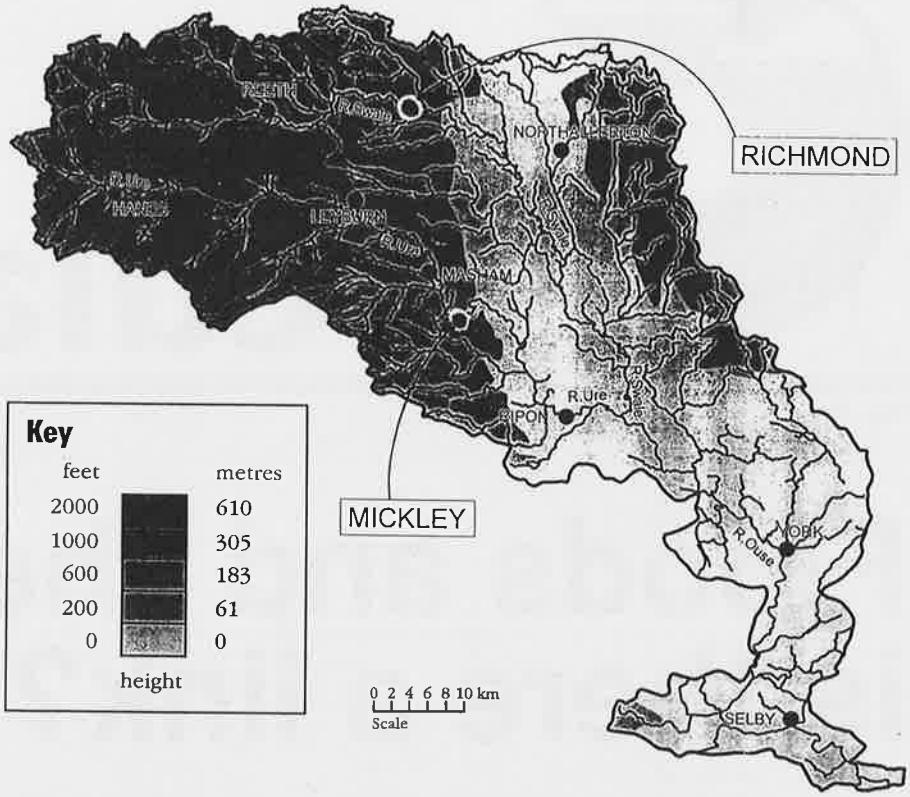


Figure 1 Rivers Swale, Ure and Ouse catchment topography

The majority of the river banks most severely affected by erosion are also permanently grazed by sheep. On the river banks grazed right up to the water's edge there are often no trees, or else the trees have been damaged by sheep, or there has been no regeneration of shrub vegetation. In many cases the pasture is also overgrazed, often severely, with exposed soil, which has led in a relatively short period to serious erosion. Thus not only are rivers in spate more violent than before, but the bankside vegetation has also been so weakened by overgrazing that more serious erosion is inevitable unless riverside management is changed.

The damage caused by sheep to some of Britain's richest areas for wildlife is well documented. Overgrazing of moorland is leading to the loss of heather; sheep and hedges cannot exist together unless the hedges are fenced, and now river banks are also being degraded. The number of sheep in North Yorkshire has increased by nearly 40% since 1982*. Sheep may be causing enough loss of vegetative cover and serious poaching of the soil surface to lead to increased runoff rates and thus to an increase in the likelihood of serious floods, such as the four major floods experienced in the last thirteen years.

These recent floods have occurred comparatively high up in the catchments of the rivers Ure and Swale, in Wensleydale and Swaledale, well before the rivers reach the flat expanse of the Vale of York. (See Figure 1). Both Dales are steep sided: Swaledale is particularly steep and has a narrower valley floor than Wensleydale. Since the severe flooding in these parts of the catchments has occurred in the last thirteen years, this suggests that the increasing runoff rates have not been due to increased land drainage (the main period of upland drainage was earlier during the 1960s and 1970s), nor to urban development or road building.

One of the four floods was an unusual event, occurring in summer rather than winter. On the August bank holiday 1986, the remains of the storm 'Hurricane Charlie' unleashed itself on the Dales (Swaledale was most seriously affected) and caused enormous damage in a very short time. The three floods in 1982, 1991 and 1995 occurred at a more usual time of year (January/February) following snowmelt.

The 1995 flood was the highest ever recorded, both at Mickley on the Ure and at Richmond on the Swale. Figure 2 shows how the flood levels recorded at

* The average increase for sheep in the UK as a whole is 34% for the same period. In the sixteenth century sheep numbered about 8 million in Britain, in the 1940s about 12 million and today about 21 million.

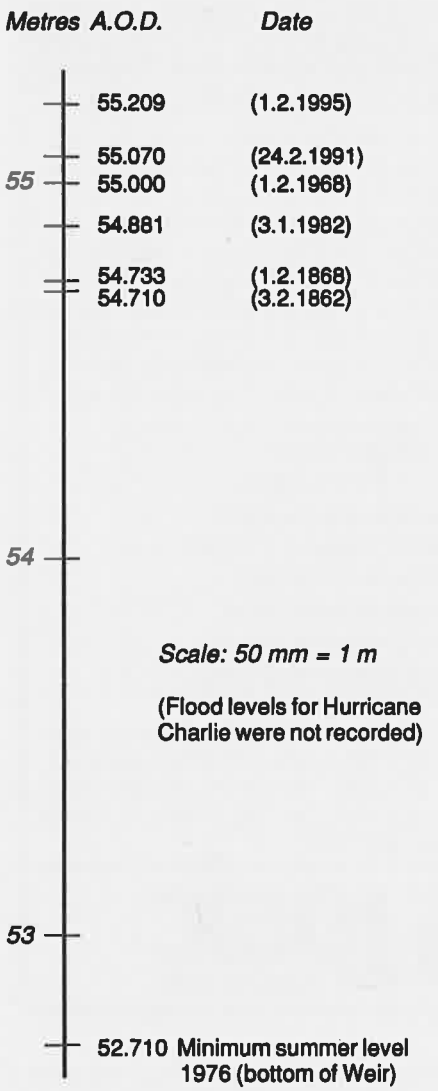


Figure 2 Flood levels recorded at Mickley Weir on the River Ure

Mickley on the Ure since 1862 have increased in chronological order. The difference in height between the 1862 flood and the 1995 flood was 0.499 metre, an enormous increase in the volume of water at this point in the catchment. The flood levels in 1862 and 1868 are recorded in the stonework on the old mill building at Mickley, suggesting that these were considered significant floods at the time. There was a much smaller increase between the 1862 and 1868 levels than between the 1991 and 1995 levels.

