

BHS 13th National Hydrology Symposium

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A.1

How to make advances in hydrological modelling

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We have many different hydrological models, from ABC to Xinanjiang (any suggestions for Y and Z?). Most are conceptual in nature, variants on the stores and storage–flux relationships of the Stanford Watershed Model of the 1960s. Some are based on (incomplete) process theories; some derived directly from the available data (ANN, DBM). Some are distributed and highly integrated into geographical information systems (SHE, Hydrogeosphere, Dynamic Topmodel). Some are modelling systems that allow the user to try out many different structural configurations (Superflex, SUMMA). Some come with databases of parameter values so that they can be applied without calibration (SWAT), although it is usually calibration that allows us to declare some sort of success. Such success is often illusory, however. Performance often degrades in even the simplest of split-record validation test, and there is no guarantee that a calibrated model will match multiple observables, all parts of the calibration series, or be fit-for-purpose when used to predict the changed conditions often required to provide evidence for decision making. Part of the problem is certainly that the data available for modelling are often not adequate; they can even be hydrologically inconsistent and feed disinformation into the modelling process. But part of the problem is also the lack of rigorous testing and invalidation of models which should best be viewed as multiple working hypotheses about how a catchment or water body functions.

How to do better in hydrological modelling requires two things: one is better Turing tests for fitness-for-purpose; the other is better measurement methodologies for both forcing and evaluation data. Possibilities for future improvements will be discussed, and particularly the need to take account of velocities and celerities in process representations and the need to be pro-active about what is required for future measurements.

A.2

Trends in UK Peak Flow Data: When did they start?

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There is currently a great deal of interest in the potential effects of climate and environmental change on the magnitude and frequency of extreme floods. For example, repeated extreme floods experienced in north-west England over the last few years have caused concern about whether such events are evidence of changes in flood-producing mechanisms. Classical approaches to flood frequency analysis rely on the assumption of stationarity, i.e. that there is no trend in the peak flow data. However, the occurrence of the most extreme events (larger than any other on record) can have a marked effect on return period estimates, which in turn introduces uncertainty when considering the design lifetime of flood risk management measures. This paper describes the application of non-stationary flood frequency analysis to annual maxima time series in the UK, and how characteristics of the most extreme events change over time.

Following on from work on low and high flows by Harrigan et al., 2017, trends in extreme flood distributions in the United Kingdom have been investigated. The UKBN2 is a near-rural collection of UK catchments with long records (more than 40 years) which makes it possible to investigate possible hydrological and meteorological trends without having to account for the influence of river management and land use change. Fitting time-dependent location, scale and shape parameters of the Generalised Logistic distribution enabled us to see the changes in flood frequency curve characteristics over time. Additionally, fitting time-independent distributions over moving and increasing time-windows allows us to identify when particular events have a marked influence on parameter estimates and hence flood frequency curves. Spatial patterns in these parameter changes across the UK are evaluated, together with changes through time. Examples of changes in the 30-, 50- and 100-year floods are presented for stations in the Benchmark Network.

A.3

Regional differences in meteorological droughts in Great Britain

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Droughts, commonly defined as a below-normal water availability, are a complex phenomenon and generally slower-developing and more widespread than other natural hazards. Their socio-economic and environmental impacts can be substantial, which has led to a large amount of recent effort invested in trying to better understand droughts. In the UK, the NERC-funded Drought and Water Scarcity Programme (DWSP) has contributed to considerable progress in this field.

The work presented here is part of the Historic Droughts project (funded under DWSP), the main objective of which is to gain an in-depth understanding of past droughts to better inform future drought planning and management decisions. This study investigates more specifically the spatial characteristics of past British droughts. Great Britain (GB) can broadly be divided into two regions which have different meteorological, topographical, geological and hydrological characteristics: (i) the South-East (SE) which is drier, dominated by lowlands and slow-responding groundwater-dominated catchments, and (ii) the North-West (NW), wetter, dominated by highlands with rapidly responding catchments.

However, the spatio-temporal characteristics of droughts and differences between these two regions are not well understood. Better understanding this spatial contrast would help improve forecasting, drought preparedness and water resources strategies (e.g. the possibility of inter-regional water transfers). Here, we focus on the spatio-temporal differences in meteorological drought. GB was divided into three similar-sized clusters (SE, NW, and a 'transition' region between the two) based on monthly precipitation anomalies and defined using k-means clustering technique applied in two successive steps. Historical gridded monthly rainfall data (1862–2015) were used to identify past drought events. Each grid point at time steps with precipitation below a 20% percentile was flagged. Following a methodology developed for studying droughts in the European Greater Alpine Region, drought events were then detected by connecting the flagged elements to space-time drought regions. Each drought event was assigned to one of the three clusters by

identifying the Core Drought Region (CDR) and assigning the event to the cluster with the largest proportion within the CDR. The CDR represents the central region of the drought with highest drought severity. Early results looking at the return period of drought events in each cluster, based on drought (i) mean area, (ii) duration, (iii) intensity, and (iv) severity suggest that longer, more extensive and more severe meteorological droughts are more frequent in the SE than the NW. However, the drought intensity at individual grid cell level is similar in both regions, but lower in the 'transition' region.

Although the geological differences between the SE (permeable) and NW (impermeable) are known to be a major influence in the type of hydrological droughts dominant in each regions (long droughts affecting groundwater levels in SE, short sharp droughts in NW), results suggest that the meteorological differences are also likely to have a great impact on river flows and groundwater.

B.1

Insights into rainfall undercatch in differing gauge types and heights: the impact of wind speed and rainfall event intensity

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The accurate measurement of rainfall is vital for many aspects of hydrology, including the accurate estimation of water resources. However, the standard installation of raingauges with rims above the ground surface results in a difference between this catch and the amount of rainfall reaching ground level, termed undercatch. Wind disturbance, gauge shape and type of rainfall events have all been shown to impact on rainfall undercatch. The UK standard installation of both storage and tipping bucket raingauges has their rim cited at 30cm above the ground: however the use of weighing gauges, installed at a minimum of 1m above the ground surface, has increased in recent years. The installation of these raingauges raises complex questions of homogeneity of rainfall series, given the simultaneous change to both the measurement technique and gauge height. The Centre for Ecology & Hydrology's meteorological station at Wallingford (Oxfordshire) has historically operated parallel daily storage and tipping-bucket gauges installed at standard height and at ground level in pits. In April 2015, three weighing raingauges were installed at ground level, partial (30cm) and full (1m) heights above the ground. Results from the first three years of the raingauge trials will be presented, looking at the difference in catch between gauge height and instrument types and investigations into the relationship between rainfall catch, wind speed and rainfall event intensity.

B.2

From Floaters to Drones and Citizens with Phones: The evolution of river flow measurement technologies in the Environment Agency and beyond

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Perhaps the single most important thing to understand when managing rivers for flood, drought and all conditions in between is: 'How much water is flowing in the river system?' This vital information is collected by Environment Agency Hydrometry and Telemetry staff, and underpins our river flow forecasting, modelling and incident management activities.

The last 20 years have marked a transformation in river flow gauging technologies and methods, away from mechanical instruments deployed from bridges, cableways and manned boats, and towards acoustic systems, often mounted in remote control boats. This has made flow gauging safer, more efficient, improved data quality and brought new insights into the function of our river systems.

Now, in 2018, we are collaborating with river scientists and practitioners around the world to help us develop and evaluate the next generation of potentially transformational new technologies, including:

- Large Scale Particle Imaging Velocimetry — video-processing for surface velocity
- Surface velocity Doppler radar (see photo overleaf)
- 'Acoustic holography' — interpreting surface features to understand depth & hydraulics beneath
- Dilution gauging, including fully automated systems
- Slope/area discharge methods
- GPS drifters for flood flow and pathway assessment

All of these techniques offer the potential for significant improvements to the efficiency, safety, robustness and scope of our flow measurement capabilities.

This presentation tells this story and looks to a future where, in the context of widely expected increases in the frequency and magnitude of climatic extremes, new and emerging technologies — developed and evaluated in partnership with a global network of river scientists — will allow even more vitally important information about river flows to be captured safely and efficiently.



A surface velocity radar gun is evaluated alongside an Acoustic Doppler Current Profiler on the River Trent at Yoxall.

B.3

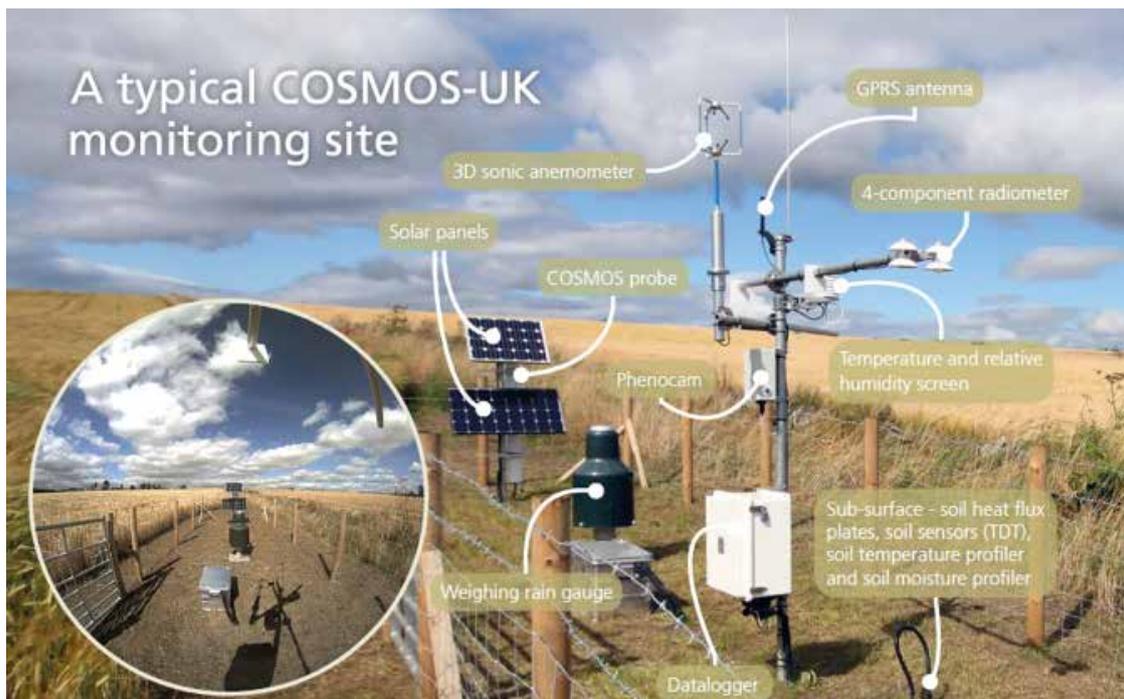
COSMOS-UK: A new field-scale national soil moisture monitoring network

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The UK COsmic-ray Soil Moisture Observing System (COSMOS-UK) is a network of soil moisture and meteorological sensors operated by the Centre for Ecology & Hydrology. It was established in 2013 and is currently still expanding. The network employs cosmic ray neutron sensors to infer field-scale soil moisture. These sensors have the advantage of a large measurement 'footprint' (~200 m radius) and are able to operate continuously providing area-averaged near-surface volumetric soil water content. Measurements of soil moisture at a scale between point sensors and remote sensing are important for our understanding of hydrological processes, land-surface coupling, biogeochemistry and ecohydrology.



