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UNIVERSITY RESEARCH ...Part VII

Department of Geography, Exeter University

The Geography Department of the University of Exeter has a long-standing tradition of research in physical hydrology which extends back over more than 20 years to its early work in a number of small instrumented catchments located in East Devon and in a small basin on the margins of Exeter which was undergoing residential development. Hydrological investigations remain a major component of the research currently undertaken in the Department. They represent the primary concern of two (*Des Walling* and *Bruce Webb*) of the six members of academic staff with interests in physical geography, and they have provided the basis for a thriving group of largely NERC-funded postgraduate students and postdoctoral assistants and fellows which has existed at Exeter for over 15 years.

Since 1970, research has focused primarily on studies of erosion and sediment transport and on investigations of background water quality in rural catchments. Much of this work has been conducted within the framework of the 1,500 km^2 catchment of the Exe Basin which has been instrumented for the detailed monitoring of suspended sediment, water chemistry and river temperature and has yielded data sets of quality and length unique within Britain. Field investigations are also being undertaken in other principal UK rivers (e.g. River Severn) and the Department has been involved in overseas research including erosion and sediment transport studies in Kenya, Algeria, Jamaica, China, Poland, and the Philippines. Major archives of water quality data relating to both the local catchments and to national and global contexts have also been built up at Exeter. The Department is strongly involved in international hydrological activities, and Exeter was host to the First Scientific Assembly of the International Association of Hydrological Sciences. Most recently, the Department of Geography was the first in the UK to be equipped with facilities for using caesium-137 for studies of soil erosion and fluvial sediment transport.

EROSION AND SEDIMENT TRANSPORT

Sediment research at Exeter has evolved through a series of stages reflecting a progressive improvement in the understanding of the hydrological processes involved and in the availability of more sophisticated methodologies of investigation.

Sediment behaviour

The suspended sediment monitoring of Devon rivers represents the most detailed work undertaken on this aspect of the hydrology of British rivers and it has highlighted the complex nature of suspended sediment behaviour, which is characterized by seasonal and storm-period hysteresis and is more strongly influenced by time-variant sediment availability than by transport energy (Walling and Webb, 1987). It has, for example, been demonstrated that suspended sediment concentrations during a sequence of stormflow events will commonly exhibit a progressive decline which reflects both a dilution effect, caused by an increasing baseflow component, and an exhaustion effect, caused through the removal (by the earlier events) of readily erodible sediment generated by physical and biological processes operated during the dry periods between storms. It has also been shown that suspended sediment transport is strongly biased towards high episodic flows, and that suspended sediment yield in a given year is not only a function of total or peak discharge but also the number, origin and sequence of major storm events. The lack of a clearly defined transport function, which relates suspended sediment concentration and discharge, introduces many problems in attempts to estimate sediment transport from data collected on a sporadic or intermittent basis. The availability of long-term and continuous sediment concentration and flow records at Exeter has allowed the reliability of commonly adopted interpolation and extrapolation procedures for the estimation of sediment loads to be assessed. Investigation of the standard rating curve approach, for

example, has revealed that annual yield estimates produced for small catchments (< 50 km^2) are typically as low as only 5% of true sediment flux. Recent studies have also shown that corrections for the transformation bias associated with the use of rating curves, which have been proposed as a means of improving such estimates, generally offer only marginal improvement in the accuracy of the resulting load estimates and that these are gained at the expense of a substantial deterioration in the precision of the predicted yields (Walling and Webb, 1988). A wider perspective on sediment behaviour has been obtained by efforts to collate and analyse data available on a national and a global basis. A synthesis of available British information has shown UK rivers to have annual suspended sediment yields of between < 1 and 500tkm^{-2}year^{-1}, which are low by world standards, and an early attempt to analyse global patterns of sediment transport was undertaken by **Abdul Kleo** in his PhD programme. The latter data-base was greatly expanded through involvement with the UNESCO International Hydrological Programme and is being continuously updated. It has not only allowed the construction of a new map of global sediment yields (Fig. 1) but has also suggested that some of the classical relationships between climate and sediment yields proposed in the literature are in need of revision (Walling and Webb, 1983). The potential of satellite imagery for the investigation of suspended sediment transport has also been investigated through an NERC research grant (Aranuvachapun and Walling, 1988). Detailed studies of suspended sediment yields in response to land-use change, the erosional impact of extreme events and problems of reservoir sedimentation are being undertaken by **Martin O'Hara** in Jamaica and by **Sue White** in the Philippines.

Sediment properties and sources

Whereas initial research at Exeter was directed to the *quantity* aspect of sediment concentrations and yields, more recent investigations have focused on the *quality* aspects which relate to the properties of the sediment itself, in order to shed further light on the mechanisms of particulate transport, on the role of the sediment-associated phase in the transport of nutrients and contaminants, and on the distribution of sediment source areas within catchments. Data from the Exe Basin (Table 1) have shown the suspended sediment to be composed primarily of phyllosilicates, quartz, organic matter and iron oxides (Walling and Kane, 1984). Mica is the dominant clay mineral group present and quartz occurs predominantly in the silt rather than the clay-sized fraction. The organic matter content ranges from < 9 to $> 15\%$, and the majority of the iron present is in a "free" form rather than being organically bound or in an inorganic "amorphous" form. Particle-size characteristics have emerged as an important property of suspended sediments but a distinction has to be drawn between the *ultimate* particle-size distribution derived from traditional laboratory procedures and the *effective* particle-size distribution which reflects actual in-stream conditions. A number of techniques have been developed at Exeter to investigate the latter distribution which, when compared with that for the chemically dispersed mineral fraction, indicates that the majority of suspended sediment is transported as aggregates of between 10 and 20 μm in diameter in which organic matter is an important binding agent. Research within the Exe Basin has also indicated that the ultimate particle-size characteristics of fluvial suspended sediment are subject to significant spatial and temporal variation (Walling and Moorehead, 1987). The contribution of sediment-associated transport to nutrient loads has been investigated by **Rick Thornton** who found that 6–16% of the nitrogen and 50–70% of the phosphorous in local catchments may be removed in particulate-associated form. Further studies of nutrients bound to fluvial sediments are currently being undertaken by **Keith Garrett**. The magnitude and controls of bank erosion as a source of suspended sediment has been studied in an instrumented reach of the River Culm in Devon by **Dave Ashbridge**, and traditional methods of assessing the relative importance of sediment contributions from channel banks and field surfaces have been applied by **Rick Curr** in the Corston Brook near Bath. Studies of sediment properties have also been developed as a means of "fingerprinting" sources of sediment within drainage basins. **Mervyn Peart** has applied this methodology to two Devon catchments, and properties such as mineral magnetism, organic matter content, C/N ratios and clay mineralogy offer considerable potential for discriminating between

Table 1 *Suspended sediment data from the Exe Basin.*

River	Composition in % of freeze-dried sediment					
	Phyllosilicates				Iron	Organic
	Mica	Others	Total	Quartz	oxides	matter
Exe at Thorverton	32.2	25.0	57.2	27.2	3.0	12.6
Creedy at Cowley	31.1	30.4	61.5	24.9	4.0	9.6
Dart at Bickleigh	25.8	25.4	51.2	34.4	3.0	11.4
Clyst at Clyst Honiton	45.7	20.0	65.7	21.3	4.5	8.5
Culm at Rewe	37.2	18.8	56.0	24.1	4.1	15.8
Jackmoor Brook	38.1	24.6	62.7	25.2	3.7	8.4

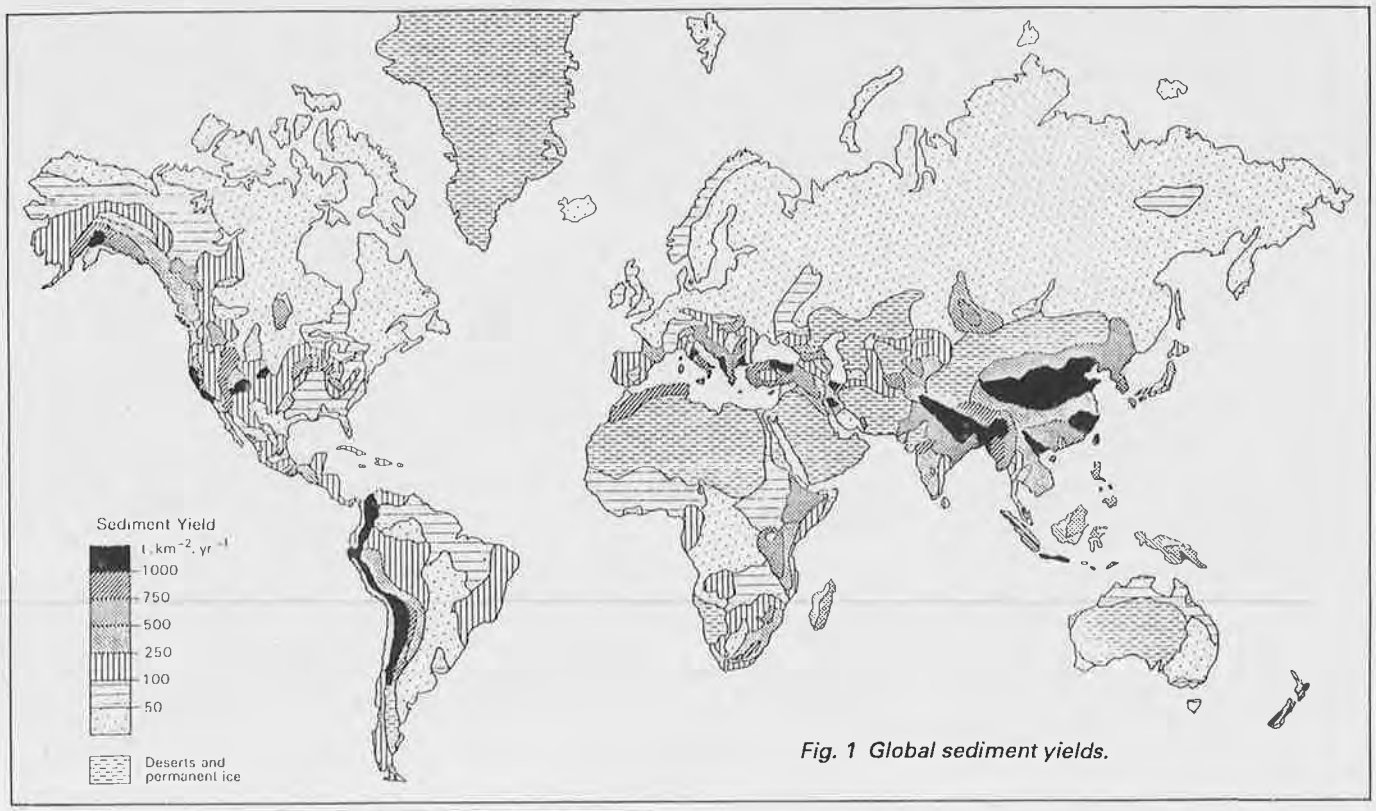
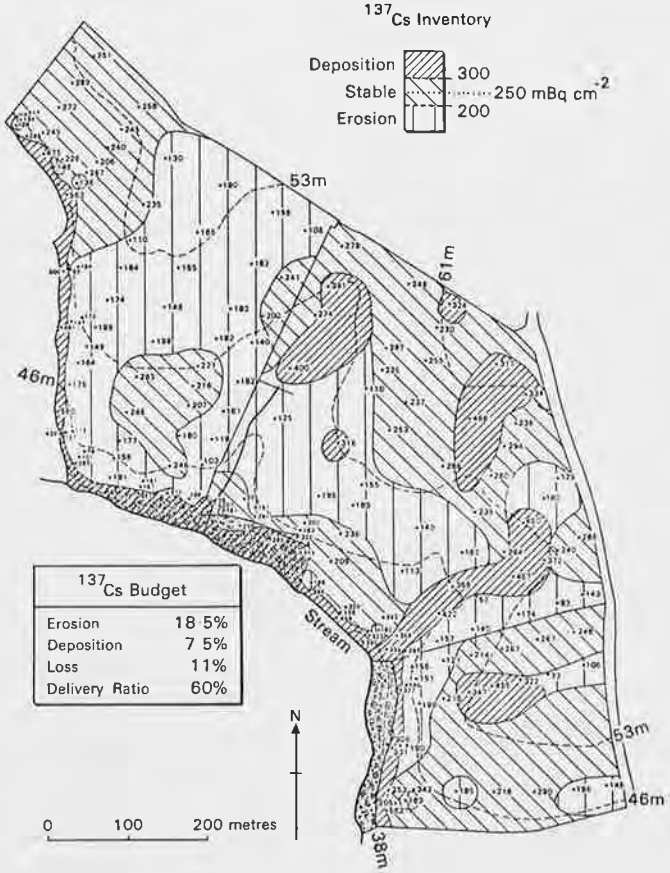


Fig. 1 Global sediment yields.