The historical perspective may provide other clues. Traditionally, cattle were more suited to the climate in the Yorkshire Dales than sheep, though the numbers were limited by the amount of fodder then available. In the summer the dairy cows (of Wensleydale cheese fame) grazed in the meadows by the river, while young stock and beef grazed on the higher ground. Both groups overwintered in the field-barns in the valleys, so there was little grazing over the winter. The meadows in the floodplain were also vital to provide a hay crop to sustain the cattle over the long winters.

Sheltered in the field barns, the cattle needed less food, a considerable benefit when fodder brought from outside the Dales was a luxury few could afford. From medieval times sheep were far more common in the Vale of York and helped to make that area rich enough to build such monuments as York Minster.

It was only about 150 years ago that sheep became more common in the Dales themselves, but they were still taken back down the drove roads to the Vale of York to overwinter in a less harsh climate. There was not enough food for them to survive over the winter in the Dales. This traditional management changed after 1945. With the increased use of fertilizers more fodder crops were grown, and improved means of transport meant that feedstuffs were cheaper and easier to bring into the Dales.

Since 1982 there has been a reduction in the number of cattle and dairy farms in the Yorkshire Dales, but there have been large increases in the numbers of sheep. The effects on the land are plain. Sheep are grazed in the uplands and valleys of the Dales all the year round. This winter nearly all the permanent pasture was grazed down to within an inch or two of ground level, and heather is also being seriously overgrazed. With so little grass cover, the wet soil is exposed to poaching, which is likely to reduce the amount of water filtering into the soil layers and increase runoff rates still further.

The area of the catchment above Richmond and Mickley is about 1000 km^2. It would seem reasonable to suggest that the runoff rate from such a large area managed in this way over the winter months will be very much greater than from the same area with taller vegetation, four to six inches in height, and a correspondingly large surface area to absorb and slow down the runoff from heavy rain and snow. In such conditions an untrampled soil surface, well protected by vegetation, will be more porous, and therefore allow easier movement of water through the soil.

Other side-effects on the Dales rivers are potentially equally serious. The faster the water runs off, the less can filter into the ground to recharge the natural aquifers, or travel to the rivers more slowly through the subsoil layers. The problems of high flows are compounded with those of low flows. The rivers can go from one extreme to the other within a very short period.

These effects were summed up in letters received at the NRA's York office in May this year. The first was from a fisherman who had fished on the River Swale all his life: "When I was a boy a spate lasted a week, now a spate lasts approximately six hours". The second contact was a gamekeeper on the Ure in Wensleydale concerned that the flow in the river during May 1995 (only three months after the highest ever recorded flood at Mickley) was almost as low as the flow usually expected during August.

There have been many similar anecdotes concerning all the Dales rivers in recent years. During low flows, more of the river banks and channel will be exposed to frost, drought, trampling and drying out, making them increasingly vulnerable to erosion. Certainly, a river that fluctuates wildly between floods and drought will be a difficult and hostile environment for all forms of life, both in the channel and along the river banks.

The environmental cost of all these effects is one thing; counting the financial cost may be more likely to influence the policy makers. There is considerable loss of land, often some of the most fertile (and flat) land in the Dales, because of erosion. To prevent it, farmers attempt (generally without success) to stabilise the banks with hardcore, concrete from old runways, even the shells of old cars filled with rock. The aesthetic cost within the Yorkshire Dales National Park is great. Highways Authorities and the National Park Authority are having to count the cost to roads and footpaths.

In the February 1995 flood, roads and bridges needed repairing and miles of footpath were damaged or completely washed away. Many of the dry stone walls, for which the Dales are famous, were strewn across the valley floors. Flood defences have been severely damaged on many of the Dales rivers, particularly on the middle Tees and Swale, and some properties were damaged by flood water. In lowland reaches large amounts of gravel, trees and flood debris have built up and need to be removed before the next winter.

In lower-lying areas, nutrient laden silts have been deposited and are causing more problems, including the rampant growth of weeds in many lowland rivers and streams and on the river banks. Low flows during the summer may lead to water use being restricted, and water quality may deteriorate because of poor dilution. Many of the effects described in this article may be found to some degree in many catchments within the UK.

So many of the changes described appear to be related directly to changing land use, including increased numbers of sheep, that it seems unlikely that climate change is a major player. Blaming climate change conveniently passes the buck to other powers 'beyond our control'. A practical solution, aimed at restoring healthy vegetative cover, particularly over the winter, would not only be relatively simple, but may have a real

possibility of success. At the very least it is hoped that this article may encourage further investigations into whether there is a link between floods and sheep.

Anne Sansom, Conservation Officer, NRA Northumbria and Yorkshire Region

(This article does not necessarily represent the views of the National Rivers Authority)

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HYDRO LOGIC

BOOKS

The Louth flood — 75 years ago

The Louth Flood: the story of the events of Saturday 29th May 1920
by D N Robinson, Louth Naturalists', Antiquarian and Literary Society. 36 pp, lavishly illustrated, A4 format. ISBN 0 9520117 2 7. Price £6. Available from The Museum, 4 Broadbank, Louth, Lincolnshire, LN11 6EQ.

The Society and David Robinson deserve the gratitude of flood hydrologists for commemorating the 75th anniversary of this disaster so usefully in this volume.

It was the worst localised event to precede Lynmouth: 23 people lost their lives and 200 were saved as waters reached first-floor level in places; 800 were made homeless, some for a very long time; 50 houses were destroyed, 250 needed rebuilding and 500 more were harmed (the numbers seem to have been rounded up from more precise figures in other accounts).

Tree trunks from a sawmill yard played havoc in narrow streets as they floated along. The Fire Station was swept away. Foul brown and yellow mud derived from the Chalk Wolds catchment left a clear floodmark behind. Other graphic details abound.