The network currently comprises 45 sites across the UK with each site providing soil moisture and meteorological data at resolutions ranging from one minute to daily. The sites cover a range of climate, land cover, soil type, geology and topography. Many sites are co-located with other scientific research, such as the Environmental Change Network, with site hosts including Universities/Colleges, Research Institutes and Natural England.

The data have many applications such as flood forecasting, drought monitoring, climate science and land-atmosphere processes and also for more unexpected uses including amateur radio, space weather research and gravity surveys. The network is NERC National Capability funded and data are available through the Environmental Information Data Centre.

This presentation will introduce the cosmic ray neutron soil moisture measurement technique, provide an overview of the COSMOS-UK network and include examples of data focusing on recent weather events.

B.4

Stochastic generation of rainfall and PET by downscaling climate model outputs

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Having an adequate level of water security is essential to sustain population well-being and economic development. Understanding the reliability of the water supply is, in fact, key during any planning process to avoid potential deficits. Water companies have traditionally based their decisions on the available historical record of rainfall and temperature and systematically test their system against past drought episodes. However, given the variable nature of climate and the potential future changes in its patterns, future droughts are likely to divert in magnitude and spatio-temporal distribution from the past ones. This introduces a significant uncertainty in the analysis that should be reduced.

A possible solution is the stochastic generation of long rainfall and temperature series that maintain the statistical features of the existing record but extend it to cover other possible drought episodes. To properly address the challenge, this weather generator (WG) should also account for the spatial variability of rainfall within a catchment and be able to consider the effects of climate change. Many UK water companies have adopted this approach for their 2019 Water Resources Management Plans, but the applied WG, although implying a significant advance, is not answering the question fully. On one hand, it has a monthly time step and the daily apportioning is obtained by selecting the historical month with the closest total rainfall and scaling it. This is preventing changes in rainfall temporal patterns, which could have an unknown impact on water systems. On the other hand, the climatic link is quite weak, which hinders the possibility of adopting the same WG for predicting future weather patterns.

As an alternative, the use of statistical downscaling has been investigated. General and Regional Circulation Models (GCM/RCM) are used to predict the evolution of key climatological variables such as temperature, pressure at different levels, relative humidity, as well as other hydrological variables which depend upon them, such as precipitation and potential evapotranspiration (PET), but their spatial and temporal resolution is coarse. However, this information can be downscaled by fitting a daily spatial-temporal disaggregator (Generalised Linear Model – GLM) which generates potential daily precipitation and PET scenarios at any point over a given area of interest. GLMs can be used to both infer teleconnections between local precipitation and PET characteristics and synoptic climate patterns (through the strength of the correlation with a covariate) and to simulate realistic rainfall and PET statistics for current and future climates.

An application of this kind of WG has been conducted in the River Blithe catchment, which is relevant for South Staffordshire Water supply system. Results are quite satisfactory regarding the representation of historical droughts, implying that more extreme episodes can be generated with ease to be input to rainfall-runoff models. Estimated climate changed rainfall and PET patterns differ from those derived in the UKCP09 dataset, in particular in the case of PET, where the use of temperature rise only could be overestimating the magnitude of the change.

B.5

Filling the Gap – A method for in-filling (and extending) rainfall records using 'Reverse Hydrology' and Spectral Decomposition

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Long rainfall and flow records are required for design purposes, for example, the design of flood protection schemes. The method proposed here utilises Reverse Hydrology and Spectral Decomposition to either extend the rainfall record, or fill a gap in that record caused, for example, by failure of a rain gauge, with a realistic rainfall series that will generate the correct hydrograph. It is assumed that a flow record exists over the gap in the rainfall record. Reverse Hydrology in this context, refers to a method for inferring rainfall from streamflow (Kretzschmar et al., 2014, 2015; Kretzschmar, 2017). Spectral decomposition splits the frequency profile of the rainfall record into slow and fast components. The combination of these components enables the complete profile to be constructed.

A model is built using a calibration section of the record that has both rainfall and streamflow data by first identifying a parsimonious continuous time transfer function model, based on the Data based Mechanistic modelling philosophy, between rainfall and streamflow using systems analysis techniques, utilising the tools available in the Captain Toolbox for Matlab, then inverting it, using the RegDer method of Kretzschmar et al. (2014, 2015), to obtain an estimate of the Discharge Generating Rainfall (DGR). This is an estimate of the low frequency component of the rainfall series. The distribution of residuals between the DGR and observed rainfall is calculated. This residual series is an estimate of the high frequency component of the rainfall series which, as it has little effect on the flow generation, could take almost any values. A uniformly distributed random number generator is used to construct a simulated, uncorrelated residual series with the distribution estimated from the calibration series. Correlation structure is introduced using an AR model based on the autocorrelation structure of the calibration residual series. The high frequency simulated residual series and low frequency DGR are then combined to create a new rainfall series that can be validated against the measured rainfall series in both time and frequency domains.

The transfer function RegDer model can then be used to estimate DGR from the flow over the missing section and a possible rainfall sequence constructed by combining a high frequency simulated residual series with the low frequency DGR. The result is a series that looks realistic, has the correct residual structure and is capable of generating the correct hydrograph. The same methodology might be used to extend a rainfall record where a flow record exists but a rainfall record does not (Kretzschmar, 2017). The method shows promise but is work in progress.

References

Kretzschmar, A., Tych, W. & Chappell, N.A., (2014) Reversing hydrology: Estimation of sub-hourly rainfall time-series from streamflow. *Environmental Modelling & Software* 60: 290-301.

Kretzschmar, A., Tych, W., Chappell, N.A. & Beven, K.J., (2015) Reversing hydrology: quantifying the temporal aggregation effect of catchment rainfall estimation using sub-hourly data. *Hydrology Research*, Jun. 2016, 47 (3) 630-645; DOI: 10.2166/nh.2015.076.

Kretzschmar, A., (2017) Utilising Reverse Hydrology to quantify and improve the spatio-temporal information content of catchment rainfall estimates for flood modelling, PhD, Lancaster University.

C.1

Macroinvertebrate and diatom community responses to river regulation by water supply reservoirs – a large-scale multi-year study

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River regulation by impoundment is considered one of the most significant and extensive anthropogenic impacts on riverine ecosystems globally. There is a growing body of research centred on quantifying the effects of impoundment, with a focus on the effects of individual large dams on downstream aquatic ecosystems. This study undertakes a comparison of paired regulated and control sites associated with multiple water supply reservoirs under managed flow regimes across a range of scales using multi-year macroinvertebrate and diatom community datasets.

Community structure and a range of biomonitoring metrics were analysed in association with spatio-temporal parameters (e.g. region, year) to identify consistent downstream patterns in ecological responses to impoundment. Macroinvertebrate and diatom communities at regulated sites differed significantly from those at control sites. The effect was most significant at a regional scale, whereas biogeographical factors appeared the primary driver of community differences at the national scale. Typically, taxonomic richness was higher at regulated sites, with a lower percentage of flow-sensitive EPT taxa present. In addition, a subset of the ecological data was analysed in association with hydrological indices to quantify the effect of flow alteration on instream communities. This research provides a basis for development and future implementation of environmental flows on impounded rivers.

C.2

Quantifying macroinvertebrate responses to hydrological variability and anthropogenic flow alterations over a >20-year period

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The flow regime of lotic environments is widely regarded as a primary control shaping the structure and function of river ecosystems. Hydrological alterations within such environments have been found to degrade the health of riverine ecosystems globally. However, the ecological implications of groundwater abstraction practices have been historically understudied. In this paper, we utilize a regional groundwater model to examine long-term (1995–2016) macroinvertebrate community responses to antecedent observed hydrological variability and anthropogenic flow alterations (including groundwater abstraction and hydrological inputs). The structure and function of macroinvertebrate communities displayed strong short-term temporal responses (<25 days) following the cessation of extreme low-flow events, although this was not evident with community responses to high-flow events. Instream communities were most responsive to indices characterising anthropogenic flow alterations compared to those quantifying hydrological variability. This highlights that the ecological responses of macroinvertebrate communities typically peaked at low-moderate abstraction influences (c. 10–15% reduction in discharge) and negative ecological responses only occurred at higher abstraction levels (c. >15% reduction in discharge). Findings from this research have strong implications for water resource management operations and how river discharges can be manipulated to balance ecosystems and societal water demands.