Fig. 2 Spatial distribution of ^{137}-Cs content of the soil profile within a cultivated field near Exeter, Devon.



surface soils and bank material as sources of suspended sediment (Peart and Walling, 1986). Caution is, however, required in using this approach, since processes of erosion and transport are selective and lead to enrichment of suspended sediment in fines, organic matter, nutrients and contaminants compared with potential source materials. In these circumstances, use of elemental ratios and comparison of results based on different sediment properties have been found to yield a more reliable picture of sediment sources.

Sediment delivery and budgets

Sediment research at Exeter has recently become increasingly concerned with the conveyance or delivery processes interposed between on-site erosion and sediment yield at the basin outlet (Walling, 1983). The aim is to identify both the erosional sources and depositional sinks for sediment within a catchment and to quantify the relevant sediment transfers in the form of a sediment budget. **Chris Lambert** has studied the storage and remobilization of fine-grained material within the channel bed and found it to be of relatively minor importance to suspended-sediment transport at downstream sites. In contrast, studies of floodplain deposition in the lower reaches of the River Culm using sediment traps have shown that this form of conveyance loss is of considerable significance to the sediment budget and amounts to 28% of the suspended sediment load entering the study reach (Lambert and Walling, 1987). A major research effort which focuses on the use of caesium isotopes in studies of sediment delivery and sediment budgets is currently underway at Exeter and a large gamma spectrometry facility has been established to support this work. These radioisotopes, generated by past atmospheric testing of nuclear weapons, have considerable potential in fingerprinting sediment sources, in establishing the magnitude and pattern of erosion at the scale of an individual field (Fig. 2), in constructing sediment budgets and in documenting rates and variation of floodplain accretion (Walling *et al.*, 1986; Walling and Bradley, 1988). Caesium research at Exeter has involved co-operation with workers in Australia, China and Poland, and over the past five years Des Walling has built up a team of postgraduate and postdoctoral researchers to investigate the hydrological and geomorphological applications of caesium studies. **Steve Bradley** has been involved in NERC-supported studies of floodplain deposition involving ^{137}Cs analysis of large numbers of cores collected from a 13 km stretch of the River Culm floodplain, whereas **Tim Quine** has been using caesium studies to quantify patterns of erosion and deposition in a national sample of cultivated fields which have been chosen to be representative of the major soil groups in England and Wales. This work also involves the development and calibration of a model which will allow the pattern of Cs activity to be converted into rates of soil gain or loss. Des Walling and Time Quine are also about to embark on an NERC-supported study of the redistribution of Chernobyl-derived ^{134}Cs and ^{137}Cs by fluvial processes within the Severn basin. Postgraduate research work based on caesium studies is also being carried out by **John Rowan**, who is investigating radionuclide transport in the Rivers Exe and Severn, and by **Dave Higgitt**, who is looking via a series of case studies into new applications for caesium measurements.

BACKGROUND WATER QUALITY

A second major area of research at Exeter is concerned with the chemical and physical characteristics of streamflow in rural catchments free from major industrial and domestic pollution.

Water chemistry

There is a continuing interest in stream solute levels and loadings and in the control which geological, climatic, topographical and other factors exert on the spatial variation of water chemistry at local, national and global scales (Walling and Webb, 1986). Temporal variation of solutes, involving seasonal and storm-period fluctuations, have been the subject of much research in local catchments, and work on the causes of annual and storm-period hysteresis in solute concentration and composition is being undertaken in conjunction with Swiss researchers (Webb *et al.*, 1987). The behaviour of NO_3-N in river

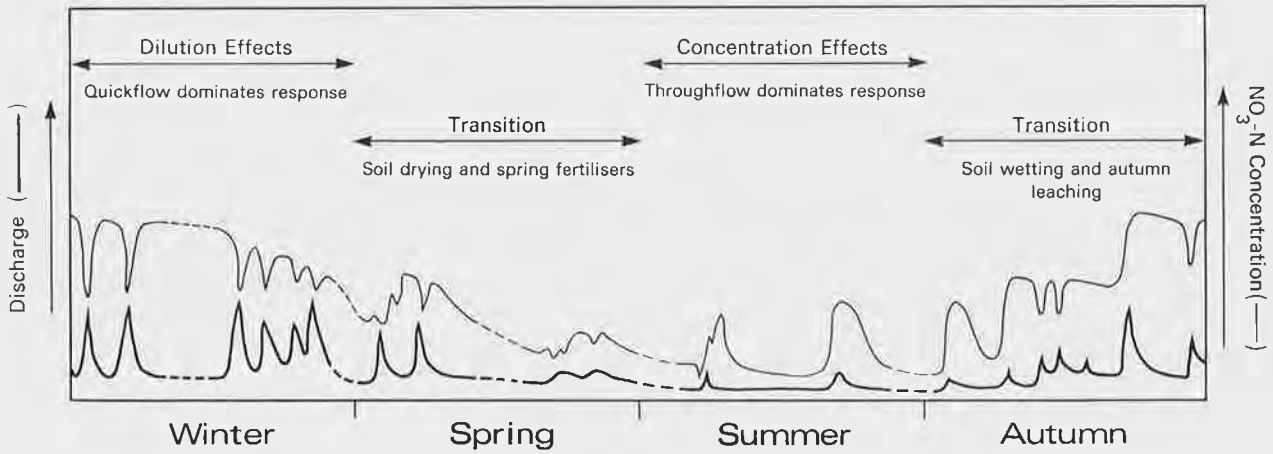
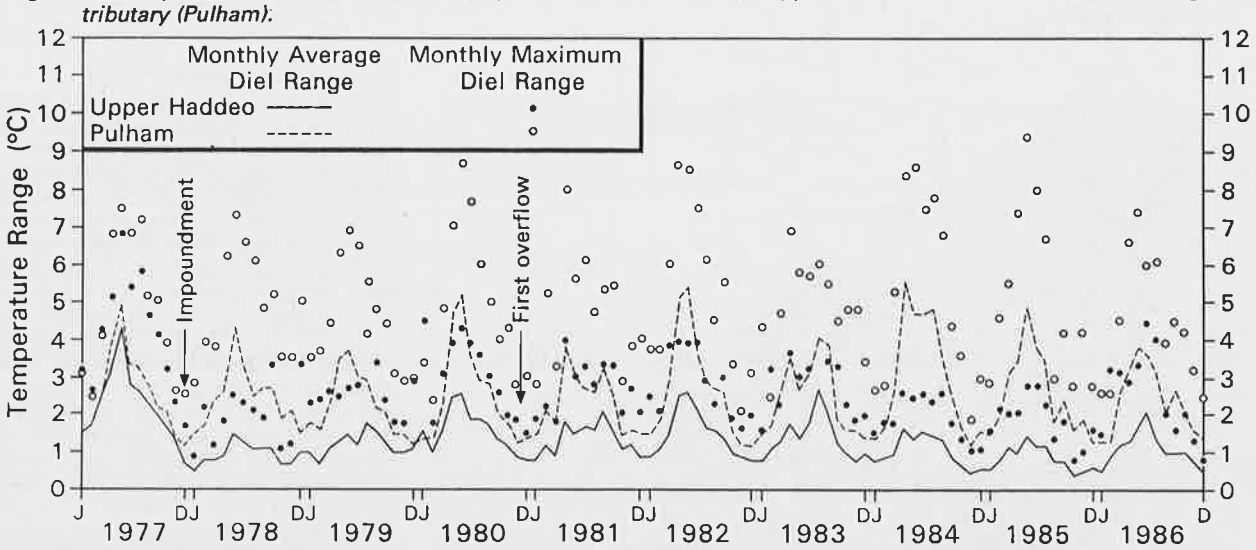


Fig. 3 Idealised seasonal cycle of storm period NO_3-N behaviour in the River Dart, Devon.

Fig. 4 Diel temperature fluctuations immediately below Wimbleball Dam (Upper Haddeo) and in an unregulated neighbouring tributary (Pulham).



systems is of particular interest. Research in the Exe Basin has demonstrated that NO_3-N levels exhibit an annual march on which is superimposed a seasonally variable response to storm events (Fig. 3), and this complex pattern reflects variation in runoff production mechanisms which operate throughout the year (Webb and Walling, 1985). The Department is collaborating in studies of the hydrology of drained grassland and its implications for nitrate behaviour with the MAFF Field Drainage Experimental Unit of ADAS and with the Institute of Animal and Grassland Production at the North Wyke field station near Okehampton, Devon. This co-operation has taken the form of three MAFF-supported and jointly supervised research studentships. In the first of these, **Mark Hallard** investigated the basic hydrology of 12 experimental plots on grassland in which different treatments for drainage, fertiliser use and cultivation practice are being applied. Aspects of the NO_3-N cycle in these plots and the relationship to their hydrology are being followed up by **Kate Blick**, who is studying nitrogen levels in soils and drainage waters, and by **Paul Blantern**, who is examining the role and controls of nitrogen mineralisation in the N-balance of drained and undrained soils. A countrywide perspective of N behaviour in streams and rivers is being obtained by **Catherine Betton**, who in her NERC-funded PhD programme is assembling and analysing information for Britain on the magnitude of N levels and loadings, their seasonal and discharge-related variations, and their trends over the last decade.

Stream and river temperatures

More than 200 station-years of continuous water temperature records have been collected in the Exe basin by the Department of Geography since 1974. These data have been investigated to establish the magnitude and controls of spatial variation in thermal regime, including annual means, seasonal marches and diurnal fluctuations. The temperature data have been analysed in conjunction with meteorological records to test simple methods of predicting the thermal characteristics of streams and rivers, and the implications of varying temperature regime on aquatic ecology are also being assessed. A particular study has been made of the impact which the construction of Wimbleball Reservoir and the associated river regulation scheme has had on temperatures within the River Exe system (Webb and Walling, 1988). It has been found that although the major influence is felt within 20 km of the dam (Fig. 4), thermal effects may be propagated to almost 40 km downstream from the impoundment under conditions of hot weather and low flows.

THE PROSPECT

Hydrological research at Exeter will continue to focus on studies of erosion and sediment transport processes and on investigations of background water quality. The Department of Geography is well placed to develop research in these areas since it has easy access to a major and well-instrumented UK drainage basin which drains a wide diversity of terrain types and encompasses conditions representative of many British rivers. There is a continuing commitment to local field-based research but the Department is also extending its international activities. For example, a research programme on erosion and sediment yields in the loess region of China, which will involve collaboration with Academica Sinica, is currently being planned.

References

Aranuvachapun, S. and Walling, D.E. 1988. Landsat-MSS radiance as a measure of suspended sediment in the Lower Yellow River (Hwang Ho). *Remote Sensing of Environment* 24, 145–65.

Lambert, C.P. and Walling, D.E. 1987. Floodplain sedimentation: a preliminary investigation of contemporary deposition within the lower reaches of the River Culm, Devon, UK. *Geografiska Annaler* 69A, 393–404.

Peart, M.R. and Walling, D.E. 1986. Fingerprinting sediment sources: the example of a small drainage basin in Devon, UK. In: *Drainage basin sediment delivery* "Proceedings of the Albuquerque Symposium", August 1986, 41–55. IAHS Publication No. 159.

Walling, D.E. 1983. The sediment delivery problem. *Journal of Hydrology* 69, 209–37.

Walling, D.E. and Bradley, 1988. The use of caesium-137 measurements to investigate sediment delivery from cultivated areas in Devon, UK. In: *Sediment Budgets* "Proceedings of the Porto Alegre Symposium, December 1988", 325–35. IAHS Publication No. 174.

Walling, D.E., Bradley, S.B. and Wilkinson, C.J. 1986. A caesium-137 budget approach to the investigation of sediment delivery from a small agricultural drainage basin in Devon, UK. In: *Drainage basin sediment delivery* "Proceedings of the Albuquerque Symposium", 423–35. IAHS Publication No. 159.

Walling, D.E. and Kane, P. 1984. Suspended sediment properties and their geomorphological significance. In: *Catchment Experiments in Fluvial Geomorphology* (ed. by T.P. Burt and D.E. Walling), 311–34. Geo Books, Norwich.