The Mayor's relief fund raised £90,000 (said to equal £2 million at today's value). The inside covers are a handy floodplain map that identifies how Louth was split by water 115 to 230 metres wide. The photos include some taken from a series of at least 25 postcards by a firm called W. Benton of 82 Rye Hill, Newcastle upon Tyne: one wonders if they covered other disasters as comprehensively, especially as the Norwich 1912 flood was commemorated by a picture postcard previously. Do BHS members know of others?

The booklet ends with a poignant essay written in 1921 by an authoress, Stella Sharpley, whose home had been damaged. It tells of a cleanup operation few of us can imagine going on through a hot sunlit June (who, even now, expects summer storms in May?):

"The mud, both from cellars and garden paths, was stacked in great mounds at the side of the road in front of each flooded house, so you could see at a glance ... which houses had suffered most by the size of the mud mounds."

Over 4.5 inches had fallen in under three hours on the headwaters of the 52 km² River Lud catchment. Rain began just before 2 p.m. and close to 5 p.m. a dam at Little Welton gave way, sending it is said a wave of water "14 feet high" towards the town – I doubt if many current reservoir panel engineers are aware of that fact, coming as it does before the Dollgarog failure.

Some lessons were learned. Blocked culverts that lost their roofs were replaced by an open channel and properties were set back. Sadly the one omission from this marvellous (and sobering) booklet is any bibliographic reference, but there were three detailed ones from that era, summarised in *Systematic Hydrology* by Rodda, Downing and Law, 1976 (p 277), which puts the peak flow at 152 cumecs.

Frank Law

President's piece

The importance of an adequate, reliable and high quality water supply in our lives has been brought home to a substantial proportion of the population of the UK over the period of the summer and autumn drought in 1995. Our reaction to shortages differs depending on their severity, our own life styles (for example, whether or not we are keen gardeners) and our background in water resources.

A much more significant example was during the period of thaw immediately following the very severe cold weather just after Christmas. For a period of two or three days, many people, particularly in the northeast of England, suffered the real hardship of damage within their homes and lack of running water following damage to the whole water supply system.

Recently, I was privileged to address a degree congregation at Birmingham University. I reflected on

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the meaning of the word 'hope' and I spoke about the hopes of others, less privileged than we are. "What of the hopes of others?" Because I am a Water Engineer, concerned with the problems of the developing world, I would like to quote from an editorial published in *World Water* at the start of the **International Sanitation and Drinking Water Decade.**

The decade itself was launched nearly twenty years ago. It had as its objective the provision of adequate sanitation in urban areas and a safe water supply for ninety percent of the world's population by the end of the decade. However, it was doomed to failure almost from the start, not because of inadequate knowledge, nor inadequate technologies, but because of the unwillingness of the developed world to share its wealth, and because of our preoccupation with fulfilling our own hopes and desires without thought for the hopes and desires of the less privileged.

The quotation reads, "On 12th October, about twelve thousand people died in the earthquake at El Asnan in Algeria and nearly 250,000 people were made homeless. The world was rightly shocked into action and millions of dollars in aid poured into Algeria. On the same day, thirty thousand people died in the third world because they had inadequate water and sanitation facilities. Countless millions of women spent half their working day in the hot sun carrying polluted water. It is not difficult to imagine the feeling of hopelessness of mothers who see their children sicken and die through lack of sanitary provision."

Many BHS members are active in their support of *Water Aid*. Conscious of this, at their meeting on 10th January, the BHS Committee resolved to recommend to the Organising Committee of the 1998 International Conference that the registration fee be increased by four per cent to provide free registration for up to twenty participants under the age of thirty from developing countries.

I am sure all members will approve of this decision, but of course the registration fee is only a small component of the total cost of attending a conference overseas. Travel expenses and the cost of accommodation still have to be met. I wonder how much support there would be for a fund-raising effort to meet the accommodation costs of those participants whose fees are waived under this initiative.

This could be done by individuals covenanting support or organising fundraising activities in their place of work. Alternatively, local sections might undertake to sponsor the accommodation costs of a number of these young participants by local fundraising events.

Can I commend this idea to you. I would welcome any reaction, positive or negative, from BHS members.

Mike Hamlin
President

New Members

We welcome the following members to the Society:

Akande, O.	Swindon
Barlow, J.G.	Chester
Bashford, K.E.	Worthing, West Sussex
Chen, Dr M.	Dept of Geography, University of Aberdeen
Easthope, M.P.	Dept of Geography, University of Reading
Hayes, P.J.	School of Engineering, University of Birmingham
Hutchins, M.G.	Teddington, Middlesex
Jackson, C.R.	Birmingham
Kervell, A.N.	Birmingham
Locks, T.J.	London
Parkin, G.	Dept of Civil Engineering, University of Newcastle
Prior, H.	Dept of Geography, University of Reading
Rice, S.	Loughborough University of Technology
Scarlett, N.	Ilkley, West Yorkshire
Shorthouse, C.	Dept of Geography, University of Southampton
Stacey, M.J.	Epsom, Surrey
Steel, M.	Dept of Geography, University of Dundee

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Recent developments in East African hydrology

BHS Southern Section Meeting
Imperial College, London
25th November 1995

Elephants, giraffes and *Andy Bullock* (Institute of Hydrology) — the connection? — his audience had a long memory, and he was sticking his neck out to discuss *Regional cooperation in East African hydrology*. After that *Chris Green* (Water Resource Associates Ltd) brought the audience back to earth with a talk on the *Athi-Tsavo-Sabaki River Model*.

Andy considered four areas in varying degrees of depth. Firstly he looked to the past, focusing on intercomparison of results from experimental catchments. Secondly he reviewed briefly the current position of several regional institutions. The third aspect was the Lake Victoria environmental management programme, followed lastly by an update on the Southern African FRIEND project.

Many studies have been carried out in eastern and southern Africa, targeting the hydrological impact of land-use change. The Erin catchment study in eastern Zimbabwe ran from 1965-1990, investigating the effects of afforestation on hydrology, and data have recently been analysed by IH in association with the Zimbabwe Hydrological Branch. Monthly runoff fell in both wet and dry seasons where there was afforestation: reductions of 400mm in runoff were found in catchments with 100% pine afforestation.

In the 1950s and 1960s the East African Agriculture and Forestry Research Organisation ran research studies throughout East Africa. However, on independence in the 1960s, interests in the various countries diversified and a general lack of cooperation in the coordination of hydrological research followed.