C.3

Staying put or moving on? Ponding in intermittent streams

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Intermittent streams are hydrologically dynamic, shifting between lotic, lentic and dry phases, yet almost all research effort has focused on the lotic phase. However, information regarding the diversity of the lentic phase is essential to determine (1) their use as flow refugia, (2) the total aquatic diversity in intermittent streams and (3) effective conservation and management strategies. We examined the diversity and composition of macro-invertebrates from perennial, intermittent and ponded sites, and whether instream ponding provided refugia for lotic taxa and a habitat for newly colonising taxa in two intermittent rivers in the UK. We found instream ponds had lower alpha diversity, but supported heterogeneous communities compared to flowing sites. A total of only 22% of taxa were recorded from ponded sites, many of which were lentic specialists, while 38% of taxa persisted in instream ponds after flow had ceased. Instream ponds provide an important flow refuge for macroinvertebrate taxa (including rheophilic taxa), which move into instream ponds when channels become hydrologically disconnected. Aquatic diversity in intermittent rivers may have been under-estimated historically, failing to acknowledge the ecological contribution of the lentic phase. As intermittent rivers are predicted to increase in number, information regarding their ecological diversity is important for the development of effective biodiversity conservation and management strategies

C.4

The effect of fine sediment size and loading on the vertical movement of a freshwater amphipod

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Sedimentation and clogging of interstitial pore space is widely considered to be one of the most significant threats to lotic ecosystem integrity and functioning. This paper presents the results of a study examining the effect of fine sediment loading (benthic and hyporheic) and particle size on the vertical movement and distribution of the freshwater amphipod, *Gammarus pulex*, within running water mesocosms. The influence of body size on the ability of individuals to access subsurface sediments was also examined. Results indicate that when vertical hydraulic exchange is upwelling, increasing the volume of fine sediment deposition limited the ability of individuals to migrate vertically into subsurface substrates. Particle size and heterogeneity of deposited sediment had a significant effect on the vertical movement of individuals, with heterogeneous sand (4 – 0.25 mm) acting as the strongest filter of individuals followed by coarse (4 – 1 mm) and fine sand (1 – 0.25 mm). The volume of deposited sediment and particle size also acted as a filter on the body size of organisms able to migrate vertically, with only smaller bodied individuals able to access the deeper layers of the column under the greatest sediment loading treatments. The results illustrate the need to consider both abiotic and biotic factors when evaluating the effects of fine sediment for individual taxa and macro-invertebrate communities in the natural environment.

C.5

The future of rivers with artificially enhanced baseflows: Central England

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In this paper the term 'artificially enhanced' is used to describe watercourses which have experienced the prolonged and sustained artificial augmentation of baseflows. This scenario may result from consented discharges, engineered transfers and flow regulation, but this paper focuses on the enhancement of baseflows resulting from consented discharges from Sewage Treatment Works.

To date, such increases in baseflows have usually been regarded as positive, or at least not detrimental to river ecology. Initial characterisation for the European Water Framework Directive (WFD) suggested that as many or more river reaches have artificially enhanced baseflows as are over-abstracted (Waddingham *et al.*, 2008). Assessment of the artificial influences operating in the catchments upstream of gauging stations indicated that a large number of rivers located within Central England have experienced artificially enhanced baseflows, some for three decades or more. Flows at over 10 per cent of gauging stations within the River Great Ouse basin have been substantially augmented by effluent return; this figure increases to almost 40 per cent within the heavily modified River Trent basin.

This paper analyses flow data from contrasting rivers located across the River Trent and River Great Ouse basins. Low flows within one river, the River Tame immediately downstream of a large Sewage Treatment Works, were identified as more than six times higher than they would have been naturally. A conceptual model is used to illustrate the intra and inter-annual variability in the impact of artificial augmentation upon baseflows. The Rivers Tame, Trent and Bedford Ouse and many other rivers have experienced artificially enhanced baseflows for several decades. In such rivers the ecology may have adapted over time to the artificially enhanced flow regime, and recreational values have emerged such that flow management approaches aiming to restore naturalised flows would potentially be detrimental. The conceptual model highlights the impacts of enhanced baseflows as loss of habitat partitioning in summer and maintained flows during the autumn (October and November) critical ecological period.

The Abstraction Licensing Strategies produced from the Catchment Abstraction Management Strategy (CAMS) process views rivers with artificially enhanced baseflows as a potentially underdeveloped resource. There are numerous uncertainties surrounding future climate change and flow regimes due to non-stationarity, and population growth and increased abstraction demands will see more

water stress in the future. Research is urgently needed to assess the societal value of rivers with artificially enhanced baseflows.

D.1

Testing novel tools and recent advances to meet decision maker needs for drought monitoring and early warning in the UK

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Droughts are multifaceted events which evade simple definition. Initial deficits in rainfall typically propagate through the hydrological cycle eventually impacting ecosystems, a broad range of economic sectors and society more widely. As such, droughts are not only among the most costly natural hazards occurring in any climatic region but also one of the most complex to manage. Drought monitoring and early warning (MEW) is a crucial part of effective drought management, yet internationally MEW efforts are hindered by the complexities of drought definition and the challenges of catering for the disparate needs of the many potential users. While the UK has a very well evolved water management framework and a range of operational MEW tools for hydrological status monitoring, the UK does not have a comprehensive nationwide drought monitoring system.

There have been substantial efforts over recent years to enhance drought monitoring and early warning activities in the UK, emerging particularly from projects within the RCUK Drought and Water Scarcity Programme and an allied international project, DrIVER. Here, we provide an overview of some recent scientific advances in drought quantification, new software tools for mapping and visualisation, and extensive stakeholder engagement, all of which underpin the design and development of novel tools for drought MEW at a UK scale. We discuss the testing and evaluation of drought indicators across the UK, before demonstrating how detailed stakeholder engagement and feedback led to the development of the UK Drought Portal, which enables users to assess rainfall deficits at their spatial and temporal scale of interest. We discuss planned developments to the UK Drought Portal, including the addition of river flow and groundwater indicators, with the potential for the addition of earth observation data for vegetation health and soil moisture data from the COSMOS-UK network.

It is crucial that the indicators presented and utilised in drought MEW systems have been 'ground-truthed' against observed drought impacts and triggers used by decision makers. We end by showing examples of how indicators have been

correlated with reported impacts of drought on society and/or ecosystems, and how indicators used in the Drought Portal are being linked to triggers used by decision makers to demonstrate the utility of drought indicators used in MEW systems and show their transferability to practical drought management contexts.

D.2

Small catchment flow monitoring and analysis to inform water abstraction at a Scottish distillery

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Water abstractions in Scotland must meet SEPA's Environmental Flow Standards (EFS) to be acceptable. EFS are applied at a variety of flow percentiles along the flow duration curve and in ungauged catchments this is usually derived from the industry standard LowFlows 2 software. Application of LowFlows 2 to small catchments can be uncertain and this can have implications for the resulting abstraction amounts and design. Field hydrometry (over a 12-month period) and desk-based analysis was undertaken to inform proposed water abstractions for a distillery from two very small (< 1 km²) catchments. Comparison of the field values with those obtained from LowFlows 2 and the earlier IH 101 method indicated that low flow statistics such as Q95 were higher using LowFlows 2 than from the field measurement or IH 101. The implication for abstraction in these particular small catchments is therefore that adoption of the LowFlows 2 values will result in higher pass forward, environmental flows, than if flow statistics from the other methods were used. With very large and ongoing investment in whisky production for export, future consideration of abstractions and discharges is likely to need more scrutiny to better understand their impact upon environmental hydrology.

D.3

The hydrological state of play for intermittent rivers

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Hydrological characterisation of intermittent rivers is required to facilitate research into their hydroecology, and quantification of their response to hydrological extremes and artificial influences. Traditional approaches are effective in quantifying network contraction or flow regime but are unable to fully characterise the systems because observations are usually of limited resolution in time or space and do not include ponded water as a distinct hydrological state. Techniques and data are required that capture both temporal and spatial variability with a multiple classification of hydrological state and such studies are extremely rare in the academic literature.

Year-round observations spanning 20 years have been made at multiple locations along ten chalk rivers in the East Chilterns. Techniques are presented for the visualisation and quantification of these data using a four-fold classification of hydrological state: high flow, moderate/low flow, ponded and dry. Heat maps provide visualisation of period of record and typical monthly hydrological state, and metrics quantify the composition and configuration along the channel and at a given site. Machine learning techniques using areal rainfall, groundwater level and gauged flows offer preliminary insights into the drivers of intermittent behaviour.

The period of record heat maps reveal spatial patterns in hydrological state along the rivers including marked differences in the occurrence of ponding and of the fragmentation of hydrological state between the groundwater-dominated and more clay-influenced rivers. Monthly average heat maps show the typical behaviour of the rivers and reveal stable artificial influences. The impact of drought years is observed in both composition metrics such as the abundance of dry state, and in configuration metrics such as lotic connectivity. Seasonal patterns are identified in the metrics and outliers highlight occurrences of unseasonable behaviour that have potential implications for aquatic and terrestrial ecology.

The dataset presents a unique opportunity to study the spatial and temporal variability of hydrological state in intermittent rivers and to investigate drivers of behaviour. The heat maps provide readily accessible ways for the data to be presented to stakeholders. Metrics allow quantification of the intermittent behaviour for a site, river or period of time, providing a framework for assessing the impact of drought and artificial influences on the highly diverse biota of these rivers.

D.4

Assessment and mitigation of storm runoff loads from an informal settlement (slum)

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The study investigates how stormwater runoff quality and quantity, in an informal settlements is influenced by anthropogenic and environmental factors and to understand the links between hydrology, geochemistry and microbiology in a peri-urban informal settlement. It is necessary to understand the processes and characteristics of runoff in these regions to mitigate significant health and environmental risks from stormwater runoff and improve sanitation. This research is based in Enkanini, an informal settlement near Stellenbosch, South Africa, where water samples were collected and analysed during the wet winter seasons of 2016 and 2017. Sample site selection was based upon catchment analysis using DEM data to determine the most suitable and key locations. Data collection within Enkanini comprised of two methodology sections for water quality (geochemical and microbiological components) and water quantity (hydrological component). Preliminary results suggest a significant relationship between certain environmental characteristics, notably total duration and rainfall intensity, and microbiological pollution. Significant differences in microbiological concentrations were also observed at sample sites impacted by different degrees of anthropogenic influence.

E.1

The hydroecological applications of hydraulic habitat modelling and mapping

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Hydraulic habitat modelling and mapping is the use of hydraulic models to predict changes in habitat availability for aquatic organisms following changes in the physical conditions (i.e. a change in flow or change in topography).

JBA have used hydraulic habitat modelling in a range of hydro-ecological applications. The basis of hydraulic habitat modelling will be outlined, and its functionality explored using two recent JBA projects:

- Fish pass design. Used to assess the hydraulics of a complex weir arrangement on the River Aire, which determined the pathways for upstream migration with the existing site conditions.
- Investigation. Used to assess the implications on habitat creation for several different river restoration options on a reach of the River Ure, including both instream and floodplain restoration.