Walling, D.E. and Moorehead, P.W. 1987. Spatial and temporal variation of the particle-size characteristics of fluvial suspended sediment. *Geografiska Annaler* 69A, 47–59.

Walling, D.E. and Webb, B.W. 1983. Patterns of sediment yield. In: *Background to palaeohydrology* (ed. by K.J. Gregory), 69–100. John Wiley & Sons Ltd., Chichester.

Walling, D.E. and Webb, B.W. 1986. Solutes in River Systems. In: *Solute Processes* (ed. by S.T. Trudgill), 251–327. John Wiley & Sons Ltd., Chichester.

Walling, D.E. and Webb, B.W. 1987. Suspended load in gravel-bed rivers: UK experience. In: *Sediment transport in gravel-bed rivers* (ed. by C.R. Thorne, J.C. Bathurst and R.D. Hey), 691–723. John Wiley & Sons Ltd., Chicester.

Walling, D.E. and Webb, B.W. 1988. The reliability of rating curve estimates of suspended sediment yield: some further comments. In: *Sediment budgets* "Proceedings of the Porto Alegre Symposium, December 1988", 337–50. IAHS Publication No. 174.

Webb, B.W., Davis, J.S. and Keller, H.M. 1987. Hysteresis in stream solute behaviour. In: *International geomorphology 1986 Part I* (ed. by V. Gardiner), 767–82. John Wiley & Sons Ltd., Chichester.

Webb, B.W. and Walling, D.E. 1985. Nitrate behaviour in streamflow from a grassland catchment in Devon, UK. *Water Research* 19, 1005–16.

Webb, B.W. and Walling, D.E. 1988. Modification of temperature behaviour through regulation of a British river system. *Regulated Rivers: Research and Management* 2, 103–16.

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Flooding in London

BHS Southern Section Meeting 21 June 1988

Whenever I explain at a party that I am a hydrologist who studies floods, I soon find myself admitting that "no, I wasn't involved with the Thames Barrier" and confessing that "in fact, I haven't actually seen it". The BHS Southern Section meeting at the Thames Barrier therefore provided an opportunity to remedy what is obviously a serious weakness in my social credibility as a hydrologist, and at the same time to find out about both the giving and receiving of flood warnings.

The visit began with a standard "technical tour" of the Thames Barrier. This was expertly led by **Ray Horner** – who oversaw the design and construction of the barrier whilst at the GLC – and involved a film show, a tour of the barrier and an opportunity for questions. Although the Barrier looks impressively sturdy from the river bank, the best indication of its size is somewhat paradoxically given from the inside. In the film presentation we were shown the "small" access tubes within the concrete sills underlying the gates, which needed to be carefully aligned with each other and tubes in the piers (I had an image of an electrician poking wires through from one end). In fact, these tubes were large, long corridors (only the substitution of cables for display boards distinguished the inside of the Barrier from the inside of IH), through which we tramped to see the enormous hydraulic jacks which reside in each pier and operate the gates. In all, it was a most illuminating visit, and I for one will in future be more self-confident at parties.

The second half of the meeting comprised two presentations on current developments in both the provision of flood forecasts and the understanding of the responses by the public to warnings. **Chris Haggett**, from Thames Water at Waltham Cross, gave an interesting review of flood warning on non-tidal rivers in London, focussing in particular on the problems of providing warnings in a changing urban environment where response times are short and where localised storms can cause significant flooding. Chris described the development at the GLC and now Thames Water of the automated forecasting systems necessary in such conditions. Weather radar data are assessed in real time using data from the telemetry network, and synthetic unit hydrograph models have been developed to predict flows at identified, critical points along watercourses. Forecasts are then passed to the Police, based on knowledge of the area and properties at risk, who then issue warnings. There are problems with the dissemination of warnings, but Thames Water hold seminars to explain how the system works and to maintain awareness amongst the Police and local authorities. Chris pointed out that although the provision of flood forecasts did yield economic benefits, flood forecasting should also be seen as a necessary service.

Jeremy Neal, from Middlesex Polytechnic Flood Hazard Research Centre, reinforced many of Chris's points in his presentation on the public response to flood warnings. Jeremy has found a great deal of variation in forecast provision and warning dissemination across Britain, and has studied in detail the responses to warnings by floodplain occupants in parts of Severn–Trent Water's area. His survey found, for example, that just over 60% of those who had been flooded but had received prior warning took some form of action, but that nearly 40% of those who had not been warned did too. The results also indicated that those who had been flooded before were more confident about what to do, but slightly less confident about the success of any action. Floodplain dwellers appear to require a warning of at least two hours, direct contact from the Water Authority and information on the expected depth of flooding, along with advice on what to actually do. Jeremy suggested that greater standardisation on procedures would encourage better coordination between Water Authorities, the Police and local authorities.

"Information" was the key theme underlying both presentations: better forecasts rely on better information on flood-producing rainfalls, better dissemination requires better information on what the Police should do and to whom, and more information on what floodplain dwellers could do upon receipt of a warning would help to actually realise the considerable benefits of flood forecasting.

Nigel Arnell

Publications

We are pleased to announce the publication of the first BHS Occasional Paper, *An Introduction to Operational Control Rules using the 10-Component Method* by Allan Lambert.

This publication has been produced by the Institute of Hydrology on behalf of the Society and is available direct from IH, price £5.00 to BHS members, £7.00 to non-members, including post and packing. The Paper has also been submitted for consideration as a HOMS component which should generate some international interest. In addition, we shall be seeking publicity for the document in other technical journals and have also negotiated its sale through the ICE bookshop in Great George Street.

A flyer with order form is enclosed with this issue of *Circulation*.

"Academic" hydrology

This is an abstract of **Andrew Bullock**'s PhD thesis on *Dambos and discharge in Central Zimbabwe*, recently accepted by the Faculty of Science, University of Southampton. Andrew now works at the Institute of Hydrology.

Published conclusions on dambo hydrological process indicate that the impedence of drainage and the seasonally high water tables within dambos lead to either (i) lower flood peaks and greater duration and magnitude of dry season flows or (ii) more rapid flood response and higher dry season evapotranspiration losses, the latter resulting in reduced dry season flows. The absence of empirical research in Zimbabwe has meant that the perception of dambos behaving in accordance with the first model has remained unchallenged. This thesis examines the extent to which river discharges in central Zimbabwe are modified by dambo density and other catchment characteristics, and provides a manual of techniques for estimating flows at ungauged basins.

A data base is assembled for 110 gauged catchments covering over 75,000 km^2, averaging 20 yers of data and having dambo density between 1% and 60% of catchment area. Twelve single number indices of catchment characteristics include dambo density, geomorphic and soil indices and climate/rainfall statistics. Eighteen flow statistics include measures of annual yield and hydrograph separation, and statistics of low and flood flows. Multivariate analysis of the data base indicates insignificant relationships between all flow statistics and dambo density at the regional scale and regime variability is attributable more to average annual rainfall, rainfall variability and regolith profiles. However, the reduction of dry season low flow indices and the separation of yield into a higher storm runoff component are significantly related to dambo density amongst basins where dambos occur in association with deeply weathered regoliths.

It is concluded that (i) rapid response runoff is the dominant process contributing to river flow, but that dambos are insignificant regionally in affecting routing of this response, (ii) baseflow contributions are small (approximately 35%) and vary with the regolith profile of the interfluve soils and (iii) dambo intensity is largely insignificant in modifying basin response, except in association with deeply weathered profiles. Multivariate procedures are developed into a practical manual for the estimation of catchment yields, low flows and floods at ungauged sites in central Zimbabwe. Dambo hydrological process rates and models are not appropriate when extrapolated throughout central Zimbabwe where dambo density is largely insignificant in explaining variability in flow regimes.

HYDROLOGY OVERSEAS

BHS National Meeting
5 December 1988

Following the AGM at the Institution of Civil Engineers, a one-day meeting on Hydrology Overseas was held. The breadth of the subject meant that there was at least "something for everyone" although it did not lead to a great deal of continuity through the various presentations. However, one theme that did emerge was the need for Hydrologists to assert themselves more forcefully within the scientific community lest they become left out in the cold.

Contrasts and developments in International Hydrology

The opening presentation was given by **John Rodda** (WMO) who began by describing the international nature of the World's major river basins. The degree of international co-operation amongst different countries within a given basin was considered to be at a lower level than exists between meteorological institutions from different countries.

The development of international hydrology has been relatively brief, dating from the establishment of the IAHS in 1922. The year 1961 saw the first session of the Commission of Hydrology of the WMO, and in 1965 UNESCO launched the International Hydrological Decade soon to be followed by other activities under the guidance of UN bodies. Phase I of the International Hydrological Programme (IHP) began in 1975 and, as a consequence of the Mar del Plata Conference, the International Drinking Water Supply and Sanitation Decade (IDWSS) was launched in 1981. It is a sobering thought that, in spite of great progress made during the decade, there will be more people without access to clean drinking water at the end of the decade than at the beginning, due of course to population trends.

The past year has seen two significant organisational events:

- The Eighth session of the IHP in Paris in June
- The Eighth session of the Commission for Hydrology in Geneva in October/ November.

A common thread linking the IHP and the OHP is the trend towards "environmental hydrology", namely environmentally sound management of water resources and sustainable development in a changing environment. These are expected to be further supported during IHP-IV and are highlighted by the appointment of **Max Beran** as a "rapporteur" for WMO on climatic change.

In addition to the developments within WMO and UNESCO, there are three significant initiatives within other areas of the scientific community that will build on these developments, as follows:

1 The IGBP (International Geosphere Biosphere Programme) commencing in 1991 and studying dynamics of the whole earth system, of which the hydrological cycle is a main component.
2 The IDNDR (International Decade for Natural Disaster Reduction) commencing in 1990 with the aim of stimulating research and improving disaster preparedness.
3 The GEWEX (Global Energy and Water Cycle Experiment) commencing in 1995 and aiming to capitallse on polar platforms to be launched between 1995 and 2000. It is intended that the coupling of these observations with ground based measurements will improve the estimation of precipitation and runoff. In discussion following the presentation, **Dr Collier** commented that hydrologists have not specified their requirements for GEWEX observation platforms which is surprising given that Hydrology provides a powerful motivating force for the experiments.

In his "Backword" or closing remarks, John expressed a desire for hydrologists to place their discipline on a much firmer scientific footing. This could be achieved via links to other sciences and also greater links across spatial scales in hydrology. The forthcoming programmes provide the opportunity to achieve this.

Water balances of four major African wetlands

Before the first session of the afternoon, the chairman, **Professor Wilkinson** (IH), apologised on behalf of Dr. Sircoulon (ORSTOM) who was unable to attend the meeting. He also thanked **John Sutcliffe** for having agreed, at such short notice, to present some work that he and **Yvonne Parks** (IH) had completed.

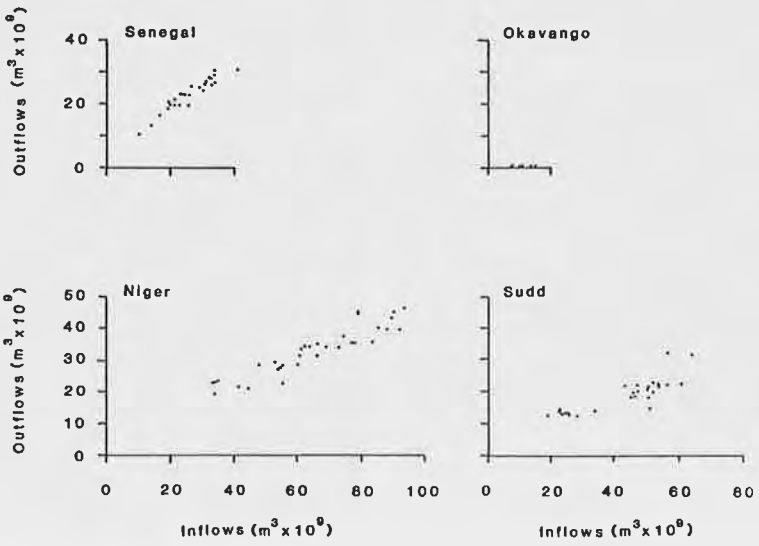
The four wetlands were compared using the Sudd, Okavango, Senegal and Niger, basic data available at IH following various engineering schemes. The first comparison, by reference to average annual inflow and outflow components, served to highlight the contrasting character of the four wetlands. Of more use in characterising the wetlands was a series of scatter diagrams in which annual outflow was plotted against annual inflow (see Fig. 1). The Okavango, with its very high losses was in stark contrast to the other wetlands. Non-linearities in the relations for other wetlands seemed worthy of further discussion.