Several regional institutions now try to coordinate hydrological research in southern and eastern Africa, including the Inter-Governmental Authority on Development and Drought (IGADD), the Southern African Development Committee (SADC) and the Technical Cooperation Committee for the Promotion of the Development and Environmental Protection of the Nile Basin (TECCONILE).

Andy concentrated on the most recent example of international collaboration, the Lake Victoria Environmental Management Programme. The three riparian countries have identified that the lake faces severe management problems — not least the expansion of water hyacinth — which begs the question: is the Lake in decline? A few trends in the water quality and nutrient levels of the Lake were proffered here, comparing determinands (e.g. dissolved oxygen, DO) in the 1990s with observations in the 1960s:

- DO in the upper 20 m of the lake has increased;
- DO in the lower 40 m has decreased;
- Chlorophyll has increased;
- Clarity has decreased;
- Phosphorus has increased.

These trends can be traced to agricultural and rural uses of pesticides and fertilisers rather than to point source inputs. Increases in agricultural activity in Kenya have given rise to higher levels of nitrogen in the Lake, and fertilisers used on grasslands in Tanzania have led to a rise in phosphorus levels.

The 1500 km^2 of wetlands once provided much needed buffering, removing high nutrient levels from runoff before it entered the Lake. However, increased demand for agricultural land has led to some 50-60% of these wetlands being drained for agricultural production. The suggestion is that this loss of wetland buffering is, in part, the cause of worsening water quality levels in the Lake.

To address these problems, a tripartite agreement was reached in August 1994 between the countries sharing the Lake in an attempt to improve the water quality. Under this agreement two Task Forces were set up. Task Force I is addressing the water hyacinth and fisheries issues. Task Force II is addressing the water quality and land use issues. A budget of US$40M is being sought for these Task Forces to accomplish their objectives.

Andy then turned briefly to his last area, which he has personally had a hand in developing: the Southern African FRIEND project. Eleven countries are participating by submitting hydrological data and/or carrying out some of the research. Three main areas are being researched by different bodies: flood research by Tanzania, rainfall-runoff by South Africa, droughts and water resources by the Institute of Hydrology. This project is due for completion in early 1997.

In the discussion following, **Mike Tomms** (Knight Piesold) related the findings of a hydroelectric study on Lake Victoria. The catchment area of the Lake was 69,000 km^2; before the two metre rise the average flow through the system was 660 m^3 s^{-1}, while after the rise it was 1200 m^3 s^{-1}. **Peter Wolf** asked if anyone knew what the increase in discharge from the Lake had been as a result of the water level rise. Unfortunately, no one present had that information to hand.

Sir Charles Pereira indicated that some funds were available for analysis of East African hydrological research data. **Yvonne Parks** (IH) asked what effects the water hyacinth was having on evaporation levels from the Lake. Andy indicated that evaporation from the hyacinth has been quoted as three times greater than open water evaporation, but as the hyacinth only covers 1% of the surface area of the Lake at present, it would not significantly affect the water balance yet.

Athi-Tsavo-Sabaki River model

Chris Green (Water Resource Associates Ltd) presented the second talk on the *Athi-Tsavo-Sabaki River Model*. Chris developed a model in response to the need to investigate the environmental impacts of developing the second major bulk water supply for Mombasa in southeast Kenya. The favourite candidate for this supply is the Mzima Springs in Tsavo West National Park. The Springs already provide the first bulk supply to Mombasa, but the reliability of the source, the quality of the water (requiring only chlorination before being put into supply), and the fact that it can be gravity fed all the way to Mombasa, make it ideal for further exploitation, from a resources point of view. The flow from the Springs has varied between 2.8 m^3 s^{-1} and 5.2 m^3 s^{-1} in the 60-year record, but fluctuates little from year to year.

The Springs discharge into the

Tsavo River, which runs east from the foothills of Kilimanjaro to join the Athi River. The Athi drains south from Nairobi, and at the confluence with the Tsavo, changes name to the Galana River. From here it flows eastwards, changing name again to the Sabaki River, and eventually discharging into the Indian Ocean at Malindi. Most of the runoff in the Athi derives from its headwaters. In the dry season flows decrease in a downstream direction.

Once every three years, on average, the river dries up for a period of around a month, upstream of the Tsavo confluence. During the rainy season, floods of up to 5000 m^3s^{-1} may be encountered. This extremely flashy behaviour contrasts with the Tsavo, which has a very steady baseflow, provided almost entirely by the Mzima Springs. The Sabaki River, therefore, displays a combination of these two characteristics, but it also loses water downstream.

The model was required for two main purposes:

- to provide data for an EIA to optimise the size of the second pipeline from Mzima to Mombasa;
- to investigate the yield potential of off-line storage on the Sabaki River.

The inputs to the model are flow data from gauging stations in the Athi catchment, and Mzima flows, extended back from 1951 (when gauging began) to 1926 by using a rainfall-runoff model developed by **Charles Eeles** for a previous study of the Springs. It was interesting to note that a marked increase in discharge from the Springs occurred in the late 1960s, entirely attributable to increased rainfall, corresponded nicely with the water level rise observed in Lake Victoria at around the same time, discussed in the previous paper.

The model nodes are located at the gauging stations and other key sites, and it uses a five-day time step — daily was found to be too fine, monthly too coarse. The length of gauged records at upstream stations on the Athi was greater that those at downstream stations, so the upstream ones were used to extend and infill the downstream records. Correlation between neighbouring stations was difficult to achieve because of the high degree of scatter encountered. However, the difficulty was neatly overcome by using percentile flows on the flow duration curves of the neighbouring stations to correlate flows. This was particularly successful because it picked up zero flows at the downstream stations when flow existed at upstream sites.

Using his correlations, and extending his data set back, Chris was able to replicate, more or less, the frequency, duration, and (in several instances) the occurrences of dry spells identified by **Mike Mansell-Moullin** in a previous study on the Sabaki River. Given the data with which he started, and the behaviour of the hydrology of the system — quite an accomplishment.

As well as the primary uses of the model, it is also capable of incorporating transfers from the Tana River (as effluent from the potential third source for Nairobi), a potential dam on the Athi River (the Yatta Dam) that would be used mainly for irrigation, and climate change effects through inferred changes in runoff characteristics.