Through these case studies, the pros and cons of hydraulic habitat mapping will be drawn out. Advantages include the ability to evaluate:

- the hydraulic habitat across the whole flow regime;
- the spatial nature of the outputs;
- the ability to produce results in a data-poor situation;
- the ability to change model topography to optimise or minimise the impact of designs.

Disadvantages include the costs of survey data and the associated scale of the modelling, and the limitations associated with knowledge of the behaviour of many aquatic species.

E.2

Investigating river wetted habitat sensitivity to flow change

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River discharge and ecological health are indirectly related, with individual species and/or communities responding directly to physical variables, which are themselves controlled by discharge (e.g. flow velocity, wetted habitat, depth). Discharge data are generally easier to collect and more widely available so that flow is commonly used as a master variable by UK environment agencies to assess ecological status or, for heavily modified water bodies, ecological potential. To ensure that using discharge provides robust evidence for ecological classification, it is necessary to understand better the relationship between flow and the physical variables which influence river ecology directly.

This study aimed to improve the understanding of the relationship between river wetted habitat and discharge in order to support ecological status and potential assessment in rivers impacted by abstraction/flow regulation. This was achieved by using existing UK river hydraulic and flow data to evaluate the distribution of habitat–discharge sensitivity zones, and their associated thresholds, against discharge, and to investigate if wetted habitat sensitivity to discharge can be related to catchment/river reach types.

Hydraulic data were sourced from UK environment agencies, yielding a UK-wide geographical coverage through a theoretical maximum of *c.* 7,000 sites; after thorough quality-control, 1057 sites were retained. Wetted perimeter (WP) was used to represent river wetted habitat in this study. Models of WP as a function of discharge were fitted, then three sensitivity zones (high/medium/low) and corresponding flow thresholds were identified mathematically.

Flow thresholds (expressed as exceedance flows) and sensitivity slopes were derived for each zone. Key catchment characteristics, capturing size, wetness, elevation, and permeability, were derived at those sites. For each sensitivity threshold, the analysis assessed the number of sites *v.* exceedance flows (distribution statistics, histograms, and cumulative distribution plots were generated). Sensitivity classes were statistically tested for potential relationships with catchment/river types, based on key catchment characteristics (all sites), and on hydro-morphological types (Scottish sites only). Sites were checked to ensure they were reasonably representative of UK rivers by using four catchment descriptors.

Sensitivity thresholds. The analysis of the number of sites *vs* exceedance flows showed that for *c.* two thirds of sites, WP is highly sensitive to flow change at Q95 or below, suggesting generic environmental flow values can mask variations in hydraulic sensitivity; there is no site featuring low WP sensitivity below Q95.

Typology pattern. Statistically significant patterns between sensitivity thresholds/ slopes and river types based on key catchment descriptors (area, altitude, permeability) were found. The wetted habitat at sites associated with catchments having smaller area, lower altitude, and/or lower permeability tend to be more sensitive to discharge at higher flows than for other types of site. Regarding sensitivity slopes, the still significant but much weaker pattern is a contrast between types (lower altitude, smaller size, higher permeability) tending to feature milder high sensitivity slopes and steeper medium and low sensitivity slopes (i.e. mild bend in wetted perimeter curve) *v.* types (medium altitude, larger size, lower permeability) featuring steeper high sensitivity and milder medium and low sensitivity slopes (i.e. sharp bend in wetted perimeter curve).

E.3

Identifying changing erosion processes: sources and sediment transport dynamics in Northern Tanzania using ground surveys and sediment tracing

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Soil erosion and associated land degradation is a widespread 'wicked problem' undermining the resilience of rural communities in Tanzania. On and off-site consequences of soil erosion have severe impacts on food, livelihood and water security as well as curtailing mobility between communities, resources and markets in fragmented landscapes. Results in Northern Tanzania demonstrate increased landscape vulnerability to soil erosion through loss of vegetation cover following drought, increased grazing pressure and forest clearance. Damage to the soil surface leads to extensive sheet wash erosion and increased run-off, which initiates rill and gully formation. As flow lines develop, the network becomes ever more connected, leading to rapid transfer of topsoil to downstream ecosystems through incised drainage networks where siltation threatens a wide range of aquatic ecosystem services.

Here we note that 'unseen' sheet erosion may be equally if not more important in terms of land degradation given (1) its key contribution to incision and gully formation through infiltration excess overland flow convergence, and (2) loss of topsoil horizons which contain most soil organic matter, nutrients and the seedbank. Deposited sediment in downstream reservoirs and floodplains evidence this narrative of changing erosion dynamics in the past thirty years. Results indicate a general increase in erosion, initiated by a phase of sheet wash erosion followed by gully incision in the late 1990s and creating the present-day landscape. The geochemical record of the past 10 years underpins observations of a heavily incised and well-connected drainage network fed and enhanced by infiltration excess overland flow which is efficiently conveyed, with eroded sediment, to downstream ecosystems.

E.4

Understanding fine sediment dynamics and its controls in a minimally impacted chalk stream

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Although fine sediment plays an important role in all river systems, chalk rivers have particularly low levels and are sensitive to elevated inputs. Fine sediment encompasses both organic and inorganic particles from allochthonous and autochthonous sources. Whether suspended in flow or deposited on the river bed fine sediments are important in maintaining instream habitats and ecology. However, many environmental issues are manifestations of too much, too little, or poor quality sediments. Although sediments are known to play a major role in environmental quality the lack of data limits our understanding and ability to inform management strategies. More specifically, there is a lack of data on deposited fines on river beds and multi-year high resolution (sub-daily) suspended sediment data. This is of particular significance in the UK given the large spatial and temporal variations in key driving forces (including rainfall, river flows, geology, soils, topography, river morphology and land use-management). Here we present multi-year (2008–2014) high resolution records of suspended sediment concentration and flux, and river bed fine sediment accumulation, from the River Lambourn to quantify their magnitudes and variability; enabling a better understand of their controlling factors. The seasonal distribution of rainfall was found to be a major control on sediment transport.

E.5

Adapting bathymetric sonar for sediment characterisation in shallow rivers

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Lowland rivers have been subject to increases in fine sediment flux globally due to direct and indirect human activity. Activities such as deforestation, agriculture, and mining have increased soil erosion that contributes to increased sediment loads, and alterations to channel and floodplain form (e.g. sectioning, widening, levees) are promoting deposition of fine sediment on and into the river bed. Elevated fine sediment loads can negatively impact aquatic ecosystems, deteriorate water quality, increase flood hazard, and shorten the lifespan of engineering infrastructure. Research on fine sediment transport dynamics in rivers has focused on storage in small wade-able streams or suspended sediment flux in large rivers, and much less is known about the mixed fine sediment beds found in the many medium-sized shallow lowland and tidal rivers in the UK and elsewhere. T

he aim of this project is to adapt current bathymetric surveying technology to improve the characterisation of mixed sediment beds in shallow water environments with high degrees of spatial variability in sediment properties (i.e. grain size and bulk density). The study is investigating whether the use of multiple sonar frequencies simultaneously and new backscatter signal processing techniques can differentiate changes in sediment properties across the channel and with depth into the surficial sediment. A commercial Phase Differencing Bathymetric Sonar (PDBS) system was modified to run using multiple frequencies (117, 234 & 468 kHz), and sediment classification was conducted using segmentation algorithms to discriminate between areas of differing sediment properties using metrics such as backscatter amplitude.

Preliminary testing has shown a difference in amplitude between different sediment types, and additional research will be presented that compares the acoustic based classification to sediment characteristics measured from sediment cores. The new survey methodology will be useful for research and management applications to map spatial-temporal variations in fine sediment storage, calculate sediment loads, investigate geomorphological form process relationships for ripple and dune formation and evolution, and monitor changes in channel capacity for flood risk modelling.

E.6

Dispersal of augmented gravel, to increase a salmonid dispersal of augmented gravel in a boulder-bed river draining Dartmoor

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Gravel augmentation is a frequent method in impounded rivers to reinstate spawning gravels previously lost due to sediment trapping behind the dam. Multiple gravel augmentations, both in time (annually since 2015) and space (100 to 4 km below the dam), have been added to a boulder-bed reach of the River Avon in Devon, England, downstream of the 33-m high Avon dam. However, the dynamics and benefits of gravel dispersal through a hydraulically-complex boulder bed channels is far from certain.

Monitoring using seismic impact plates, RFID-tagged particles and winter/summer fluvial audits is aimed at establishing particle mobility rates, dispersal distances and depositional settings to assist in determining the appropriateness of the restoration approach and appropriate volumes, frequencies and locations for future augmentation. Over 500 'tagged' particles have been introduced into the river over the last three years and tracked within two 500-metre reaches. Analyses indicate that augmented particles have been transported downstream with a number of 'tagged' particles found in excess of 400 metres below augmentation locations. Impact plates downstream of the lower most augmentation site have received over 300,000 impacts. In addition, winter/summer fluvial audits undertaken since 2016 over a 5 km reach downstream of the dam. With regard to the fluvial audits, the March 2018 survey identified 700 individual gravel accumulations over a distance of approximately 4 kilometres with each gravel patch being coded according to size and depositional setting. The augmented gravels are creating a variety of gravel habitats, predominantly at channel margins, in the lee of boulders and in lower stream power reaches. The biological significance of the accumulations has yet to be fully established.

F.1

Detecting coherent changes in flood risk in the Great Britain

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Flooding is a natural hazard which has affected the UK throughout history, with significant costs for both the development and maintenance of flood protection schemes and for the recovery of the areas affected by flooding. The recent large repeated floods in Northern England and other parts of the country raise the question of whether the risk of flooding is changing, possibly as a result of climate change, so that different strategies would be needed for the effective management of flood risk. To assess whether any change in flood risk can be identified, one would typically investigate the presence of some changing patterns in peak flow records for each station across the country. Nevertheless, the coherent detection of any clear pattern in the data is hindered by the limited sample size of the peak flow records, which typically cover about 45 years. We investigate the use of multi-level hierarchical models to better use the information available at all stations in a unique model which can detect the presence of any sizeable change in the peak flow behaviour at a larger scale. Further, we also investigate the possibility of attributing any detected change to naturally varying climatological variables.