A simple, water balance model was set up for each of the wetlands. The components of the water balance formulatiion were known, or could be estimated, with the exception of a proportionality constant in the relationship between water area and stored volume. The constant is effectively a mean depth and was assumed equal to 1 for all wetlands save the Senegal which was assigned a value of 2. The model was used to explore contrasting flow regimes. Mass plots showed clearly the effects of recent droughts in the Sahel and, by contrast, the rise in Lake Victoria between 1961 and 1964. The contrast in seasonal flooded extent also offers a key to vegetation distributions and the ability, for example, of the Sudd to support a cattle population of 1 million during the dry season.

Irrigation operations during a drought in Swaziland

The second paper of the afternoon session, presented by **Tim Yates** (formerly of Binnie & Partners) was concerned with a 12,000 ha irrigation development in the low-veld of Swaziland. The water supply was derived from the Komati river, which rises in South Africa and flows through Swaziland and South Africa again and Mozambique before entering the Indian Ocean north of

Fig. 1 Comparison of annual inflows and outflows of four African wetlands.



Maputo.

With the help of slides, Tim described the irrigation scheme, most of which is given over to sugar cane with about 1,000 ha of citrus. The maximum demand (MD) of the scheme is, on average, about 187 million $m^3 year^{-1}$ or roughtly one third of the average annual runoff. Balancing storage is provided by a reservoir with a storage of 44 million m^3.

During the 1982/83 season, the Komati river, in common with large parts of southern Africa, experienced severe drought. Modelling studies and frequency analyses suggested that the return period associated with the drought event was in the order of 100 to 200 years. Although the balancing reservoir provided a limited buffer against the drought, there were two management options for scheme operation during the drought:

- applying restrictions
- reduction of cross-border releases.

Restrictions were applied to all consumers beginning at 50% in April and reaching 85% at the end of the 1983 dry season. The reservoir storage had fallen to 10% of live storage at this time. Control curves were also developed for the scheme's pumped storage reservoir. The reduction of cross-border flows was facilitated by the absence of any international agreement covering border releases.

John Goudie (now with Engineering and Power Development) was the Chief Irrigation Engineer of the scheme during the drought. He summarised the management strategy that was explained to the farmers through meetings and simple forecasting tools.

During questions, **Professor Wilkinson**, enquired as to the effect of reduced water supply on crop yield. John said that a 40% reduction in supply resulted in approximately 10% reduction in yield. It was suggested that this reflected an over supply in non-drought conditions, a situation which may have been encouraged by the nature of the charging system. John felt that although this may have been the case on some of the larger farms, it was not universally true.

Groundwater recharge from ephemeral flows

The third and final session was chaired by **Mr. T. Pike**, Principal Engineering Adviser with ODA. The first paper was presented by **Howard Wheater** of Imperial College and **Gavin Hamilton** of Dames & Moore and was a series of observations from a study of five wadis in South West Saudi Arabia – part of a five-year study for the Ministry of Agriculture and Water.

Flow in the wadis occurs following intense and localised storms of short duration. Surface flows are then propagated downstream as ephemeral flood waves, commonly over a dry wadi bed. The wadi flows constitute an important water resource due to recharge of unconfined groundwater in the wadi alluvium. The understanding of the recharge mechanisms is limited for a variety of reasons and it was decided to carry out both field and numerical experiments.

A 1-D controlled infiltration experiment was carried out at a site which had been instrumented for monitoring during the flood season, but which had failed to produce any floods. A numerical model to solve the full unsaturated flow (Richards) equation provided an excellent fit to the field data.

Research at Imperial College has recently led to the development of a 2-D model of the saturated/unsaturated response. This was used to explain the behaviour of a 900 m wide section of Wadi Tabalah during a large recorded flood event. Use of the model required a number of assumptions to be made concerning the subsurface material texture and distribution. The model indicated the controlling influence of a silty-clay layer at the surface on propagation of the wetting-front. The problems that can be caused by such layers were well illustrated by one of the slides which revealed dry sand in an excavation immediately adjacent to a perched water table.

There was good correlation between observed and modelled subsurface water level hydrographs for the selected event but it was conceded that there was considerable uncertainty regarding the estimated transmission loss for the event of 320 $m^3 m^{-1}$.

Gavin then described the use of multiple linear regression analysis to derive functional relationships for predicting transmission losses. Screening of the available recorded events meant that only 17 could be used in developing the potentially useful relationships. The losses predicted using the equations were between 1 and 90 $m^3 m^{-1}$ considerably less than the estimates derived from numerical modelling described above. The need for further research is apparent and Howard suggested that this should consider factors such as the sediment concentration of river flow, bed movement and the influence of entrapped air on constraining movement of the wetting front.

There followed discussion on the use of bunds to increase recharge. The experience to date suggests that the reservoirs formed by the bunds become sealed by a silt layer which inhibits, rather than increases, infiltration. The provisional recommendations of the current project do provide for the construction of structures across the wadis, but with the emphasis on attenuation of flow rather than retention.

In further discussions after the presentation, Howard was advised of field and laboratory research which is in progress in Namibia. The work is at an early stage, but observations from a number of recorded flood events have demonstrated that silt carried by flood waters can effectively seal the alluvial surface even during floods with unexpectedly high flow velocities. This has been confirmed by laboratory analyses.

Tropical deforestation and low river flows

The second paper of the final session was presented by **Mike Mansell-Moullin** who began by drawing attention to the well publicised rapid rate, and vast scale, at which the natural, tropical rainforests are being felled. Although there is a reasonable body of knowledge concerning the effects of deforestation on total yields, there is very little on the effects on low flow characteristics. This is surprising given the many millions of people living in the plains below tropical watersheds, and upon which they depend.

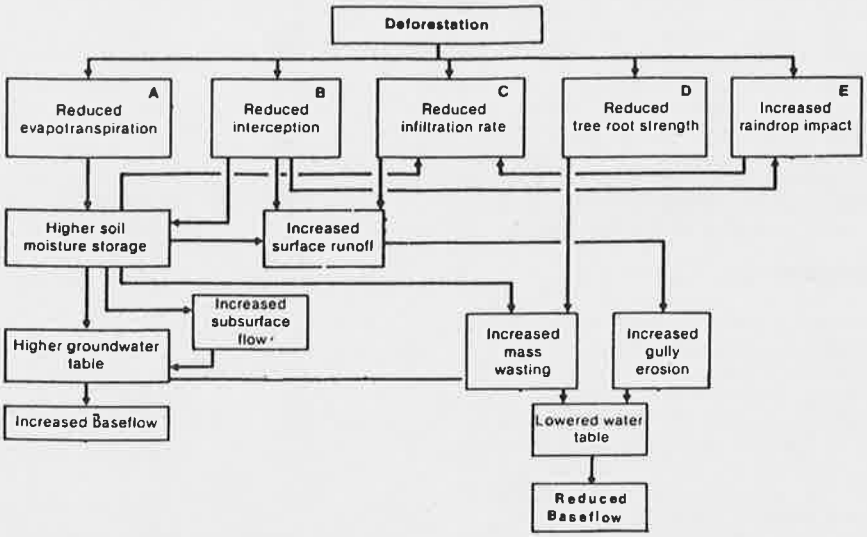
The shifting culture of tribal groups of the tropical rainforests is a classic example of "sustainable development". Historically, the low population pressures permitted lengthy resting periods for given clearings of land, possibly 15 to 30 years, which was sufficient for natural regeneration and soil recovery. Increasing population pressures have reduced the length of the resting period, or made the system of shifting culture inappropriate. Land use following deforestation may range from sustainable agricultural crops to grassland. All too often, the land use degrades to a condition approximating scrubland.

Research on the hydrological effects of deforestation on low river flows is limited. At a workshop in 1981, the East-West Centre's Environment and Policy Institute was unable to provide quantitative guidelines on "cause and effect mechanisms". Figure 2 shows some of the consequences of deforestation and indicates that both an increase and a decrease of baseflows are theoretically possible. Mike cited two studies with which Binnie & Partners were involved. In Johor, Malaysia, strong evidence suggested that deforestation led to reduced baseflows with serious implications for run-of-river schemes. However, the results of a study in Brazil were unable to identify any clear relation between low-flow variations and the extent of forest clearing.

In summing up, Mike read a quotation from Charles Pereira's book, published in 1973, in which research programmes were proposed, the results of which would have contributed greatly to resolution of some of the problems discussed during the paper. Mike stressed the need for immediate, applied research programmes, with the aim of producing interim results as soon as possible.

During discussion **James Bathurst** suggested the use of the SHE family of models, whose parameters have a physical meaning in the evaluation of complex cause and effects described above. Mike felt that al-

Fig. 2 Some likely hydrological changes following deforestation.



though the models could play a role in highlighting certain key variables, they could not substitute for the fundamental observations that were required of, for example, the effect of burning upon infiltration.

John Rodda confirmed that money was allocated within WMO for such projects and felt that motivation of suitable projects should be relatively straightforward. He also noted that certain deforestation projects in Brazil with adverse environmental effects were no longer to be funded by the World Bank.

Instrumentation

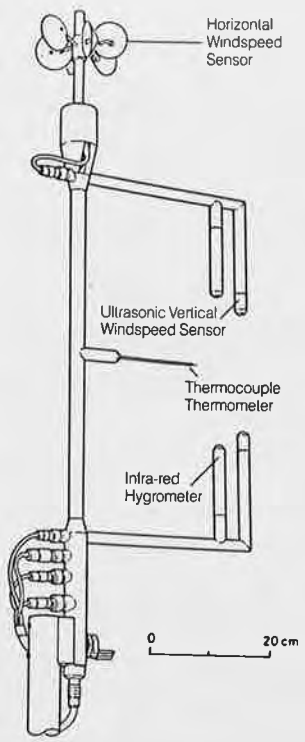
The final presentation was made by **Ian Strangeways** and **John Gash**, both of IH. Ian dwelt briefly on the inadequacies of the somewhat outdated instrumentation which currently accounts for most hydrometerological networks around the world. He then described, with the help of slides, many of the difficulties associated with data collection in today's world, including:

- Operators
- Maintenance
- Environmental factors
- Remoteness.

He then outlined some of the developments, which are familiar to most hydrologists, that have taken place at IH over the past two decades. These include automatic weather stations (AWS), a cold regions AWS, various rain gauges and HYDRA, a multi-headed instrument for measurement of actual evaporation.

Looking ahead, Ian commented that remote sensing was unlikely to provide an alternative to in-situ instruments for the forseeable future. There is therefore an easily substantiated argument for continued development and research of new, reliable instruments for remote operation. In today's economic climate however, the source of funding for such development work remains an unanswered question. Continued use of outdated instrumentation would probably serve only to reinforce the sceptical attitudes with which the scientific community views much hydrological work.

Fig. 3 The Mk 2 Hydra



In the short time remaining John gave a brief description of the HYDRA (see Fig. 3) which consists of:

- An ultra-sonic anemometer for measuring the vertical component of the wind
- An infra-red hygrometer for measuring the fluctuations in humidity
- A fine wire thermocouple for measuring temperature
- A sensitive cup anemometer for measuring the horizontal component of the wind.

Measurements are taken 10 times per second by a microprocessor controlled data acquisition system and the resultant data are stored on an hourly basis. Two solar powered 12V lead-acid batteries are sufficient to meet the power requirement of 4W. HYDRA has given good results in a variety of environments, including:

- Tropical rain forest near Manaus, Brazil
- Pine forests in south-west France
- Kansas Prairies
- Millet fields in Niger.

In summary, John commented that measuring evaporation remains a task which requires sophisticated instruments, and careful installation. However, it is now possible to obtain reliable estimates of actual evaporation and this has a most pressing application in situations characterised by tall vegetation or vegetation suffering water stress.

Paul Webster
Sir M. MacDonald and Partners

Probable Maximum Precipitation in Kenya

The identification of the probable maximum precipitation (PMP) of a catchment is an important step in the design process of a water supply or hydro-electric power generation project. Earlier this year a firm of consulting engineers asked the UK Met Office to carry out a PMP study for the Thika catchment in Kenya. Although projects of this kind generally occur only intermittently, they are often in areas of patchy availability of weather data. Thus a description of how this project was handled may be of interest to readers to illustrate the ways in which meteorological knowledge and judgement can be used to assist engineers in providing the best practicable design.