The conclusion of the modelling on the EIA on the Sabaki was that, with an additional 1.5 m^3s^{-1} being taken from Mzima, dry spells would be experienced at Baricho, in the lower Sabaki, where previously there were none recorded.

In the discussion **Jacob Tompkins** (Imperial College) asked if there were any groundwater contributions to the Sabaki. Chris replied that the Sabaki loses water during the dry season, and that this loss can be more or less explained by evapotranspiration from the river, the exposed bed and the vegetation corridor along the river. It would appear, therefore, that there are no significant groundwater contributions. **David Beale** (DHV) has been involved in modelling river flows on the Thika River. He asked if the effects of the potentially additional water from the transfer through the new Nairobi sewage treatment works was included in the EIA, and if there were any abstractions downstream on the Sabaki. Chris said that the potential to look at the effect of the transfer existed in the model, but had not been looked at, to his knowledge.

Abstractions downstream on the Sabaki existed for water supply at Baricho, although this was not being used extensively at present because of extreme siltation problems at the intake to the works. Some other minor abstractions were known to exist, but they were insignificant. **Marcus Frances** (Howard Humphreys) asked how much of the data used was infilled, and whether rainfall-runoff modelling had been considered. Chris replied that, with the quality of flow data, and the difficulties of trying to correlate flows from neighbouring stations on the same river, the prospect of introducing another set of unknowns and errors into the scenario, by trying to calibrate a rainfall-runoff model, was not appealing, despite the fact that rainfall data had been collected in order to keep this option open.

Howard Wheater (Imperial College) asked how sensitive the aquifer at Mzima was to abstraction. **Jimmie Blackie** (IH) responded, having been involved with Charles Eeles' modelling of the aquifer. He indicated that the aquifer is as sensitive as it is in the National Park, and Mzima Springs account for around 70% of the outflow from the Chyulu Hills aquifer. **Ron Manley** (Water Resource Associates Ltd) asked why flows from Mzima had been more stable prior to the 1960s. Chris did not know the answer to this, but most of the variance in the Springs outflow was accounted for by rainfall, and this must be where the explanation would lie.

All in all, we were presented with two very interesting papers, and a welcome mix of the light-hearted and the serious. The turnout to the meeting testified to the popularity, as ever, of this nostalgic topic. Until the next African hydrology meeting, then...

Rob Brown

Letter to *Circulation*

A hydrological mystery: Part 2

From Mike Price, Senior Lecturer in Hydrogeology, PRIS, Reading University

Dear Editor,

Ron Manley is still not completely happy that his "mystery" is solved (*Circulation 46* and *48*).

Ron worries that the variations in the water table and the variations in river stage are virtually synchronous, and feels that there should be a delay because it will take the water a finite time to flow from the aquifer to the stream. I suspect that he is making the mistake — which is not uncommon — of confusing the time of transmission of a perturbation in head with the time of movement of a water molecule.

Anyone who has conducted a pumping test knows that the change in head in an observation well will usually occur within minutes or even seconds of the pump starting in the production well, even though the wells may be tens or hundreds of metres apart. This does not mean that water has actually flowed from one well to the other in that time — that process commonly takes months or years in a sand aquifer.

Similarly, the water level in an observation well in an aquifer a few metres from the coast will rise and fall in response to the tide, with a time lag that increases with distance from the shoreline, but which is typically minutes. This does not mean that sea water is flowing into and out of the well with each tidal cycle.

The characteristic time of propagation for any diffusive process is given by

$$t = x^2/D$$

where x is the distance and D is the diffusivity (the conductivity property divided by the storage property). For groundwater flow, we can use the aquifer transmissivity, T, for the conductivity term and the storage coefficient, S, for the storage term. For a sand aquifer, let's assume a T value of 250 m^2/day and a value of 0.005 for S.

For a distance of 15 m — of the order that Ron was talking about — this gives a response time of 7 minutes. That would be a very slow response for a pumping test, because the initial response even in an unconfined aquifer would be an elastic one, with a much smaller effective value of S. For a cyclic fluctuation with a time period of 24 hours, the effective storage coefficient will be somewhere between the elastic value of about 0.0001 and the true specific yield, which may be about 0.1 — this is why I have suggested using 0.005.

In comparison, the speed of movement of a water molecule is given by

$$v = -\frac{K}{n_d} \cdot \frac{dh}{dl}$$

where K is the hydraulic conductivity, dh/dl is the hydraulic gradient and n_d is the dynamic or kinematic porosity (the proportion of the rock mass through which flow is occurring). Inserting reasonable values of K = 10 m/d, n_d = 0.1 and dh/dl = 0.005, we calculate a flow speed of 0.5 m/day, which means that a water molecule would take 30 days to travel the same 15 metres.

So the fact that there is an almost immediate response of the river and the water table is no problem, and there seems little doubt that the fluctuations first described were caused by evapotranspiration from the flood plain.

Michael Price
Postgraduate Research Institute for Sedimentology, University of Reading
Tel: + 44 (0)1734 318293 (direct)
Fax: + 44 (0)1734 310279

Publications

So far BHS has published six occasional papers, five volumes of symposium proceedings and a research strategy. The next occasional paper will be based on the National Meeting on 4 December 1995 on *Palæohydrology*, edited by Dr Julia Branson.

Occasional Papers Nos. 3, 4, 5 and 6, the Research Strategy and the Fifth National Symposium proceedings are all still in print.

Publications must be paid for by cheque in advance, including £2 to cover postage. Please use the order form in this issue of *Circulation*, or contact Professor Angela Gurnell, School of Geography, University of Birmingham, Edgbaston, Birmingham, B15 2TT.

Tel 0121 414 5526, Fax 0121 414 5528
Email gurnelam@novell2.bham.ac.uk

The hydrological impacts of used gravel workings — management or mayhem?

BHS Southern Section meeting Imperial College, London 6th December 1995

About 40 people braved the elements, after the first significant snowfalls to occur in southern England this winter, to hear two presentations on the hydrological impacts of used gravel workings.

The first speaker, **Simon Taylor** (Water Resources Manager, NRA Southern Region), gave a talk entitled "Planning for the future: lessons from the Chichester gravels".