F.2

Flood flows in North-west England – are peak flows increasing?

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Many flow gauging stations in Cumbria and northern Lancashire show clear apparent trends of increasing peak flow over the period of gauged record. The presentation will summarise these apparent trends and start to address some of the questions. How strong is the evidence? Do these apparent changes reflect changes in data processing and quality? Are these changes real long-term trends or just a short-term cluster? Do historical records help? Can apparent trends be accounted for in practical flood estimation and applied to the design of flood alleviation schemes? Are similar trends likely to be seen elsewhere in the UK?

F.3

Flood seasonality and implications for UK rainfall-runoff modelling

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Flood seasonality tends to be a less studied aspect of flood risk management and yet it is particularly important for a number of theoretical and practical reasons. As this talk will outline, it has importance in the application of rainfall-runoff methods for design flood estimation and understanding future flood risk.

Using data from 520 gauging stations in Britain and a Met Office gridded rainfall dataset, the seasonality of storm rainfall and flood runoff is compared and mapped. Differences of over 50% were found between seasonal annual maximum daily rainfall and flood occurrence for dry catchments mainly in southeast England. The differences diminish with increasing catchment wetness, increase with rainfalls shorter than a daily duration and are shown to depend primarily on catchment wetness, as illustrated by variations in seasonal soil moisture deficit and mean annual rainfall. The results have implications for rainfall runoff methods of flood risk estimation in the UK where estimation is based on a DDF (depth duration frequency) of rainfall highly biased to summer.

The discordance between seasonal rainfall and seasonal flooding is of theoretical relevance and practical importance for flood risk estimation using FSR/FEH rainfall runoff methods as the methods are based on AMAX rainfall statistics that are heavily biased towards summer. With respect to climate change, an increase in summer storm rainfall may not lead to an increase in fluvial flooding unless there is an increase in the probability of concurrent catchment wetness.

F.4

Estimation of design floods in a permeable, urban catchment using continuous simulation techniques

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Flood estimation in the UK has been standardised using the Flood Estimation Handbook (FEH) for two principle methods namely, the FEH statistical approach and Revitalised Flood Hydrograph (ReFH). These methods often struggle to predict floods in ungauged and unusual catchments such as combinations of highly urbanised, permeable and those affected by reservoirs. While there are many alternative approaches, one approach that has been used in a limited way until now is fully-distributed continuous simulation for such complex catchments. This approach permits the generation of a flow series at any point in the catchment for subsequent flood frequency analysis. Data requirements for such techniques can often be onerous to apply in a practical way for most studies. Therefore, a more practical continuous simulation approach with readily-available data is required.

As part of the investigation into flooding for Stevenage, continuous simulation techniques have been investigated for design flood estimation in permeable urban areas heavily influenced by flood storage reservoirs. The Stevenage Brook catchment has one gauge located downstream of the flood storage areas and areas vulnerable to flooding in the town. The rapid urbanisation since the installation of the gauge and changing control structures in the flood storage areas on top of the permeable soils leads to very different flood estimates from standard FEH approach to the observed record.

The focus of the investigation has been on the use of TETIS, a fully-distributed continuous simulation hydrological model, to improve flood frequency estimates upstream of the flood storage reservoirs to extend the gauged record for the past 100 years. This makes best use of observed rainfall and synthetic rainfall techniques to extend and consider the full range of potential flood events.

The calibrated model has then been utilised to investigate the impacts of future climatic and catchment changes. In particular, the variability of rainfall and soil moisture through the year on flood rarity and mechanisms compared with the standard FEH-river flow uplift approach.

F.5

'Deja vu and the path to failure'- Organisational fear of reputational harm impeding the learning cycle?

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There are clear indications that in the planning and implementation of an expensive new flood defence project the Environment Agency is at risk of repeating the mistakes of the past. The Jubilee River extension proposal — now known as The River Thames Scheme (Datchet to Teddington) — is currently in the development phase. Recently re-costed from £309m to £588m, the partnership funding shortfall is significant — the project is at risk and there is no 'Plan B'.

Factors influencing the increasing stage and reducing discharge over time of the River Thames are considered. In addition, sub-standard design and construction of the Jubilee River flood channel led directly to significant structural failures, limited discharge and an out-of-court settlement. The original Jubilee River channel failed to achieve the projected cost/benefit ratio and resulted in an assortment of unintended consequences. Experience has shown that professional assertions given in evidence at the 1992 Maidenhead, Windsor and Eton Flood Alleviation Scheme Planning Inquiry have not been achieved and furthermore that the Inspector's concerns about hydraulic model limitations went unheeded. An ever-changing hierarchy, defective strategy, inadequate scrutiny and insufficient knowledge, combined with a lack of honesty/openness and a reluctance to accept responsibility for mistakes due to consequential reputational harm, leads directly to an inability to learn and thus improve future performance. Are we at risk of history repeating itself?

The Thames-side towns of Windsor, Eton and Maidenhead flooded often simply because they were located on flood plain. In the mid 1980s the Maidenhead, Windsor and Eton Flood Alleviation Scheme (MWEFAS) was conceived. Without going into detail, the National Rivers Authority (having considered many options) submitted a plan for a parallel channel approximately 50m wide x 12km long that took flood water out of the Thames up-stream of Maidenhead and returned it into the Thames down-stream of Windsor. This proposal was properly considered at a Planning Inquiry commencing in October 1992. Overleaf is the expert view of the Assessor: P Ackers, MSc(Eng), FCGI, FICE, MIWEM, MASCE — on the hydraulic models used to justify the scheme.

Some three years elapsed between the 1992 Inquiry and Ministerial Approval in 1995 and it appears that Mr Ackers concerns about hydraulic model limitations went unheeded or forgotten by the scheme designers and the Environment Agency

Extract from 1992 Maidenhead, Windsor and Eton Flood Alleviation Scheme Public Inquiry - Report to Minister.

15. Further aspects of hydraulic performance

15.1. It would be very embarrassing to all concerned if the intended discharge capacity of the FRC was not achieved. Thus the hydraulic computations are particularly important, and in this context the sensitivity of the channel to the roughness coefficients used and the method of dealing with two-stage channels implicit in the modelling are dominant issues. This is the largest fluvial flood alleviation scheme ever to be carried out in the Thames region, and any deficiency in capacity would bring wide-spread – and justified – criticism. It would be the largest man-made river to be created in the UK with full regard to the latest policies regarding environmental enhancements. The question of the flow capacity likely to be obtained is not an issue that can be clouded over in the hope that design tolerances could later explain away any deficiency. It is my firm view that there is no room for retaining optimistic assumptions in the hydraulic design: in view of the novelty and scale of environmental enhancements proposed, some conservatism, some consideration of tolerances on assumptions is necessary.

who were now in charge of the project. The project commenced in about 1996 and was inaugurated in mid-2002. With the arrival of the January 2003 flood event Maidenhead, Windsor and Eton were protected by the new channel but the undefended villages downstream were inundated for the first time since 1947. Manual operation of the new channel control flow structure at only 2/3rds capacity allowed flood water to bypass the attenuating characteristics of the natural upstream flood plains. Thus flood flows arrived downstream earlier, rose more quickly and finished at a higher level. Furthermore the new channel suffered significant structural damage during the 2003 flood event. In particular the Taplow Flow Control Structure lacked a stilling basin and consequently suffered severe erosion. Marsh Lane Structure embankments suffered severe erosion, Manor Farm Weir was curved downstream in the middle, Slough Weir downstream face protection was swept away and the Myrke Embankment in Datchet almost collapsed. Repair and rebuild costs totalling millions of pounds were offset by an out-of-court settlement of £2.75m received from the designers for sub-standard design and construction.

The recommendations from Clive Onion's 2004 *Mechanisms of Flooding Report* have not been adopted. These referred to Main River dredging and also arrangements for the disposal of dredged materials. The 2007 Summer Floods could be categorised as a 'near miss event' in the Windsor area and were far worse elsewhere. This incident preceded firstly the 'Pitt Review' and ultimately to the Flood and Water Management Act 2010 which created the 'lead local flood authorities' (LLFA) and clarified responsibility for different types of flooding. The FWMA 2010 (s19) introduced a requirement for the LLFAs to investigate and publish a report on flood events within its area. I do think we need a Royal Commission on Land Drainage and we would also benefit from legislation requiring Parish and Town Councils to report regularly on the state of their land drainage infrastructure.

I would like to acknowledge the contribution of the late Sq. Ldr. Mike Reade (BHS member - of Munich, Germany) in particular with reference to River Thames blocked flood arches, rising bed levels and the Royal Commission on Land Drainage.

F.6

A New Flood Hydrology Road Map

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The Environment Agency is working with others to outline a future vision for flood hydrology and a plan to deliver that vision. The project will cover all inland flood risk sources: rivers and lakes, surface water, groundwater and reservoirs and we are involving around 40 different organisations across the UK.

We want hydrology users and experts to work together using their knowledge to plan the short-term and long-term future of flood hydrology. We want to change mind-sets to alter the way we approach hydrology so it will be fit for flood risk management now and in future.

It is time to act because:

- We need to reflect that risk changes over time;

- We have to understand the spatial nature of flooding and the effect of interventions across catchments;

- The National Flood Resilience Review calls for an ambitious, long-term, joined-up approach to hydrology and meteorology for flood events;

- We are seeing disparate and competing hydrology research proposals in the Defra/EA Joint Research Programme on floods.

This roadmap will allow us to bring these needs together and prioritise them properly.

This presentation will summarise progress to date and invite discussion.

G.1

13 Mixture Gumbel models for extreme series including infrequent phenomena

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A Gumbel mixture distribution is proposed, explicitly accounting for annual maximum series including events originating from two different underlying mechanisms producing extreme events; one occurring annually and one infrequently occurring phenomena. A new Monte Carlo simulation procedure is presented based on theoretical developments, ensuring that the simulated mixture annual maximum series contain the correct mixture of the two types of events. The Monte Carlo procedure is employed to assess the consequence of fitting traditional single population distributions (Gumbel and GEV) to annual maximum series originating as the result of two distinctly different populations, each described by a Gumbel distribution. The results show that when the two underlying populations are very different, the use of a mixture model is preferred to a single population model. Finally, the usefulness of the Gumbel model is tested on annual maximum 24-hour extreme rainfall data from a network of 64 South Korean rain gauges. The data were split into events generated by typhoon and monsoon rainfall, respectively. The results show that the use of a mixture model provide a more accurate description of the observed data than the Gumbel distribution, but finds little difference between the mixture and the GEV model. The theoretical and practical results presented in this study highlight the need for more robust methods for distinguishing between the underlying populations before mixture models can be recommended for more operational use.