The Thika catchment, which has an area of 71 km^2, lies just south of the equator near the southern tip of the Aberdare mountains. The heaviest rainfall events are associated with the passage of the inter-tropical convergence zone across the catchment. Then moist air is brought inland from the Indian Ocean by the prevailing easterly winds. During these periods, heavy and often thundery night-time storms occur regularly. These storms are a result of the forced ascent of the moist air by the mountains, enhanced by mixing with the katabatic flow which forms during the evening. A previous Met Office study, done in 1966, was for a catchment adjacent to that in the present study. Consequently details of the local meteorology were readily available, along with ball-park PMP values for comparison.

A physical method involving the transposition and maximization of observed storms was used to determine the PMP. The techniques used were based on the recommendations given in the WMO Manual for Estimation of PMP (WMO, 1986) but it was necessary to take into consideration two aspects of this particular study. Firstly, the Thika catchment lies in the tropics for which comparatively few previous studies have been done. Consequently the correct approach is less well established. Secondly, no data were available for surrounding low-lying regions so it was not possible to maximize the orographic and non-orographic components of the rainfall separately. However, this should not be a problem since it appears that the night-time storms are essentially a consequence of the moist air flow being modified by the high ground.

Storm analysis

The Kenyan Met Service provided daily rainfall totals for 27 major storms which had occurred in the area of the catchment during the period 1957 to 1986. Of these, seven were selected for analysis by virtue of having the largest 3-day rainfall totals at any individual station. (One particularly large storm was not chosen because it was considered to lie outside the region of transposability). The characteristics of each storm were summarized in the form of a table giving the maximum average depth of precipitation observed for a range of areas and durations. These depth-area-duration (DAD) analyses were performed using standard procedures (WMO, 1969) although several difficulties did arise.

Firstly, although the network of rainfall stations is unusually dense for a mountainous area (average separation 8 km), during any individual storm, rainfall values were available for only around half of the total of 69 stations for which data had been provided. In addition, the scale of the storms was such that typically only four to six stations would lie within the area of heaviest rainfall. This meant that when drawing the storm isohyetal maps it was necessary to have some insight

into the situation. Nevertheless there was still some uncertainty about the detailed positioning of a number of the contours.

Secondly, during the rainy season there are often prolonged periods of significant daily rainfall, therefore it was often difficult to identify when a storm started and finished. Each storm was considered to be an event lasting three, four or five days; several were, however, analysed for more than one duration.

Finally, it is conventional to analyse storms for durations that are multiples of six hours but, as insufficient autographic records were available, the analysis was restricted to durations that were multiples of 24 hours. It is unlikely that this affected the accuracy of the results significantly since the majority of the rain is known to fall at around the same time in each 24 hour period (generally between 2100 and 0300 local time).

Storm maximization

Each storm was maximized for moisture content and for wind speed by multiplying the DAD tables by appropriate factors. For moisture maximization it is common to use the ratio

$$\frac{W_{100}}{W_{ST}}$$

where W_{100} is the 100-year return period (M100) exceedance value of the precipitable water content (pwc) of a column of air at the storm site and W_{ST} is the actual pwc at the time of the storm. The pwc is usually calculated from the surface dew point (by assuming that the air is saturated throughout) but in this instance no records of sufficient length for calculating an M100 value were available. The solution was to use sea surface temperature (SST) data. The principal moisture source is the Indian Ocean and in tropical regions the SST is often a better measure of the moisture content of the atmosphere in depth than inland surface dew points (WMO, 1986).

The M100 SST was calculated by adding two and one third standard deviations to the 30-year climatological mean value (assuming a normal distribution). The SST at the time of the storm was obtained by interpolation from 5-day or monthly mean values. In both cases the pwc was calculated from a weighted mean of SST values from three 5° squares. The squares were selected according to the direction of the prevailing wind, with greater weight being given to squares nearer the coast.

The principal behind maximizing the storms for wind speed is that, for higher wind speeds, more moist air will flow over the catchment in a given time and the amount of rainfall will be correspondingly greater. The recommended maximization factor is given by the ratio

$$\frac{V_{50}}{V_{ST}}$$

where V_{50} is the M50 wind speed at the storm site and V_{ST} is the observed wind speed at the time of the storm. It is common to use either 24-hour mean surface wind speeds or wind run values, but again no long records were available. The problem was solved by using radiosonde data from Nairobi. The reported wind speed and direction at a pressure level of 700 mb were used since this corresponds to about 1,250 metres above the ground, a level representative of moisture inflow.

The individual storm wind speeds were taken to be the largest mean wind speed occuring during the heaviest three days of rainfall. Mean wind speeds were calculated by taking the average of three successive observations, although it was required that the first and third observations should be no more than two days apart. Only directions which were important for moisture inflow were considered; any occasions when the wind direction did not lie between north-east and south were excluded.

Initially an M50 wind speed was calculated for each month using extreme value analysis (EVA). However it was found that using the highest monthly mean wind speed in the analysis produced unrealistic maximization factors of 3 to 4. Closer inspection of the data suggested that high wind speeds never occurred during major storms and therefore it was incorrect to maximize the storms as if this were possible. Instead a single M50 wind speed was derived by applying EVA to the storm wind speeds themselves. This produced a more appropriate value suitable for maximizing storms occurring in the rainy season.

Transposition and PMP

The amount of rain that falls during a storm is dependent on the storm location. For the windward slopes of the Aberdares in the area of the Thika catchment the average annual rainfall increases steadily with altitude. Since none of the selected storms were centred over the catchment it was necessary to modify the observed precipitation amounts to allow for the transposition of the storms to the catchment site. This was achieved by multiplying the DAD values by the ratio of the median annual rainfall at the centre of the catchment to that at the centre of the storm. This assumes that the storms which predominantly contribute to the median value are of the same type as those being analysed.

Once the storms have been maximized and transposed the PMP values can be derived. This is done for each duration by plotting the modified rainfall amounts against the corresponding areas and then drawing an enveloping curve. An estimate of the PMP for a given duration and area can then be read off the appropriate curve.

Comments

The principal factor controlling the PMP values was found to be the wind speed, with maximization ratios in the range 1.30 to 1.76. By contrast the moisture maximization factors were much smaller, varying between 1.04 and 1.13. This is consistent with the fact that in tropical regions the atmosphere is frequently very moist i.e. there is little potential for increasing the amount of rainfall by introducing more moisture because the air is already close to saturation.

Comparison with the earlier PMP study for the adjacent catchment shows that for a duration of three days the figures are very similar. However for a duration of one day the new values are about 40% less than the previous estimates.

This case study illustrates and ways in which weather data and, more importantly, meteorological knowledge and judgement can be used as vital aids to the design process.

References

WMO, 1969, *Manual for Depth-Area-Duration Analysis of Storm Precipitation*. WMO No. 237, TP 129.

WMO, 1986, *Manual for Estimation of Probable Maximum Precipitation* (second edition). WMO No. 332.

BOOKS

Hydrology Texts Revisited

Hydrology in Practice, 2nd Edition – Elizabeth M. Shaw. Van Nostrand Reinhold (International), 1988. xii + 539pp. £14.95. Softback. ISBN 0–278–00061–4

In a book review in *Circulation 20*, November 1988, Keith Beven posed the (semi-rhetorical?) question "Why does it seem to be so difficult to write a satisfactory introductory text on hydrology?" For many long-term users and authors of introductory hydrological texts the answer is, of course, that the difficulty lies not in the writing but in selecting the appropriate text to use. There are *many* satisfactory introductory hydrological texts, just as there are many satisfactory motor cars, and we each select the model which best suits our purpose. In some cases this will require a scientific discussion of the environmental processes which govern the occurrence, distribution and movement of water in the landscape; in other cases the need will be for an introduction to mathematical and numerical modelling techniques.

Elizabeth Shaw's *Hydrology in Practice* is a successful introductory textbook whose objective was described in the Preface to the first edition as ". . .to bridge the gap between the text concerned with scientific processes and the applied numerical text". In Elizabeth's inimitably enthuiastic style, this objective is achieved through the creation of a "cookbook" of good practice. This book is an excellent compendium of techniques and methods of hydrological measurement and data analysis which contains little serious description or discussion of the relevant hydrological processes. As in the first edition, the contents are set out in three parts: Hydrological Measurements (hydrometric networks, precipitation, evaporation, soil moisture, river flow, groundwater, water quality and data processing), Hydrological Analysis (precipitation analysis, evaporation calculations, river flow analysis, rainfall-runoff relationships, catchment modelling and stochastic hydrology) and Engineering Applications (flood routing, design floods, urban hydrology, water resources and river basin management).

Such a structure leads inevitably to internal tensions in some cases and to inequalities of treatment in some others. For example, Chapter 4 deals with evaporation *measurement*, including the use of pans, lysimeters, etc. and the collection of meteorological data, but the *use* of those meteorological data to

calculate evaporation is not discussed until Chapter 11. Again, precipitation measurement and data analysis are treated separately in Chapters 3 and 10. In the case of groundwater however, measurement, data analysis, modelling and exploration are all covered in Chapter 7 under the general heading Hydrological Measurements.

One of the great values of the book lies in the numerous graphs, tables and equations which can be used directly for "working things out". There is also a "Problems" section at the end, although the usefulness of this for the student or instructor varies enormously with the nature of the problem. Worked examples with numerical solutions are very helpful; general essay questions are probably of little direct help.

A fundamental question with which I am left having used the first edition and read the second edition is "What constitutes a new edition?" In the Preface to the second edition the author claims, amongst other changes, that technological progress in the past five years has necessitated "the *rewriting of much* of the data processing chapter (9) and *considerable modifications* to the important chapters on precipitation (3 and 10) and riverflow measurement (6)" and the cover blurb tells us that "the text has been *updated throughout*" (my italics). Unfortunately none of these claims can be substantiated. There are a few minor changes and five new references in Chapter 9, some minor modifications to Chapter 3, but none of any significance in Chapter 10, where even the reference list remains identical, while in Chapter 6 there are eight new lines on pressure gauges and two each on the electromagnetic method and the integrating float technique. As for updating throughout, there are 18 more post-1975 references in the second edition than in the first and the total of 105 post-1975 items constitutes only 30% of the total reference list.

In fairness, there is also additional material on the Penman-Monteith evaporation formula and the evaluation of crop water requirements, on the SHE model and urban hydrology models and on flood forecasting, and many of the diagrams are reproduced more clearly, but all the new material amounts to less than 20 pages in a book of well over 500 pages!

Despite this disappointing lack of innovation my verdict on *Hydrology in Practice* remains much the same as before, that is good value for money.

Roy Ward
Hull

International Contributions to Hydrogeology – reviews of the first seven volumes

1. Hydrogeology of Karstic Terrains: Case histories – Edited by A. Burger and L. Dubertret, 1984. 264pp. DM 92. ISBN 3–922705–05–7. (See below for purchase details.)

Sixty case studies from around the world, evenly split between water resources, methods of extraction and environmental issues. An excellent source book for anyone interested in Karst groundwater.

2. Hydrology of Limestone Terrains: Annotated Bibliography of Carbonate Rocks – Edited by P.E. LaMoreaux, J.M. Tanner and P. ShoreDavis, 1984. 342pp. DM 92. ISBN 3–922705–12–X.

There are 2,175 references in this bibliography, about half of them annotated, not with authors' abstracts but with a reviewer's comments. The material covers the period 1975–85, and is in fact Volume 3 of the bibliography: Volumes 1 and 2 were published by the Geological Survey of Alabama, and Volume 4 is said to be due in 1988. There are indices of authors, locations and subjects and lists of relevant textbooks and conferences. A valuable reference book – make sure your library has a copy.

3. List of Terms of Hydrogeology – H.R. Langguth, 1984. 92pp. DM 102. ISBN 3–922705–07–3.

A multi-language dictionary and glossary, this volume translates 299 hydrogeological terms between English, French, Spanish, Russian, German and Arabic. The glossary explains 53 of the terms in English, French and Russian. What is a "flank of an artesian structure"? To be fair, I found few other English oddities, and would have found the book very useful when, in my youth, I wrote a report for Algerian clients: I wrote in English, which was translated into French, and I had to check that the French was technically correct!

4. Hydrogeology of the Dinaric Karst – Edited by B.F. Mijatovic. 1984. 254pp. DM 102. ISBN 3–922705–08–1.

This monograph on the Karst of Yugoslavia was compiled in advance of a professional field trip around the area in 1983. The 13 papers cover regional geological structure, hydrogeological features in general and of particular areas, speleological phenomena, problems of sea water intrusion and geophysical methods of exploration.