Simon began with a detailed interpretation of recent investigations into the groundwater regimes through the chalk and gravels around Chichester, and their influence on the severe flooding of the city in January 1994. He focused on the environmental problems arising from gravel workings in the area of Westhampnett, in particular at Church Farm pit. This is an exhausted gravel working to the east of Chichester, next to the River Lavant and the A27, which has recently been developed into a recreational amenity.

An important geological feature is the marine and terrace gravels that overlie the Chichester chalk block. During the winter the gravels are recharged from below by the chalk and provide, at least historically, a major pathway for groundwater flow. However, over the last fifty years successive excavations have resulted in major modifications to the hydrogeological characteristics of the gravel layer. As pits have been excavated and then infilled there has been a significant reduction in the conductive pathways for groundwater. Planning permission has been granted for development on the reclaimed land, in some cases with the proviso that roof levels be limited to original ground level, but since construction there have been problems with groundwater leakage in these areas, causing considerable damage to the new buildings.

In January 1994, following heavy rainfall over the region, raised groundwater levels in the chalk resulted in major inflows to the gravels, in turn causing the water level in Church Farm pit to overflow, flooding the newly constructed A27 road and the surrounding area. One of the main reasons for this was that Church Farm pit is lined with a clay seal. The high heads of water in the chalk were forcing groundwater into the overlying gravels which was then able to flow over the top of the seal and into the lake, where it was essentially contained until the system overflowed. To prevent this recurring, two culverts can now be opened to provide additional drainage during critical periods.

Between 1948 and 1994, a steady programme of infilling of the old workings has left few areas of gravel remaining, and new plans are out for

consultation for future gravel extraction in the area. Thus, this vital geological material, which provides an essential medium for the high groundwater flows, is in danger of being lost completely. The NRA are keen to maintain an embargo on these plans until a strategy has been put together for managing the system effectively.

Simon concluded that there were several major issues which had to be fully understood and acted upon before further development of the gravels for abstraction could be approved. These included: methods available for controlling groundwater levels in a supportable way; flood protection requirements for the local people and land; the viability of further development on reclaimed land (bearing in mind the high pumping requirements inevitably needed by such proposals), and the water quality issues associated with rising water levels interacting with pits infilled with domestic rubbish tips, which may then contaminate adjacent amenity resources.

He highlighted the lack of information currently available on topics such as siltation rates in the lakes, post gravel-winning recovery of the water levels, the condition of the flood defence bunds around the lakes, and the long-term groundwater movements. He suggested that instead of ad-hoc permission being granted for further developments, careful planning together with an overall strategic approach needed to be adopted to ensure a sustainable and practicable future for the area.

The Blashford Lakes story

The second speaker was **John Eastwood** (Wessex Water). In his presentation he spoke on "Worked Out Gravel Pits as a Valuable Water Resource: The Story of the Blashford Lakes". A series of old gravel pits in the Avon valley have been used as a valuable resource for both local and regional water supply, whilst maintaining an appropriate balance between nature conservation, recreation and general amenity value.

John outlined briefly the history of the region, which was not exploited for gravel until after the war. Terraced gravels up to 9 m deep overlie the Brackersham series, with a water table only 1-2 m below ground level. Different methods of working the gravels were dry abstraction with continuous de-watering, and wet working, which caused silts to accumulate at the base of the lakes.

Potential flooding problems were identified in the area, and Hampshire County Council began to undertake hydrological studies in the 1970s in liaison with Avon & Dorset Water Authority (now Wessex Water). Two major problems were identified. The first resulted from high winter water levels in several lakes, superimposed on southerly groundwater flows (where water tables were already 1-2 m above the natural ground level), and exacerbated by impermeable barriers of accumulated silts in the lakes, preventing some potential natural drainage. This was solved by requiring the gravel companies to construct spillways to discharge excess groundwater into the flashy New Forest streams.

The second problem was that uncontrolled dewatering impinged on other users' rights to the water. Closed recirculation systems of pumped groundwater were recommended, and Wessex Water imposed onerous conditions on dewatering operations.

Lax planning controls in the 1960s meant that the area developed in a particularly ad-hoc way, generally for recreation. However in 1983, very dry summer months were coupled with increasingly high peak demand flows: as a result, the Blashford Lakes were identified for development as an additional water resource. This solution had three major advantages: the resource could act as a pollution standby, it could be developed in phases, and it would also be an environmentally acceptable option.

Towards the end of 1993, an extensive environmental impact assessment and programme of consultation were commissioned and hydrometric measurement stations were constructed. John Eastwood spoke about the extensive programme of pumping tests carried out on the lakes: together with a full groundwater model simulating flows through the complex lake system, these were used to determine that through-flows were negligible and that the New Forest streams were effectively isolated from the workings.

Planning permission was granted in 1986 for water to be transferred from the lakes through a water treatment works into a distribution system, for refill of the lakes from the Hampshire Avon river, and for the possible further development of the resource.

John described some technical aspects of the final design of the development. The lakes were not sealed, so natural storage was relied upon and any leakage resulting from this was shown to affect the system efficiency only minimally. Huge effort was put into landscaping and environmental enhancement projects, including constructing impermeable bunds to maintain a small area of consistently high water levels for wildfowl. In 1989, a consultative committee was set up to ensure that the concerns of all interested parties were acknowledged, and to prepare a management plan for the area — this was implemented in 1992.

He concluded that the £18 million development of the Blashford Lakes had not only met all their aspirations from a water supply point of view but had also provided the region with a resource of national importance, from both the nature conservation and the recreational perspective.

A lively discussion then ensued, in which key points from the two presentations were discussed, along with the wider implications of planning controls for licensing gravel extraction. It was agreed that there was a vital need for detailed understanding of these often extremely complex hydrological systems in order to enable the impacts to be assessed properly.

Bridget Woods Ballard

Professorship

Chris Collier, a former Hon. Secretary of BHS, has left Met Star Consultants and is now Professor of Environmental Remote Sensing at the Telford Institute of Environmental Systems, Salford University. His hydrometeorological expertise is now focused on a flood potential product for developing countries, using synthetic aperture radar data from the ERS 1/2 satellites.

New Welsh Group contact

Rob Drayton has now taken over as the Welsh Hydrological Group's representative on the Main Committee. Thanks to **Linda Aucott**, who has moved from Bridgwater to the NRA's Exeter office, for her four years' service in that rôle.