G.2

Big data processing in hydrology

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At the present time there is a huge database in hydrometeorology: about 100 years of temperature, precipitation and river runoff records for many weather and hydrometric stations. The data processing heterogeneity in atmospheric science and hydrology poses a major challenge in hydrometeorological studies.

The central concept of hydrology is based on the hydrological cycle. The driving force of the water cycle in general is the solar energy from the Sun, which provides the energy needed for evaporation. Increase of solar radiation leads to accelerated atmospheric circulation, glacier melting, precipitation- river runoff increase and finally to global sea-level rising.

This paper presents an integrated system for the large data processing for uniformity of calculations in meteorology and hydrology on the basis of solar cycles. The solar cycle value can be conceived as an attractor in the time series of measured meteorological data. This calculated attractor is a set of numerical values toward a hydrometeorological system tends to evolve.

We compared averaged solar indices with an average for the same cycle air temperature, precipitation and river discharge for many weather stations and found close relationships. This inverse statistical model can explain the contribution of solar radiation in many terrestrial processes, with a correlation coefficient - 0.8.

In this study we also present Big Data processing using examples of: global sea level, global air temperature, as well as many weather stations, precipitation patterns and river discharges.

The technique of meteorological data consolidation on basis of solar cycle attractors can be also used for predicting trends in air temperature, river discharge and precipitation.

G.3

Integration of hillslope hydrology and hydraulics for improved flood and sediment modelling

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NFM has recently invigorated the hydrological community into re-deploying its process understanding of hydrology and hydraulics to try to quantify the impacts of many distributed, 'nature-based' measures on the whole-catchment response. Advances in spatial data analysis, direct rainfall modelling and efficient hillslope hydrological modelling mean that whole catchment modelling including uncertainty is possible, although perhaps the community has not yet rounded on the best overall framework that encompasses all the desired functionality within a parsimonious framework.

To model the effects of tree-planting we need to understand changes to wet canopy evaporation, surface roughness and infiltration capacity. To model inline storage created by 'leaky-barriers' or offline storage we need accurate channel hydraulics to understand the changes to attenuation and effects of performance failure. To model the complex behaviour of the whole network of NFM measures, and the possibility of flood peak synchronisation effects, we need efficient, realistic routing models, linked to key flow pathways that take into account the main physical processes in soils and the antecedent moisture conditions for a range of different rainfall events. All of these processes need to be modelled efficiently so that Monte-Carlo simulations can be undertaken to help quantify uncertainties in our answers.

By combining Dynamic-Topmodel with JFLOW we demonstrate a possible framework that can account for all of this in a parsimonious way, applied to an upland Cumbrian catchment, where the efficient hillslope process modelling feeds the different runoff fractions into the fast GPU-based 2d shallow water equation (SWE) to generate flood inundation. Modelled depths and velocities have then been used to identify areas of sediment deposition and erosion. This is undertaken in an uncertainty framework, using acceptable ranges of parameters based on our work in the new NERC Q-NFM project, to generate possibilistic outputs for all these variables. For instance, we can show maps of likelihood of exceedance of different depths of sediment deposition or erosion.

Key advantages include efficient, distributed representation of hillslope processes (and changes to these as a result of adding distributed NFM measures). For example, we can model both overland flow (including effects of 'run-on') and subsurface flow

that includes realistic representations of surface-subsurface interactions further downstream, which is usually missing from simplified direct rainfall and losses approaches. The use of the fast 2d SWE hydraulic model allows the impacts of in-channel modifications such as 'leaky barriers' and floodplain re-connection (and failures of these features) to be more adequately explored at larger scales, including their positive and negative effects on sediment transport, in ways that take into account the large uncertainties inherent in the modelling process (including the parameters representing change within the models).

G.4

Improved basin representation using fully distributed hydrological modelling: application in data scarce catchments in East Anglia

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The estimation of flows in ungauged basins has received significant attention in the last decade among hydrologists in order to improve decision making for the management of water resources when there is little or no hydrometric information to enable traditional calibration of lumped rainfall-runoff models. Distributed hydrological models are often used to estimate flows at ungauged locations in poorly monitored areas as they provide a reliable representation of a catchment based on a local calibration and regionalisation using spatial datasets of physical properties. This spatial consistency also acts as a powerful scientific tool to test the validity of input data or the model structure.

This presentation will look at the application of a distributed model (TETIS) as a validation tool in two heavily modified catchments in East Anglia; the Ely Ouse and the Witham. Whilst the UK is a well-monitored country with one of the longest and densest meteorological and hydrometric records worldwide, both of these catchments lack extensive downstream gauging station records. They are also considered locally important for meeting the current and future water demand of the East of England. Catchments like these, with incomplete gauging records, or none at all, are typical of many catchments worldwide and present high uncertainty when determining water resource availability. The approach has shown its capability of considering differences in climate and physical properties when transposing the calibration made at an upstream gauging station to other gauged and ungauged points in the catchment.

One of the key benefits of this approach is in the identification of potential deficiencies in and reliability of the input data. This presentation demonstrates how the modelling facilitated the identification of suspect gauging station records, uncertainty in the Potential Evapotranspiration (PET) data used in the analysis and the quantification of significant uncontrolled abstractions in the lower catchments. The distributed modelling approach has shown clear advantages over traditionally adopted lumped approaches, where potential issues like these may be compensated by calibration of the input parameters, which can subsequently impact on the validity of long-term simulations. This approach therefore provides a robust method for assessing water resource availability not just in the UK but in any location globally where data scarcity or reliability is a significant issue.

G.5

Use of mathematical model as a tool for urban drainage study: Improvement in surface water drainage system of Comilla City Corporation in Bangladesh (Case Study)

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Due to urbanization and increase in population, urban regions of Bangladesh require immediate improvement in drainage systems. Realizing the importance of this issue, the Government of Bangladesh (GOB) has emphasized this matter and has already taken the initiative to develop or improve the drainage system of the Township/ Municipal areas/City Corporations in Bangladesh. In this regard, under the Feasibility Study and Master Plan Review (FSMP) project, the Comilla City Corporation has been identified for a drainage improvement study. At present, the urban infrastructures of the Comilla City corporation — especially drainage, sewage, solid waste and piped water supply facilities — are not sufficiently developed, which cause flooding and water logging in many locations of the city area every year. Considering the inadequate drainage system of the city area and the necessity for the improvement of drainage systems, the objective is set up a study of the improvement of existing drainage situations leading to reductions in yearly flooding and water logging of the city area. It is worthy mentioning that nowadays the computer-based mathematical models are being increasingly used by engineers in Bangladesh for water resources system planning, design, management, and as well as the study of the impact of various existing and proposed projects for improving urban drainage systems.

The bed levels of drainage systems are increasing due to siltation: as a result water levels increase significantly in the drainage systems, specially during high flow. A one-dimensional mathematical model is applied to simulate the water level due to the change of bed levels (siltation) in the drainage system of Comilla City Corporation in Bangladesh. The results show the potential of computer-based simulation models for evaluating the existing condition of the drainage system. Such models are very versatile and permit the rapid simulation of wide range of conditions. Given the data describing the topography and boundary conditions, the model will simulate the performance of the system. The system may then be altered according to certain design proposals and return to simulate the effect. So, a mathematical model constitutes a useful tool for the development, control and utilization of water resources.

G.6

Estimating storm inflow volumes for a sequence of multiple peaks of the quickflow hydrograph

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Presented with a quickflow hydrograph containing a sequence of multiple peaks, the traditional approach has been to divide up the complete hydrograph into a series of separate storm events by extending the recession curves occurring prior to each rising portion of the hydrograph. One consequence is that problems occur in estimating the runoff volume for each individual storm event precisely, because this runoff is enclosed between the extended pre-event and post-event recession curves, both of which possess very long slowly declining tails as the time ordinate increases.

Here a different approach is presented which assumes the quickflow hydrograph can be represented by the outflow from a conceptual non-linear reservoir; this means that all the recession curves from different storm events on a particular catchment form various portions of a single master quickflow recession curve. Note that this technique is not directly applicable to observed hydrographs, as the slowflow component has first to be subtracted to give the relevant quickflow hydrograph. A formula is devised which estimates the volume of the inflow into the conceptual reservoir that will simulate the outflow corresponding to a single quickflow hydrograph. This formula provides a theoretically correct estimate of this storm inflow volume. A practical example is described for one storm event occurring in September 1968 over the catchment of the River Enborne at Brimpton, located south of Newbury.

By casting the formula in a slightly different format, it can be shown to be also applicable to the case of the traditional approach mentioned above. In a sequence of multiple quickflow peaks, it can be used to estimate the inflow volume for each separate storm. The formula is found to be consistent because, if used to analyse the complete sequence of multiple peaks when considered as a single storm event, the resulting inflow volume is found to be exactly the same as the sum of the individual storm inflow volumes.