5. Impact of Agricultural Activities on Ground Water – J. Vrba and E. Romijn. 1986. 332pp. DM 102. ISBN 3–922705–09–X.

This multi-author book is well put together, and contains descriptions of processes, hard facts and case studies. The weakest sections are on the movement of agrochemicals in the subsurface, and on modelling. The section on modelling is mostly partial differential equations – what many people need are conceptual descriptions of contaminant movement, backed up with examples of field data. Then we all want predictive methods that do not need a Cray computer and impossibly large quantities of data – at present those sorts of models are only for research and hypothetical studies. The modelling section is all about the systems approach – always a sign to my cynical eye that the author knows more about maths than about real life problems – but don't let these two poor chapters detract from the good chapters on fertilisers and pesticides, irrigation and drainage, monitoring, and management and control. The better case studies deal with Irish groundwater, nitrates, and the British Chalk.

6. Theoretical Background, Hydrogeology and Practice of Groundwater Protection Zones – G. Matthess, S.S.D. Foster and A.C. Skinner. 1985. 208p-p. DM 102. ISBN 3–922705–10–3.

I have found this the most useful and interesting of the *Contributions*. The subject is of great importance to all practising hydrogeologists and yet no other textbook brings together the necessary material. As with all multi-author books, coverage is patchy at times, but contrasting approaches provide a useful reminder that there is no single right method for most practical problems. The book starts with a thorough review of theoretical aspects of the behaviour of contaminants and of their movement. It then discusses groundwater protection in different aquifer types, with sections on porous rocks (based on the Netherlands), fissured rocks (written by Andrew Skinner, with a UK perspective) and a rather poor section on carbonate rocks. European practices are reviewed before the book closes with one of Stephen Foster's typically wideranging and practical discussions of groundwater protection in developing countries. A recommended text both for individuals and for libraries.

7. Hydrogeological Mapping in Asia and the Pacific Region – Edited by W.F. Grimmelmann, K.D. Krampe and W. Struckmeier. 1985. 410pp. DM 102. ISBN 3–922705–11–1.

These Proceedings of a workshop held in Bandung, Indonesia, contain material for 21 countries, from Australia to Vanuatu in the Pacific, and from Afghanistan through China and India to Vietnam in Asia. They would make a good starting point for anyone going to work in the region, and should be in all consultants' and reference libraries.

Purchasing Information: All volumes are published by Verlag Heinz Heise GmbH, PO Box 61 04 07, D–3000 Hannover 61, FRG, from where they can be bought. Individual prices are given in each review; all seven can be bought for the reduced total of DM 575.

David Lerner
Birmingham

A Field Guide to Groundwater?

Field Hydrogeology – R. Brasington. Geological Society of London, Open University Press, Milton Keynes/Halsted Press, New York/Toronto. 1988. 175pp. £15.95. Paperback. ISBN 0–470–21078–8.

This slim paperback is one of a series of handbooks being prepared and published by the Geological Society in association with the Open University Press. The volume deals primarily with work done in the field, but includes a section on desk studies, as these are required to guide formulation of fieldwork programmes. It excludes geophysics and the making of waterwells and boreholes, dealt with in companion volumes by Milsom and Clark respectively. The latter was reviewed in *Circulation 20*.

The preface says that the book is intended for recently graduated geologists who find themselves involved with the problems of hydrogeological fieldwork, and is intended to be basic. The treatment is descriptive. There are tabular summaries, which are helpful, and most tables and figures have extended captions, which makes the illustrations independent of the main text; a useful feature. This feature and the good index are the main qualifications for the title "Handbook". The writing style is not ideal for a handbook, but sections are short and easy to find in the detailed contents list. The Author clearly has a great deal of fieldwork behind him. His enthusiasm shows clearly in some sections. The chapter on rainfall, springs and streams assumes that the reader will be there with his own pick and spade. The tools he will need for this and other work are listed in an earlier chapter. The precautions he should take are graphically described in a chapter on good

working practice, which includes dealing with hypothermia and heat exhaustion, as well as the hazards of gas.

"The book is not concerned with solution of complex problems, but with general methodology for sound understanding of local hydrogeological conditions, by following the techniques in this book," the Author tells us (Chapter 9). The book is not mathematical, nor does it discuss computer modelling. The list of contents is good, but the text does not always live up to the promise. This I found particularly in parts of the first five chapters, where the Author has little constructive to say under some of his sub-headings.

Chapter 6 introduces an example on the study of the St. Bees Sandstone in Cumbria. This interesting case study could have been discussed further in later sections of the book, to illustrate further points. It is left as a description of use of all available types of data in preparation of a hydrogeological map of the aquifer at reconnaissance stage.

The book contains interesting and useful material, and may fit well with companion volumes in the series. It will find its way onto shelves of libraries and practitioners, but I am not sure that it will travel regularly on the field excursions with which it deals.

Paul Helliwell
Southampton

Hydraulic Miscellany

Developments in Hydraulic Engineering – 5 – Edited by P. Novak. Elsevier Applied Science, 1988. 234pp. £40.00. Hardback.

This book represents the fifth volume in the series "Developments in Hydraulic Engineering" which started in 1983. The aim of the series is to publish in-depth review chapters covering a range of topics in hydraulic engineering. Four topics are covered in this volume.

The first chapter by Mosonyi is on water power development. Most of the text is orientated towards low-head river developments, including their layout, planning criteria, magnitude and evaluation of their producable power and energy, generating sets and their operation, electrical equipment, environmental aspects and economic appraisal. The text is well illustrated with figures and contains the theoretical basis plus practical considerations based on the author's lifetime experience in hydro-electric power. Although some of the material has been published previously, it is dispersed in many publications; this text has been thoroughly revised and updated and does contain a considerable amount of previously unpublished material.

Ice and river engineering was discussed in Volume three. The second chapter by Ashton on intake design for ice conditions discusses a particular topic in ice engineering which is of particular importance in power development and water supply. It deals with the characteristics of ice problems that need to be taken into account in the design and operation of intakes, the ice growth and production rates and its behaviour at intakes in various conditions and the counter measures to be taken. Various examples are given to illustrate the magnitude and diversity of typical ice conditions at intakes.

Aspects of wave climate and its impact on coastal and port engineering have been briefly mentioned in previous volumes. Major advances made recently in the effect of tidal currents and waves on sediment transport at the sea-estuarine interface have not previously been discussed. McDowell addresses this particular topic in Chapter 3 by first describing three typical estuaries with widely different characteristics: the Santos in Brazil, Rio Pungue in Mozambique and the Mersey in the UK. Methods for studying the hydraulic behaviour of estuaries are discussed, concentrating on numerical analyses. There follows a detailed treatment of regional modelling of tidal flows and tidal currents at estuary mouths, regional modelling of waves and of nearshore waves and currents, a discussion of sea-bed stresses and induced sediment transport and a summary of the properties of various wave models. The chapter concludes with a section speculating how the techniques could be used to model the previously mentioned estuaries.

The final chapter by Luijendijk, Schulty and Segeren is concerned with land reclamation and flood control in low lying coastal zones. The Dutch have pioneered the development and protection of polders and in this chapter the Duch authors consider soil characteristics and the complex water management of polders including the design of irrigation, drainage and flood control systems. They conclude by speculating about polders of the future.

R.D. Hey
Norwich

Committee Works

Water Resource Assessment Activities: Handbook for National Evaluation – Anon. UNESCO 1988. 116pp. Softback. (Price not given).

The Value of Groundwater Models for Planners and Decision Makers – K.H. Jensen. Technical Documents in Hydrology SC-87/WS-44. UNESCO 1987. 34pp. Free. Softback.

Casebook of Methods for Computing Hydrological Parameters for Water Projects – Edited by M.J. Lowing for Working Group: Project A2.10. Studies and Reports in Hydrology no. 48, UNESCO 1987. 324pp. Softback. ISBN 92–3–102472–8. (Price not given).

Available through HMSO or direct from UNESCO Division of Water Sciences, 7 Place de Fonteney, F 75700 Paris.

This sample of UNESCO output is listed in order of increasing usefulness to *Circulation* readers. Not even the most egalitarian of countries expects a novel to be written by a committee; perhaps this explains why UNESCO publications are so rarely looked forward to eagerly. They are at best more like the Oxford English Dictionary, useful for everything but straight reading.

The anonymous handbook does not tell you how to assess water resources but how to check whether somebody is doing so comprehensively. It is heartbreakingly turgid, has no contents list, and is the sort of book up with which Churchill would not put, e.g.: "3.2.2.1.1. Historical Data. The infrastructure for obtaining historical data consists usually of – (sixth item) equipment manufacturing shops and staff (not absolutely required when equipment imported)."

Its foreword says that water resource assessment is a national responsibility. With that unwelcome restriction there is the inevitable Chapter 2 on Institutional Framework. Of 28 references cited throughout the whole text 24 are UNESCO, WMO or UN documents. It takes until Appendiv IV until one of the many check lists for surveys gives some practical advice (about network densities and hydrometric staffing needs in different climatic and geological settings). These surveys are qualified by "emphasis levels".

It is hard to see how this could be the outcome of an eight year project said to have been pilot tested in seven countries. Perhaps the brief for the project was just too tough for anyone.

Jensen, from the Technical University of Denmark, has put a lot into a few pages. The illustrations are of good quality and the two case studies in the last 16 pages are well worth reading. The firt looks at the impact within Nile delta deposits of navigational river changes and the second deals with a landfall leachate movement in Denmark. Both are real situations with Konikow and Bredehoeft's 1978 USGS model being cited.

However I doubt whether the document will reach the decision-makers in the way the title implies. Putting the simple Darcy Law into tensor notation is an early set-back for many readers. No advice is given on how to test whether a model calibration is acceptable. There are nine mathematical formulae described but no summary of the standard computer programs that the planner could invoke, just a mention of van der Heijde *et al* producing a review of these in 1985. So again it will be left to the groundwater engineer, armed with the confidence this text gives him or her, to get the message across to the decision-maker about "the gold in them there models".

The last reference is altogether more substantial and a credit to the Working Group Chairman, J.W. van der Made, his 10 colleagues from as many countries and the consultant UNESCO editor, Mike Lowing. The first 200 pages show international examples of hydrological techniques and the remaining text gives case studies from engineering projects in committee members' countries.

The Contents list whets your appetite by naming the technique and adding the river and country by which it is exemplified. Coverage includes homogeneity tests, accuracy estimation, gap filling, hydrological probability distributions (the usual ones plus Johnson and Kritsky-Menkel), deterministic models, flow hydrographs and drought discharges.

Case studies range from real time flood forecasting in Belgium through to an irrigation project in Mali, with five others from Argentina, Czechoslovakia, Holland, Norway and China. River and reservoir projects are handled with admirable breadth, depth and brevity. The graphs look all too real and have not been massaged.

The comprehensive series of annexes gives a wide range of statistical tables that some readers may otherwise find hard to obtain. In summary I suggest that any hydrologist working internationally would benefit from this as would anyone becoming conscious of 1992. More copies might be sold if a second edition was given the shorter title "Casebook of Hydrological Techniques for Water Projects".

Meanwhile if any reader would like a copy of the contents list of the Casebook before investing in the necessary purchase of French francs, just ring me on 0491–38800.

Frank M. Law
Wallingford

Another . . .

The process of water resources project planning: a systems approach – Edited by Y.Y. Haimes, J. Kindler, and E.J. Plate. Studies and reports in hydrology no. 44. UNESCO 1987. 196pp. ISBN 92–3–102476–0.

This volume is a report of a Working Group under UNESCO's International Hydrological

Programme (IHP), a long term intergovernmental initiative set up in 1975 following the International Hydrological Decade. This Working Group was "charged with evaluating the experience of countries in the application of operations research techniques in the implementation of water resource, development and management". The study was in fact strongly linked to case histories of the use of systems analysis in water resources project planning. It sets out to assess the gap between the state of the art of systems analysis techniques and their current use in practice.

The core of the report presents a model of the stages in the water resources planning process. In this, four stages prior to design, construction and operation are identified: plan initiation and preliminary planning; data collection and processing; formulation and screening of project alternatives (this represents the end of prefeasibility study); and development of final study results (end of feasibility study). A generally applicable flow diagram is presented, the following chapters dealing with each stage in turn. Despite the first editor's strong interests in multiobjective optimatization (the Surrogate Worth Trade-off method in particular), this aspect is not pushed too much. The overall treatment of the process and the stages is clear and concise and represents an excellent exposition of the systems approach In water resources, though little is actually new. On the basis of the stages, a 30-question questionnaire was developed to give structure to the case studies.