Hazards Forum

The January edition of the *Hazards Forum* Newsletter has been received. The Overseas Development Administration is funding a research associate, **Mohammed Omer Mukhier**, to extend the Cranfield training package on slow-onset disasters (developed for Sudan) to countries in Southern Africa, where drought is an increasing problem.

Contributions for the next edition should go to Darlene Torey, Hazards Forum Secretariat, 1 Great George Street, London SW1P 3AA (tel 0171 839 9971, fax 0171 233 1806) by *1st March*.

Copy Deadline for Issue No. 50 4th April 1996

FORTHCOMING EVENTS

Fifth BHS Postgraduate Symposium

Newcastle upon Tyne 1-3 April 1996

All you fledgling and newly-fledged hydrologists out there: this is for *you*!

We want you to come and tell us about your current research, or the PhD or MSc thesis you have recently finished — or indeed, the exciting results of your first job in industry. We welcome papers on pure and applied hydrology, in its broadest sense.

Abstracts must be submitted by **1st March 1996.** Submission by e-mail is preferred, to P.L.Younger@ncl.ac.uk. If you *insist*, we will grudgingly accept paper copy (single-spaced, 1 side of A4).

The Postgraduate Symposium is usually the best-attended (and arguably the best fun) of all BHS's programme meetings. This year it will be hosted by the Department of Civil Engineering at the University of Newcastle upon Tyne.

The cost of accommodation will be kept low, thanks to the success of last year's National Symposium, and we intend to arrange some exciting evening activities, as well as a trip to the Kielder System in Northumberland.

For further information and booking details, please contact Dr Paul L Younger, Lecturer in Water Resources, Dept of Civil Engineering, Cassie Building, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU Tel 0191-222-7942 Fax 0191-222-6669 E-mail: P.L.Younger@ncl.ac.uk

Meetings

Workshop on
NITROGEN DEPOSITION & THE ACIDIFICATION OF NATURAL & SEMI-NATURAL ECOSYSTEMS
Aberdeen
8-10 September 1996

The European acid emission abatement policy for sulphur uses the critical loads approach, derived from process-based scientific research. Now attention is turning to atmospheric nitrogen. This workshop will examine current understanding of the deposition of nitrogen compounds and the relationship with soil processes and ecosystems.

Abstracts of oral and poster papers must be submitted by **31 March 1996.**

The venue is the Macaulay Land Use Research Institute. The registration fee (£85) includes lunches and proceedings. Hotel accommodation is £45 per night (but £60 for Tuesday night). There will be a field trip (optional, £30 extra) to the Dee and Don valleys on 8 March; the main sessions are on 9 & 10 March.

To register or for more information please contact Dr Sue Bird, MLURI, Craigiebuckler, Aberdeen AB9 2QJ (Tel 01224 318611, Fax 01224 311556, Email mi307@mluri.sari.ac.uk).

International conference on
MULTIPLE LAND USE & CATCHMENT MANAGEMENT
Aberdeen
11-13 September 1996

Following immediately after the workshop at MLURI *(see above)*, this important and innovative conference will make the case for integrated catchment management as the best way to cope with potentially conflicting uses.

There will be invited papers, posters, model demonstrations and interactive workshops on 11 and 12 September, with site visits and case studies on Friday 13 September.

The venue is the Kings College Conference Centre in Old Aberdeen.

For more information please contact Dr Sue Bird at MLURI *(address above)*.

1st International Conference on
GEOCOMPUTATION
Leeds
17-19 September 1996

This conference aims to bring together emergent computer-based techniques in geography to transfer methods between the different areas of research and thus drive future developments.

Sessions will cover expert systems, neural networks, fractals and chaos, data analysis and data mining, GIS, macro- and micro-modelling and scaling, process-based and fuzzy modelling.

Abstracts are invited, to be submitted by **15 May 1996**; publication of accepted papers is anticipated.

Further information (including the updated list of speakers) is available on the World Wide Web — http://www.geog.leeds.ac.uk/geocomputation.html — or from Tracey Harris, School of Geography, University of Leeds, LS2 9JT (tel 0113 233 3324, fax 0113 233 3308, Email geocomputation@geog.leeds.ac.uk).

Sixth ERB General Assembly and Conference on
ECOHYDROLOGICAL PROCESSES IN SMALL BASINS
Strasbourg, France
24-26 September 1996

The 6th biennial conference of the European Network of Experimental and Representative Basins (ERB) will focus on monitoring and modelling soil-water-vegetation-atmosphere interactions in small catchments.

Contributions of papers and posters are invited. Please send one copy on paper and one on disk (Word or WordPerfect 5.2 or later) of your extended abstract (3-4 pages, up to 3000 words) or poster description (1 page, up to 1000 words), each including diagrams, to Daniel Viville, CEREG, 3 rue de l'Argonne, F 67083 Strasbourg Cedex, (fax +33 88 41 13 59) by **31 March 1996.**

Refereed papers will be published after the meeting as Proceedings. Authors will be notified by 31 May 1996: the full papers are required at the start of the conference.

The registration fee will be about FFr300, including conference dinner, field trip to Vosges catchments (25 September) and Proceedings. Accommodation and meals will be available from about FFr200 per day.

For further information contact Dr Mark Robinson, Institute of Hydrology (Tel: 01491 838800, Fax 01491 692424).

BHS National Meeting
LOW FLOW SOLUTIONS
Bristol
February 1997

The South West Section, probably in association with the Welsh Hydrological Group, is planning a National Meeting on Low Flow Hydrology, particularly looking at proposed or implemented solutions to the problems of deprived stretches of river.

The organisers would like to hear from anyone working in this field who would be interested in presenting a paper at this meeting, or just attending.

The venue will be in Bristol. Please contact **Graeme Boyce** or **Paul Sadler,** NRA South Western Region, Exeter (tel 01392 444000, fax 01392 442041).