Assumption: quickflow Q is represented as outflow from a conceptual non-linear reservoir with storage-outflow relationship

$$S = f(Q)$$

The volume of quickflow runoff occurring during the central peak storm, highlighted in Figure 1 overleaf, can be shown to be equivalent to the inflow volume given by the formulae below. Times t_3 and t_4 are, respectively, the end point of the pre-event

recession, and the start point of the post-event recession. Similarly, S_3 and S_4 , are the storages occurring in the non-linear reservoir at these two times.

$$\begin{aligned} \text{Quickflow inflow volume is } & \int_{t_3}^{t_4} Q dt + [S_4 - S_3] \\ & = \int_{t_3}^{t_4} Q dt + [f(Q_4) - f(Q_3)] \end{aligned}$$

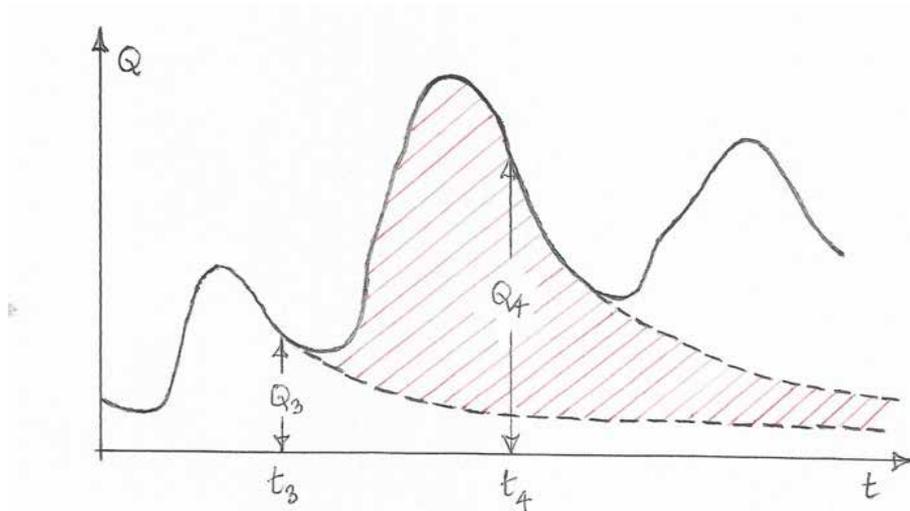


Figure 1 Quickflow runoff volume identified for central storm

H.1

A hydrological whodunnit: the role of hydrology in the court case following flooding of Cork in 2009

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In November 2009 University College Cork suffered millions of Euros of flood damage. The River Lee overflowed into a new computer building, an art gallery and student accommodation.

Upstream of Cork is a pair of hydroelectric dams which released water during the flood. The university's insurers sued ESB (Ireland's Electricity Supply Board), the owner of the dams. The resulting court case lasted ten months. Among the arguments flung back and forth between barristers were the role of the dams, the implications of human intervention in a river, the foreseeability of the flood and the purpose of the dam operating rules. The expert witnesses subjected to the glaring spotlight of cross-examination included dam operators, engineers, economists, meteorologists, emergency planners and – of course – hydrologists.

This presentation will explain the role of hydrology in the case and draw parallels with other litigation elsewhere in the world.



H.2

Improving data and tools for flood estimation in small catchments

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Many of the flood risk assessments carried out in the UK are for small catchments, typically under 25 km² in area and often under 10 km². They are needed for the assessment of planning applications and drainage proposals and to provide inflows to river modelling studies. At an even smaller scale, estimates of greenfield runoff rates are often required for plots of land which form part of a catchment and may not contain a watercourse. Recent research funded by the Environment Agency through the Joint Flood and Coastal Risk Management Research and Development Programme (FCERM) is about to report on the project and update the guidance available to hydrological practitioners. The presentation outlines the technical findings of the research and describes how the evidence has driven the recommendations and the implications for current practice.

A new set of peak flow data for small catchments was put together and this was used to review the applicability of the current Flood Estimation Handbook (FEH) methods to small catchment flood estimation. Unfortunately the availability of plot-scale data was very limited, but this did allow some consideration of greenfield runoff rates. A number of new methods was developed and tested but not all demonstrated enough of a reduction in uncertainty compared to existing methods to be worthy of recommendation. However, the study has refined the currently recommended method of estimating flood risk by pooling data from similar sites and has clarified best practice for obtaining design hydrographs in small catchments. Finally, a new free dataset of greenfield runoff rates and volumes for the pre-planning stage of new developments has been constructed and this will be rolled out through the FEH Web Service in the near future.

H.3

Revising the BFIHOST catchment descriptor to improve UK flood frequency estimates

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The estimate of base flow index (BFI) based on the 29-class Hydrology of Soil Types (HOST) classification is known as BFIHOST and provides a measure of catchment responsiveness. The BFIHOST descriptor is used with other variables to estimate the median annual maximum flood (QMED) at ungauged sites in the UK standard Flood Estimation Handbook (FEH) statistical method. BFIHOST is also an explanatory variable in the parameter estimation equations in ReFH2, the FEH design hydrograph package.

Currently BFIHOST is estimated using a restricted linear regression model that explains the variability in BFI measured across gauged catchments in Great Britain. Although the model was developed primarily as a classification tool during the HOST project, it has become a fundamental part of the standard flood estimation techniques which are routinely used throughout the UK.

A number of issues with the BFIHOST model have been identified, for example the value of BFI calculated through base flow separation applied to gauged data tends to be underestimated in clay-dominated catchments. The pragmatic bounding of BFI coefficients for permeable soils overlying aquifer outcrops is also problematic when considering plot- or small catchment-scale estimation.

The presentation describes a short analysis which has revisited the relationship between BFI estimated from small gauged catchments and the dominant HOST classes to update the BFIHOST model and produce a revised BFIHOST grid. In due course, this will lead to a complete revision of the methods that are used to derive BFIHOST catchment descriptor values for Great Britain, involving a re-examination of the presence of water bodies and dominant HOST classes to better identify an appropriate method of estimation of BFI at ungauged sites using HOST-class data.

H.4

Improving satellite-based and ground radar-based estimations of sub-daily rainfall in the Malaysia flood prediction context

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Ground weather radar-based and satellite-based rainfall (RBR and SBR) estimates are advantageous for environmental modelling due to their high temporal resolution and large spatial coverage over land. The datasets are especially valuable in areas with a limited number of rain gauges. However, applications in hydrology, especially in the South East Asia region, have been scarce due to various scientific and technical constraints. RBR and SBR rainfall extraction is highly technical and the datasets have multiple degrees of uncertainty due to sensor, sampling and processing errors that need to be assessed and reduced. In this study, the Integrated Multi-satellite Retrievals for Global Precipitation Measurement Global Precipitation Measurement (IMERG late run, half hourly 0.1° gridded) product was evaluated against rain gauges in a flood-prone northern state of Malaysia within a three-year period between 2014 and 2016 at an hourly timescale. In addition, RBR estimates (10 min, ~800 m gridded) from a ground-based S-band radar were also assessed. The error performance statistics such as the Root Mean Squared Error (RMSE), the correlation coefficient (CC), and the Percent Bias (PBIAS) as well as detection metrics such as the Probability of Detection (POD) and False Alarm Rate (FAR) were analyzed. Error reduction was conducted using multiple methods such as mean bias reduction and residual inverse distance weighting, as well as recalibration of the rainfall-reflectivity relationship of the RBR. Results show mean positive and negative biases by the IMERG and radar respectively when compared to the rain gauge estimates during periods of extreme rainfall. Furthermore, a stronger correlation and higher detection rate is found with IMERG compared to the radar. Error performance statistics were improved with the corrected rainfall estimation. These results indicate the potential of corrected RBR and SBR for driving data in water resources predictive modelling at a catchment scale.

H.5

Estimating effectiveness of Natural Flood Management – keeping it simple

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Expectations of natural flood management are high, whilst budgets available to deliver schemes are often very small. As a result delivery organisations such as Catchment Partnerships often progress schemes rapidly to construction, with little time available for design or quantifying the benefits a scheme can yield. Comprehensive hydrological and hydraulic modelling of schemes is often not possible — either because of prohibitive expensive (a full-blown modelling study can sometimes cost as much as delivering a small NFM scheme on the ground) or access to skills. But is there a 'happy medium', in which a simple hydrological assessment can be rapidly undertaken to inform key decisions about design and better understand the benefits a scheme might yield?

This paper will set out a simple workflow for developing Natural Flood Management schemes. It will then go on to explore how simple hydrological calculations might be used to assess the effectiveness of natural flood management measures in reducing flood risk. Using a small catchment in Essex upstream of a village vulnerable to frequent flooding as a case study, it compares the outputs of (a) a full hydrological-hydraulic model setup with (b) simple analysis of key hydrological indicators (e.g. comparison of bankfull and peak flow and hydrograph and design storage volumes) to explore how each approach informs the design and assessment of benefits. The key is whether the simpler hydrology based approach provides adequate information around which to understand the likely effectiveness and benefits of applying natural flood management.

The paper argues that simple hydrological assessment may indeed be an appropriate technology for informing the design and benefits assessment of natural flood management schemes. It can be a cost-effective alternative to full modelling, enabling delivery organisations operating on limited budgets to make (a) more informed decisions about design parameters fundamental to the effective functioning of schemes and (b) a clearer case to support applications for funding.

H.6

Landscape-scale change and hydrological response: Devils in the detail

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The ongoing quest for catchment-based solutions to flood risk and the consequences of climate change involves a spectrum of modelling approaches, while field observation can often be limited by resourcing and logistical constraints. Questions of scale underlie both the modelling and empirical investigations: the scales at which land management effects may be implemented, and the transfer of modelled behaviours between plot and small-scale catchments to those catchments where communities are most at risk; often these are larger-scale catchments.

We report from two studies in Scotland where a heavy commitment has been made to detailed hydrometric monitoring, with a view to addressing scaling issues and elucidating the nature of hydrological effects arising from planned and unplanned catchment changes.

In the Eddleston catchment (Scottish Borders), flow restrictors in a 2 km² catchment have delayed runoff peaks by 1–2 hours since their installation, with empirical observations confirming model results. However, after a period of two years, this effect has recently faltered, for reasons yet to be established, with runoff response times now in line with pre-intervention conditions. Also on the Eddleston Water itself (70 km² catchment), peak travel time has quickened by ~1 hour following a rare (~1% Annual Exceedance Probability) flood in 2012. Natural flood management measures in the catchment commenced ~2013, including the planting of >300,000 trees, the re-meandering of 2.8 km of main stem river channel and the construction of 28 ponds.

Overall, the response of the catchment to date has been mixed: lag time remains similar to the baseline conditions, while travel time for the majority of events above a low threshold (4 exceedances per year) is shorter than in the 2011–12 baseline period. However, no major flood has occurred since the deployment of measures has begun, and indeed it may take many years for the tree planting to achieve the desired effect. Meantime, it is clear that peak outflows from the Eddleston catchment typically arrive at the confluence with the River Tweed at the same time, in the flood-risk area of Peebles, such that delays to the Eddleston response remain desirable as a means of reducing urban flood risk.