The 10 case studies, all from the developed world, make up over half of the report. They range in scale from long term national planning to municipal planning. Most have an emphasis on water supply, although one is primarily concerned with flood control, and several deal explicitly with multi-purpose river basin management. The format of each is a brief introduction followed by treatment of the 30 questions; they are thus not intended to be read as self-contained units. However, there is much useful material here.

It seems a pity therefore that the conclusions from the case studies are limited to two pages. These brief conclusions are generalized and find, not unexpectedly, that systems analysis has yet to become the norm. More specifically, simulation techniques are being more readily used than optimization of objective functions.

I would like to have seen the model of the planning process and its detailed stages evaluated in the light of the case studies (it contains only brief passing references to them), and more detailed comparative analysis of the case studies, perhaps stage by stage: a matrix might have been useful in this respect. Such reservations apart, the work is valuable and the report makes interesting reading, especially for those involved in water resource planning and management. It should fulfil the team's hope of promoting understanding and improvement of the planning process for water resource projects.

Tony Hill
Sunderland

International Association of Hydrogeologists

The International Association of Hydrogeologists (IAH) is a non-governmental, non-profit making, scientific and educational organisation. With nearly 2,000 individual members in 70 countries, it is in a unique position to encourage international exchange of hydrogeological information and to advance the science and study of groundwater and aquifers. Its principal objectives are to:

- Promote international cooperation.
- Sponsor technical meetings and symposia.
- Publish hydrogeological reports, maps and memoirs.
- Establish working groups and commissions to report on special topics.
- Encourage the worldwide use of hydrogeology to the benefit of mankind.

Publications

All IAH's publications are free to members who have paid their annual subscription – this is of particular benefit to those who cannot attend the annual congress or other conferences, or to those who do not have ready access to journals and new books. Members thus receive:

- The proceedings of the annual congress (and sometimes of other meetings).
- New volumes in the *International Contributions to Hydrogeology* series (the seven pubished to date are reviewed in this issue of *Circulation*, and can still be bought).
- A twice yearly Newsletter.
- Membership list, regularly updated.

Several new volumes are in preparation in the *Contributions* series, including one on Groundwater Recharge Estimation which will be published during 1989. There is talk of a journal specialising in case studies of hydrogeological problems, but no definite plans yet.

UK group

There are 49 UK members at the last count. Their activities, including a UK newsletter, are channelled through the Hydrogeological group of the Geological Society (and that group is rather more expensive to join!).

Membership information

IAH will accept anyone engaged in hydrogeology or related sciences as an individual member. Two existing members are needed as sponsors but I, or the UK treasurer, can arrange these for any member of BHS. The 1988 subscription was £18.50 and, given the recent strength of the pound, will be only £17.00 for 1989. Application forms can be obtained from the UK Treasurer (Dr. A.C. Skinner, 2(b) Bertie Road, Kenilworth, CV8 1JP) or from me.

Even at this low price, many in developing countries cannot afford to join. IAH have therefore recently started a sponsorship scheme whereby members can pay the subscription of someone less well off, whether a personal acquaintance, or someone proposed by IAH.

David Lerner
Birmingham

Scottish Hydraulics Study Group

The Scottish Hydraulics Study Group had its inaugral meeting in February 1988. The group is an interdisciplinary organisation composed of practising engineers and researchers with a primary aim of promoting discussion and disseminating information in all aspects of hydraulics.

The group will normally have four evening meetings each year together with a one-day seminar which this year will focus on the design, modelling and operation of spillways.

Further information about the Scottish Hydraulics Study Group can be obtained from: Dr. J. Crowder, Department of Physics and Applied Physics, University of Strathclyde, John Anderson Building, 107 Rottenrow, Glasgow G4 0NG. Tel: 041–552–4400.

New Members

We welcome the following new members to the Society:

J.R.W. ADAMS	Severn Trent Water
P.A.C. HOLMES	Watson Hawksley
M. SOCARRAS	Self-Employed
A. AKRAM	Research Scholar, Aligarth University, India
MISS. N. MANSOUR	Student
DR. J. PITMAN	Lecturer, Kings College, London
V. ESAT	Research Asst., Middlesex Polytechnic
A.J. EDWARDS	Student, Bristol University

Hydrology of Landfill Sites

Scottish Hydrological Group/BHS Meeting 3 November 1988

The symposium organised by the ICE Scottish Hydrological Group in association with the British Hydrological Society at the Albany Hotel, Glasgow, attracted 116 delegates from local authorities, river purification boards, consultants and waste disposal contractors from all over the UK. The aim was to highlight the problems which can be caused by the ingress of water to landfilled waste and to review current practice in tackling the problem. Seven papers were presented by recognised experts in their fields and the topics covered legislation, enforcement, design and operation. There were also case studies of operational and restored sites.

Landfill and water – a difficult mix. This was the general theme of the symposium and the title of the keynote paper presented by Professor George Fleming of Strathclyde University. He and the other speakers called for more resources to be made available for design aspects of landfill. For too long landfill had been "the cinderella of the waste disposal industry". However with the increase in environmental awareness and political interest it was no longer acceptable to adopt short-term steady state principles in the design and operation of landfills as these often led to serious pollution problems. If landfill is to remain the primary means of disposal of the domestic and industrial waste produced in the UK, more time and effort will need to be spent on the hydrological and hydrogeological investigation, engineering design and infill strategy of sites. Indeed, designing for water is so fundamental to the success of a landfill site that it should be given the highest priority in the early stages of site development.

Difficulties in the management of landfill sites were highlighted, in particular the gap that sometimes exists between the conceptual design and the practicalities of implementing this on site. In many cases, individuals operating sites have no formal training in waste management and hence may not appreciate the potential problems of deviating from the design specification.

It was concluded that the operator could control the waste disposal process – and the problems of methane production and leachate – only if more detailed attention is given to the design and management of landfill sites.

Hydrology of Landfill Sites, the published proceedings of this meeting is available from Dr. Graham Herbertson of the Department of Civil Engineering, University of Glasgow, Glasgow G12 8LT (Tel: 041 339 8855), price £15.00 (cheques to be made payable to the Scottish Hydraulics Study Group).

BHS FIRST OCCASIONAL PAPER

An Introduction to Operational Control Rules using the 10 - Component Model

The British Hydrological Society celebrates the introduction of its Occasional Papers with publication on a much vaunted subject by one of the United Kingdom's leading practitioners. **Allan Lambert** has worked for 25 years in the Water Industry and he has dedicated a great deal of that time to the development and presentation of operational guidelines for the tactical control of regional water resources. Apart from describing procedures involved, "An Introuction to Operational Control Rules Using the 10-Component Method" summarises a way of thinking which, to the Water Industry at least, has the very great merit of resolving complex issues in an eminently practical way.

The background to Allan's approach is a basic pragmatic appreciation that reservoir contents are, on the whole, subject to a seasonal phase of emptying followed by a seasonal phase of refilling. Development of Drawdown curves and of Refill curves, components 3 and 4 respectively of the 10-Component method, are therefore key elements in the overall approach. Allan Lambert describes these with simplicity. He also describes how consideration and incorporation of another 8-components, all practical and therefore meaningful to those responsible for reservoir management, results in storage and release control information represented broadly as a set of zones on a graph of reservoir storage versus time of year. The 8 components are: Demands – Resources – Zones, Bandwidths and Action lines – Aggregated storage – Segregated storage – Decision diagrams – Recession curves and Operational economics.

Zonalised information of reservoir storage is designed to resolve a variety of resource management questions, such as:

- During an emptying phase, are reservoir contents low enough to justify constraints and "drought control measures"?
- During a filling phase, are reservoir contents low enough to justify "demand" constraints to protect future water supply interests (in the following emptying phase)?
- Do reservoir contents provide sufficient excess to support extra releases for certain non-essential uses, referred to as Conditional Demands?
- Are reservoir contents sufficient to support Opportunistic Demands such as fish freshets?

Description of the 10-component method is substantially assited by the Cwmstradllyn Case Study and various aspects detailed in Appendix A. An opportunity was missed at this point to consolidate the readers understanding since a comprehensive diary of events (simulated or real) would, it is felt, have usefully illustrated how operational management monitors, react to, and make decisions on, emerging drought conditions and/or excess storage in a reservoir.

Nevertheless Allan's approach to the development of reservoir control information seems to satisfy five criteria which are important to those responsible for managing regional water resources:

1 Ensures prime objectives are met
2 Maximises incidental benefits
3 Can be modified at short notice to cope with unpredictable events
4 Can be used, understood and refined by operational staff
5 Uses available data, however minimal.

For these reasons the many features described are of relevant interest to other practitioners, but they should also be of significant interest to those hydrologists working in education and research, because they direct attention to real-world water resources and the real issues needing to be resolved.

Publication of the paper is also timely. Allan Lambert observes that the creation of a National Rivers Authority encourages the use of "Operating Agreements" between the NRA and the public utility companies for the operation of water resources systems. He rightly claims "that it seems reasonable to suppose that such Operating Agreements will not work effectively unless they incorporate practical operational control rules, and provision for their periodic review".

This first Occasional Paper of the British Hydrological Society will undoubtedly become a useful point of reference for all those associated with reservoir management in the newly organised water industry of England and Wales.

Phil Johnson

REORGANISATION

The changes which are taking place as a result of the creation of the NRA and the PLCs will undoubtedly have lasting effects on many aspects of our roles as professional hydrologists. Accordingly, the Society felt that it had a duty to make a further statement of our views to the appropriate Government departments and other organisations, concerning itself mainly with the technical aspects of hydrometric data (see also *Circulation*, no. 16, 11 and 10).

This new document "The role of hydrology in the changing water industry" was drafted by Sue Walker (NWWA), Phil Johnson (NWA) and Mike Lowing (IH) and is being circulated with this issue of *Circulation*. We understand that it has subsequently filtered down to the new NRA offices.

NEWS FROM MEMBERS

BHS Honours First President

Mike Mansell-Moullin, Chairman of the intiial planning committee which led to the formation of the British Hydrological Society, and its first President, was given life-membership of the Society at the AGM in December.

This honour was by way of saying thank you for all Mike's efforts on the Society's behalf – with a membership now of some 560, the Society seems sure of a sound future.

News from IH

Max Beran has two new jobs. The first is to take over administrative responsibility for the Applications Research Division at the Institute for six months while Tony Debney is on secondment to NERC headquarters at Swindon. The second is to lead a task force on climate change on behalf of the Terrestrial and Freshwater Sciences Directorate of NERC. This task force aims to coordinate existing research within the Institutes of TFSD (the Freshwater Biological Association, Institute of Hydrology, Institute of Terrestrial Ecology, the Unit of Comparative Plant Ecology and the Institute of Virology) and to develop new initiatives. The emphasis of the work will be on the threatened impacts of climate change.

Andy Bullock is going to the UNESCO-organised international colloquium on the "Development of Hydrologic and Water Management Strategies in the Humid Tropics" in mid-July, to be held in Townsville, Queensland, Australia. He has brought to our attention the special request inviting delegates to submit – in advance – a "Needs Statement" which will be available as base material for consideration by workshop participants during the colloquium.

Special hydrological and water management problems and issues of the humid tropics are to be discussed, as well as human resource needs and the problems and potentials for transfer of technological procedures. The immediate outcome of the colloquium is to be a report on proposed strategies and recommendations to be widely circulated; in particular, UNESCO's International Hydrological Programme will be looking to use them in the development of its fourth phase (1990–95).

If you feel you would like to contribute to the meeting by committing your thoughts to paper via such a *Needs Statement*, Andy would be pleased to send you a copy and/or discuss how your views might be incorporated into existing proposals.

A Dry Record ?

1988 certainly has not matched the record drought of 1788 (*Circulation*, November issue). It was however a dry year with below-average rainfall in all months except January and July in the Thames Valley. December in particular was very dry with only 8.0 mm recorded at the Institute of Hydrology, the lowest figure since records began on this site in 1962. The September–December "recharge period" figure of 110 mm is also the lowest recorded at the Institute, considerably lower than the 1975 figure of 167 mm in the run-up to the 1976 drought. The effects of this lack of recharge are already evident in the levels of the local chalk streams.