Diary

21st February 1996
BHS National/Pennines Meeting
"Practical application of quality

standards in hydrometry & hydrology"
Venue: Salford University — 1.15 p.m.
Contact: Dr Liz Kaar, NRA North West Region, P.O. Box 12, Knutsford Road, Warrington, Cheshire WA4 1HG *(Tel 01925 653999, ext. 2131)*

28th February 1996
BHS Southern Section
"Source controls and sustainability" — John Gardiner (Middlesex University) and Phil Aldous (Thames Water)
Venue: Imperial College, London
Time: 5.30 p.m. (tea at 5.00 p.m.)
Contact: Professor H S Wheater, Dept of Civil Engineering, Imperial College, London SW7 2BU *(Tel: 0171 589 5111 ext 4736/4720. Fax: 0171 823 8525)*

29th February 1996
Geological Society
"Natural Groundwater Chemistry"
Venue: Burlington House, London
Contact: N S Robins, BGS Wallingford *(Tel: 01491 692400 Fax: 01491 692345)*

29th February 1996
CIWEM One-day Conference
"Water conservation and reuse"
Venue: Scientific Societies, London
Contact: Hannah Sime, CIWEM Conferences *(Tel 0171 831 3110, Fax 0171 405 4967)*

2nd March 1996
"Urban Drainage & Flood Control"
Venue: Glasgow Caledonian University
Contact: Dr J Crowther *(Tel 0141 331 3666)*

6th March 1996
Scottish Hydrological Group / CIWEM
"Shaping the future: new management for Scottish water" – Water Authority & SEPA speakers
Venue: Heriot-Watt University
Time: 2.00 – 5.30 p.m.
Fee: £15 in advance, payable to ICE
Contact: Dr A R Black, Geography Dept, Dundee University, DD1 4HN *(Tel 01382 344433, Fax 01382 344434)*

13th March 1996
BHS Midlands Section
Hydrological Research at East Midlands Universities
Venue: University of Derby
Contact: Paul Webster, School of Civil Engineering, University of Birmingham, Birmingham B15 2TT. *(Tel 0121 414 5055, Fax: 0121 414 3675)*

25th March 1996
BHS & British Dam Society
"Floods, waves & reservoir safety — an engineering guide" *(see insert)*
Venue: ICE, 1 Great George St, London
Contact: Richard Howard, ICE, 1 Great George Street, London SW1P 3AA *(Tel 0171 839 9836, Fax 0171 799 1325)*

27th – 28th March 1996
CIWEM, ICE & BHS Conference
"Water Environment '96: Supply & demand — a fragile balance"
Venue: ICE, 1 Great George St, London
Contact: Lavinia Gittins, CIWEM Conferences *(Tel 0171 831 3110, Fax 0171 405 4967)*

1st – 3rd April 1996
BHS VIth Postgraduate Symposium
Venue: University of Newcastle
Contact: Dr Paul Younger, Dept. of Civil Engineering, University of Newcastle upon Tyne *(Tel 0191 222 7942, Fax 0191-222-6669)*

6th April 1996
Royal Society of Chemistry
"Environmental fate of water pollutants"
Venue: WRc Medmenham, Marlow
Contact: L A Hart *(Tel 0171 437 8656, Fax 0171 287 9825)*

11th April 1996
Welsh Hydrological Group
"Ultrasonic flow-gauging" – Richard Iredale (NRA Severn Trent Region)
Venue: Upton on Severn & Tewkesbury (Afternoon visit + evening meeting)
Contact: Dr Rob Drayton, 208 Fidlas Road, Llanishen, Cardiff CF4 5NA *(Tel 01222 754879, Fax 01222 754879)*

15th – 18th April 1996
Geological Society
"Applied Geoscience" *(sessions on groundwater pollution and protection)*
Venue: Warwick University
Contact: N S Robins, *address above*

16th – 19th April 1996
HydroGIS '96 International Conference
Application of geographic information systems in hydrology / water resources
Venue: Vienna, Austria
Contact: Dr M J Clark, GeoData Institute, University of Southampton *(Tel 01703 594488, Fax 01703 592849)*

24th April 1996
BHS Southern Section Meeting & AGM
Programme to be announced
Venue: Imperial College, London
Time: 5.30 p.m. (tea at 5.00 p.m.)
Contact: Professor H S Wheater, Dept of Civil Engineering, Imperial College, London SW7 2BU *(Tel: 0171 589 5111 ext 4736/4720. Fax: 0171 823 8525)*

15th May 1996
BHS Pennines Group Meeting & AGM
"Impact of hydrological change on catchment management"
Contact: Dr Liz Kaar, *address above*

5th June 1996
"Floodplain restoration"
Venue: Birmingham
Contact: Andy Large, University of Newcastle upon Tyne *(Tel 0191 222 6342, Fax 0191 222 5421)*

18th June 1996
BHS South West Section Meeting
"Hydrology and nature conservation"
Venue: Bristol *(details to be confirmed)*
Time: 6.00 p.m. for 6.30 p.m.
Contact: Bill Finlayson, RUST Environmental, Queen Victoria House, Redland Hill, Bristol BS6 6US *(Tel 0117 973 9090)*

8th – 11th July 1996
IAHS, BHS — Interceltic Colloquium on Hydrology and Water Management
Venue: Rennes, Brittany
Contact: Alain Jigorel *(Fax +33 99 63 67 05, E-mail: alain.jigorel@insa-rennes.fr)*

15th – 19th July 1996
IAHS — "Global Patterns of Erosion and Sediment Control"
Venue: Exeter University
Contact: Prof Des Walling, Dept of Geography, Exeter University, EX4 4RJ. *(Tel 01392 263345, Fax 01392 263305)*

3rd – 5th September 1996
UNESCO IHP-V Conference
"Conflicts in reservoir development and management" (see *Circulation* 46)
Venue: City University, London
Contact: Mrs Pat Walker *(Tel 0171 477 8141, Fax 0171 477 8570, Email* PWalker@city.ac.uk)

10th September 1996
BHS National Meeting & AGM
"Capturing the hydrological cycle" — Dr John Rodda (Honorary Member)
Venue: Imperial College, London
Contacts: Dr P L Younger or Professor H S Wheater, *addresses above*

8th – 10th September 1996
"Nitrogen deposition & acidification of natural ecosystems" *(see Meetings)*

11th – 13th September 1996
"Multiple land use & catchment management" *(see Meetings)*

17th – 19th September 1996
1st International Conference on "Geocomputation" *(see Meetings)*

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.
Circulation is produced by the Institute of Hydrology and indexed in *Geosystems' Hydrotitles & GeoArchive.*