Members on the Move

The division of responsibilities between North West Water and the North West NRA Unit (designate) is well under way. **Peter Walsh** is to be the Flood Defence Manager in the NRA Unit. **Rick Brassington** will head the Water Resources department. Reporting to him will be **Mike Knowles** (responsible for flood warning, licensing and hydrology), **John Owen** (responsible for technical data including hydrometry) and **Mike Eggboro** (responsible for hydrogeology). On the Utility side **Sue Walker** will be the Hydrological Services Manager. Other appointments will shortly be made on both sides.

Paul Webster, Sir M. MacDonald & Partners, writes to tell us about "Members on the Move", including himself who has been posted to Hong Kong for 12 months (from January) on a drainage study for the New Territories. **Tim Jolley** has gone to Newcastle where he hopes to encourage hydrological interest at one of the firm's Regional Offices. **Fred Kaul** has recently joined the Hydrology Department of the firm as a Principal Engineer.

Standardisation of Precipitation Measurements

The British Standards Institution has invited the Society to appoint by the end of February one or more Experts to serve on a proposed new Working Panel of PLC/3, the BSI Technical Committee on "flow measurement of surface and ground water", to prepare standardization of:

(1) instrumentation and measuring techniques
(2) siting
(3) network design for various applications
(4) collection, quality control and archiving of data.

Snow measurement is not to be considered by this Panel.

Could members of the Society willing and able to serve on the Working Panel please write as soon as may be possible to the President, Prof. P.O. Wolf, FEng, 69 Shepherd's Hill, London, N6 5RE, and provide him with a brief statement of their qualifications and experience in any of the four areas?

FORTHCOMING EVENTS

Meetings

IAHS THIRD SCIENTIFIC ASSEMBLY
10–19 May 1989
Baltimore, Maryland, USA

The Third Scientific Assembly will provide an interdisciplinary forum for review of the latest developments in the field of hydrology. A series of symposia and workshops will bring together international specialists in hydrology and related sciences to present results of research and practice, to create an opportunity for cross communication of the experiences representative of the various Commissions and Committee, and to point the way to needed research for the future.

Tentative programme includes the following topics:

- Atmospheric deposition
- Closing the gap between theory and practice
- Surface water modelling – new directions for hydrologic prediction
- Regional characterisation of water quality
- Glacier and snow cover variations
- Sediment and the environment
- Groundwater contamination
- Remote sensing and large-scale global processes

In addition there will be a series of workshops "Personal computer applications in the Hydrological Sciences" and a number of Field Trips.

Details from: IAHS Assembly, c/o American Geophysical Union, 2000 Florida Avenue, N.W. Washington, DC 20009, or to register by phone, call 202–462–6903 (in the D.C. area or outside the U.S.) 800–424–2488 toll free.

CONFERENCE
on
DRAINAGE
and
WASTE MANAGEMENT
into the
1990's
9–11 May 1989
Dundee, Scotland

☆First announcement and call for papers☆

This conference is planned by Dundee College of Technology and aims to bring together engineers and scientists involved with the control, operation, design, maintenance and construction of wastewater and solid waste collection, treatment and disposal systems. The conference will review the methodologies applied to current and likely future management of these systems. The subjects to be covered under six principal headings will include:

Solid wastes – management and disposal policies and options – recovery of resources.
Sewerage – design, ageing problems, renewal and renovation – control and instrumentation – overflow and storage problems – outfalls and dispersion.
Sewage treatment – design and operation of works – monitoring and control of performance – sludge disposal, treatment and utilization.
Instrumentation and control – data acquisition – real-time monitoring and on-line control.
River impact – quality objectives and standards – river basin management – quality models.
Legislation and management – COPA and EC directives – towards privatisation – District or Regional Authorities – River Purification Boards and a National Rivers Authority.

The conference will be held at the Stakis Earl Grey Hotel at the Dundee waterfront. Residential accommodation will be available in the Dundee College of Technology hall of residence or local hotels. Information will be issued with the final programme. Correspondence should be addressed to: The Conference Secretary, Technology of Transfer Centre, Bell Street, Dundee DD1 1HG, Scotland.

BHS NATIONAL MEETING
PRESCRIBED FLOWS, ABSTRACTIONS
and
ENVIRONMENTAL PROTECTION
16 June 1989
Institution of Civil Engineers, London

The meeting will focus on the main themes:

- The historical development of present day compensation release policy and a review of current releases and their impact on reservoir yield and downstream flow regimes
- Methods used for assessing instream flow requirements for environmental protection
- Policy issues relating to abstractions in the 1990s.

Speakers have been invited from the Water Industry, Universities, Research Institutes, Department of the Environment and the National Rivers Authority. Papers will be circulted in advance of the meeting. Further details from: G. Petts, Secretary BHS, Department of Geography, University of Loughborough.

GROUNDWATER RECHARGE
National Meeting
University of Birmingham
July 1989

☆Call for contributions☆

This meeting will discuss advances in methods of estimating groundwater recharge. It is hoped to cover all sources (precipitation, channels, urban areas, irrigation), to deal with both UK and overseas conditions, and to discuss the difficulty of moving from point to catchment estimates; both research and case studies are sought. The meeting is co-sponsored by the Hydrogeological Group of the Geological Society. Potential contributors are asked to contact the convenor, David Lerner, School of Earth Sciences, University of Birmingham. Tel: 021–414–6156 by the **end of February.**

INTERNATIONAL SYMPOSIUM
ON HYDROLOGICAL APPLICATIONS
OF WEATHER RADAR
14–17 August 1989
University of Salford, Manchester, UK

☆Announcement and call for papers☆

This International Symposium will complement the successful symposium held at the University of Lancaster, UK on Flood Forecasting and Weather Radar in 1984. The UK has been at the centre of developments in operational weather radar for many years in the meteorological area and more recently has expanded the use of such quantitative data into the hydrological arena. The timing of the Salford Symposium, immediately following the 5th Scientific Assembly of the International Association of Meteorology and Atmospheric Physics (IAMAP 89) at Reading, should allow many delegates, with an interest in Hydrological Applications of Weather Radar, to remain in the UK and attend the Salford Symposium subsequently.

Original papers on the following themes are invited. The specific subjects are for guidance only and are not intended to restrict contributions relevant to the Symposium:

Quantitative calibration procedures
Synoptic type dependence and automatic storm type recognition
Range dependence
Real-time calibration procedures
Off-line recalibration of archived data
Snowfall measurement
Signal adjustments for attenuation and occultation
Bright band correction

Modelling of rainfall fields
Short-term rainfall forecasting
Statistical description of rainfall fields
Storm precipitation mechanisms
Design of rainfall measuring networks

Real-time flow forecasting
Lumped and semi-distributed models
Grid-Square based distributed flood forecasting models
Snowmelt forecasting
Real-time updating procedures

Operational and design aspects
River basin forecasting systems
Operational management of urban drainage
Design of stormwater drainage systems

Radar display systems
Environmental impact through remote sensing

A one-page (A4) abstract should be provided by **28th February 1989** and initial acceptance will be notified prior to full length papers (maximum ten A4 pages) being provided by **1st May 1989**. Pre-prints will be distributed at the Symposium and the proceedings will subsequently appear in book form. The Symposium language will be English; no simultaneous translation facilities will be available. All correspondence connected with the Symposium should be addressed to: Prof. I.D. Cluckie, Int. Symp. Hydrological Applications of Weather Radar, Department of Civil Engineering, University of Salford, Salford, M5 4WT, United Kingdom. Tel: 061–736 5843 Extension 7265. Fax: 061–745 7027. Telex: 668680 (SULIB).

WATER RESOURCE CONSEQUENCES FOLLOWING A NUCLEAR EVENT
International Conference
7–8 September 1989
Glasgow, Scotland

The impact of the Chernobyl accident, which drew attention to the potential vulnerability of the water cycle to radionuclide contamination, has been highly variable and wide ranging throughout Europe. This conference aims to cover the complete water cycle as it impacts on water resources; the accidental release of radionuclides will be the central issue with a view to formulating strategies to deal with future events. Sessions include:

- Introduction and theme paper
- Present radiological standards relating to drinking water supply
- Radiological monitoring requirements
- The consequences of a nuclear event on water resources
- Water resource management strategy

Prospective authors are invited to send synopses of 500 words, in English, to the conference secretariat, no later than **15th August 1988.** Completed papers should be up to 5,000 words in length, and final manuscripts will be required in the Spring 1989.

Correspondence to: The Conference Office, (Water Resources), The Institution of Civil Engineers, 1–7 Great George Street, Westminster, London SW1P 3AA, England.

WATER SPECIALISTS in POLYTECHNICS and UNIVERSITIES
13–15 September 1989
Hatfield Polytechnic, Herts

This annual meeting provides a forum for discussion of matters of interest in teaching, research, funding, collaboration, etc., to staff in any department or field of study within the broad area of hydrology. Sessions of particular interest to hydrology lecturers and researchers on 14th September.

Details from: Dr. C.J. Pratt, Department of Civil and Structural Engineering, Trent Polytechnic, Nottingham NG1 4BU.

HYDRAULIC and ENVIRONMENTAL MODELLING of COASTAL, ESTUARINE and RIVER WATERS
19–21 September 1989
Bradford, England

The Computational Hydraulics and Environmental Modelling Research Group, at the University of Bradford, will host this international conference. The meeting will address delegates from water authorities, consulting and contracting engineering companies, universities and polytechnics, local authorities, local, national and international government organisations and research and development organisations. The main themes of the conference relate to the development and application of deterministic mathematical models in connection with the following:

- Tidal currents, constituents and circulation patterns, tidal flushing, and pollution
- Interaction of pollutants and sediments
- Coastal hydrodynamics and wave motion
- Coastal impact modelling
- Estuarine and river hydraulics
- Physical and numerical model studies of flow processes and sediment and pollutant transport rates
- Field and laboratory measuring techniques for model calibration and verification
- Numerical techniques, solution algorithms and graphical presentation developments in the field, particularly with the aid of personal computers.

Exhibition facilities will be available throughout the conference; interested delegates or organisations are invited to contact the Conference Co-ordinator: Prof. Roger A. Falconer, Co-ordinator, Computational Hydraulics and Environmental Modelling Group (Ext. 8391) or Mr. John H. Ayers, Conference Co-ordinator (Ext. 8236) Department of Civil Engineering, University of Bradford, Bradford, West Yorkshire BD7 1DP, England. Tel: 0274–733466. Telex: 51309 UNIBFD G. Fax: 0274–305340.

Courses

GROUNDWATER POLLUTION
17–21 April 1989
Birmingham

Birmingham University is offering its highly successful, one week course again this year, for the **last time!** The mixture of lectures, workshops and equipment exhibition emphasises the practical in parallel with an understanding of the science of groundwater pollution. The course is intended as an introduction for technical staff and a refresher for managers with little formal training in the subject.

Details are available from David Lerner, School of Earth Sciences, University of Birmingham, Birmingham B15 2TT. Tel: 021–414 6156.

Diary

14th February 1989
BHS Southern Section.
"Flood frequency analysis of chalk catchments" – Nigel Arnell, Institute of Hydrology.

10th March 1989
Scottish Hydrological Group.
"Hydrology of ash lagoons" – A.J. Cowan, Jas. Williamson & Partners.
6 p.m. for 6.30 p.m. The Wellcome Room, Royal Society of Edinburgh, 22–24 George Street, Edinburgh.

17th March 1989
Scottish Hydraulics Study Group.
"SPILLWAYS – Design, modelling and operation".
One day seminar at The Albany Hotel, Glasgow. Cost is £45, by 17th February to Dr. D.A. Ervine, Department of Civil Engineering, University of Glasgow, Glasgow G12 8LT. Tel: 041–339–8855 (ex. 5210).

9th May 1989
BHS National Meeting.
"Forest Hydrology".
Institute of Hydrology.

10th May 1989
Pennines Hydrological Group.
AGM, followed by presentation on Urban Flood Storage (quantity).
Sheffield University.

16th May 1989
"Monitoring Sahel rainfall".
Met. Office, Bracknell.

16th June 1989
BHS Midlands Section.
"Prescribed flow, abstractions and environmental protection".

4th July 1989
BHS National Meeting.
"Groundwater recharge" – joint with Hydrogeological Group of Geol. Soc. London.
Venue: Birmingham.
Contact: David Lerner, Birmingham University. Tel: 021–414 6156.

Copy Deadline for Issue No. 22
6th April 1989

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 £13. Please address all correspondence to the Editor, Institute of Hydrology, Wallingford, OX10 8BB. Telephone 0491–38800.