Synchronisation is an important feature of the runoff response of the River Feshie (Cairngorm Mountains, 230 km²) also, given its interaction with flows from the confluent River Spey, the latter draining a larger catchment and attenuated due to low gradient and a main-stem loch. Forest regeneration and plans for rewilding of high altitude peatlands in the Feshie catchment offer potential for reductions in peak runoff rates. However, these raise the unwelcome prospect of a reduction in the temporal separation of confluent runoff peaks. Initial results of investigation of the Feshie runoff behaviour are presented, along with recommendations and questions for future landscape-scale management interventions.

I.1

Hydromorphological and ecological impacts of water injection dredging in the River Parrett, Somerset Levels, Somerset, UK

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The Somerset Levels ('The Levels' hereafter) are a low-lying and flood-prone agricultural landscape in South West England. The rivers, rhynes and ditches of The Levels are heavily managed for navigation and flood relief purposes and there is a legacy of dredging, typically excavation (using large mechanical digging / dredging apparatus), to help mitigate flood risk. Despite the widespread application of the technique internationally, knowledge of the short to medium-term effects of dredging in the wider ecosystem remains limited. In addition, the potential impacts of new dredging technologies, such as water injection dredging, have rarely been considered or quantified, nor have the effects of these operations on instream biota.

A programme of work therefore investigated the ecological (macroinvertebrate, diatom, fish) and hydromorphological (bed material grain size, bathymetry, water physicochemistry) effects of water injection dredging temporally and spatially within the River Parrett, Somerset. Ecological and hydromorphological sampling occurred at a control site (upstream of the injection site), within the managed area (injected) and downstream of the dredge site on multiple occasions before and after dredging. Additionally, during dredging, the sediment plume was surveyed via pelagic trawling and captured fish were inspected for mortality or signs of stress or ill health. With regard to the fish, all 236 individuals captured during the dredging operation were alive, showed no obvious signs of dredging-induced stress and were returned unharmed post-processing. The caudal fins of seven fish, representing a small proportion (8.26%) of the total catch, were either split or torn but injuries did not appear to influence swimming capabilities of fish. The injuries incurred by these fish were unlikely, but not impossible, a result of dredging, and typical in nature and extent to those observed in other, similar fisheries. No further signs of fish damage or ill health were observed. Post-dredging, fish abundances within the managed reach were significantly reduced, possibly due to fish avoidance of the dredging vessel. Studies such as these that utilise robust experimental designs are integral for understanding the factors that contribute to successful restoration and flood risk management and form a fundamental bridge between academic research to underpin practice.

I.2

A novel application of remote sensing for modelling impacts of tree shading on water quality

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Uncertainty in capturing the effects of riparian tree shade for assessment of algal growth rates and water temperature hinders the predictive capability of models applied to river basin management. Using photogrammetry-derived tree canopy data, we quantified hourly shade along the River Thames (UK) and used it to estimate the reduction in the amount of direct radiation reaching the water surface. In addition we tested the suitability of freely-available LIDAR data to map ground elevation. Following removal of buildings and objects other than trees from the LIDAR dataset, results revealed considerable differences between photogrammetry- and LIDAR-derived methods in variables including mean canopy height (10.5 m and 4.0 m respectively), percentage occupancy of riparian zones by trees (45% and 16% respectively) and mid-summer fractional penetration of direct radiation (65% and 76% respectively). The generated data for daily direct radiation for 2010 were used as input to a river network water quality model. Impacts of tree shading were assessed in terms of upper quartile levels, revealing substantial differences in indicators such as Biochemical Oxygen Demand (BOD) (1.58 – 2.19 mg L⁻¹ respectively) and water temperature (20.1 and 21.2 °C respectively) between 'shaded' and 'non-shaded' radiation inputs. Whilst the differences in canopy height and extent derived by the two methods are appreciable, they only make small differences to water quality in the Thames. However such differences may prove more critical in smaller rivers. We highlight the importance of accurate estimation of shading in water quality modelling and recommend use of high resolution remotely-sensed spatial data to characterise riparian canopies. Our paper illustrates how it is now possible to make better reach-scale estimates of shade and make aggregations of these for use at river basin scale. This will allow provision of more effective guidance for riparian management programmes than is currently possible. This is important to support adaptation to future warming and maintenance of water quality standards.

I.3

Zen and the art of lotic life cycle maintenance

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“What is good, Phædrus, and what is not good... need we ask anyone to tell us these things?”— *Robert M. Pirsig: Zen and the Art of Motorcycle Maintenance.*

When considering the setting of environmental flows in rivers, having an agreed concept between all interested parties of what constitutes good ecological quality is fundamental. For some parties, the attainment of ‘good’ can be defined by a set of biological, chemical and hydro-morphological metrics, each of which are taken as evidence of the correct functioning of the ‘working parts’ of an ecosystem. For others it may be the presence or absence of certain species with particular economic or conservation value. Some of these distinctions indicate the more prosaic drivers operating on the agents involved but it is proposed here that they may also be bedded in by the prevailing culture or philosophy of each organisation, much like the consideration of the classical and romantic viewpoints of Pirsig’s novel.

Looking at SEPA’s experiences of setting environmental flows in Scotland, this paper explores how the different viewpoints on what constitutes a ‘good’ end-state for a river impacted by water resource pressures influence views on the prioritisation of actions, the methods of data collection, the mitigation measures required to achieve good quality and cost/benefit analysis of deploying these measures. Existing guidance for SEPA highlights the importance of working collaboratively with the regulated businesses, conservation agencies and other third parties. In order to do this effectively, this paper proposes that it is important for each party to understand not only the more obvious legislative or economic drivers of each other’s viewpoint but also how these influence the underlying epistemologies of the actors involved. By doing this it should become easier to arrive at a common understanding of what constitutes ‘good’ environmental quality and how to get there.

I.4

A new approach to solve fundamental ecological data storage issues

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Ecological surveys are an extremely important tool used to assess the condition of terrestrial and aquatic ecological resources. However there are many and varied challenges when it comes to storing, managing and reporting on this type of data, not least of which is the inherent complexity and inhomogeneity of the data. It is difficult to provide a single consistent system to effectively rationalise these differing datasets.

A new system has been developed to solve these fundamental ecological data storage issues. Using the flexibility and functionality of a flexible metadata framework and GIS systems, the system provides a solid, generic framework for the storage of all kinds of ecological survey data.

Spatial data storage has been expanded to include the representation of points, lines and polygons through the use of the OGC standard. An extensible and flexible metadata system was introduced so that all levels of the locational hierarchy can be covered with the complete bandwidth of its individual attributes. This allows any manner of survey metadata to be stored at any level of the tree, based on customer defined 'Observation Types'. This allows any number of simple data fields to be created as well as more complex multiple records associated with these different types. Customised data entry forms can be built in accordance with the requirements of the specific survey, all without the need for software or database development. Observation attributes are a specialised feature of the new system that allows taxon-related biological data to be stored. A biological observation is a combination of a taxon, an attribute and a value. The taxonomic elements of the taxonomic tree are linked to parameter types, whilst observation attributes are linked to an observation type. In this way we can store any combination of data that can be specific to only a given type of data.

In order to demonstrate the practical suitability of the new approach to ecological data management, the presentation will focus on the implementation of the new system within Natural Resources Wales.

I.5

Moving beyond salmo-centric fishway science and management

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Migratory salmonids have traditionally dominated fish passage research, leading to a proliferation of fishways that do not work for native fishes in diverse ecological settings around the world. In many cases, salmonid invasions already pose a threat to the conservation of biodiversity and cultural fisheries highly valued by indigenous communities. The rapid development of hydropower in the Global South, paired with the construction of fishways designed on the basis of work conducted with strong-swimming, migratory species in Europe and the Pacific Northwest, severely compounds the problem. Most species do not undertake extensive movements between critical habitats and may lack the motivation to traverse highly energetic hydraulic environments, yet the movement of individuals and the genetic information they carry is nevertheless important for their preservation. Over the last three years, an international network has been forming around the need to develop new concepts in fish passage research and new hydraulic designs for fishways that work for a broad range of species. Our systematic evidence review found a severe lack of robust information on effective designs for the small-bodied fish that are characteristic of the Global South. Following this, we gathered a group of expert fishway designers to generate design criteria for native species. Most recently, we established a new framework for setting fishway targets to support population viability, rather than assuming that 100% of the population needs to pass.

J.1

Where's the evidence for that? Has hydrology embraced post-truth?

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A number of recent issues and experiences have raised the question of what constitutes the solid evidence on which hydrological understanding and practice should be based. The Oxford Dictionary's entry for post-truth contains the following usage example: "in this era of post-truth politics, it's easy to cherry-pick data and come to whatever conclusion you desire". Hydrologists must recognise the danger in cherry-picking data, and adopt robust approaches to ensure that conclusions are derived from a proper process to discover and assess all the available data.

Hydrology directly influences the lives of most people, and many people have their own view of how hydrological systems function and what actions and measures are appropriate in particular situations. Hydrologists must be clear in their communications with the public concerning the difference between facts and opinions regarding both hydrological theory and practice. We cannot allow 'alternative facts' to enter hydrology, and we need to ensure that the expertise of hydrologists is appreciated, and cannot be dismissed in the way Michael Gove did by saying that Britain "has had enough of experts". By presenting experiences and examples relating to the issue of evidence, how it is derived and presented, it is hoped to stimulate discussion within the hydrological community, and raise awareness of techniques adopted in other sciences to review and collate scientific data.

J.2

Sensitivity of river temperature to climate and other drivers of change

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The potential consequences of climate change for river environments makes the need to understand the mechanisms controlling river temperature patterns more crucial than ever. Water temperature is often referred to as the 'master water quality parameter' due to its critical importance for physical, chemical and biological processes in rivers and streams. To better manage water resources and land-use for ecosystem and societal benefit, it is essential to improve knowledge of drivers of change and processes across multiple scales. To address this critical gap, the talk presents research undertaken at different scales (from reach- to national-scale) that aims to understand the sensitivity of river water temperature to climate, land management and other controls. Together, this research provides robust scientific insights on the drivers of change and fundamental processes to underpin management decisions and strategies related to temperature of flowing waters. Looking to the future, the talk will consider the potential of novel monitoring and modelling technologies to advance river temperature research and practice.

J.3

A Big Hydro Vision for 2030

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What might be on the programme of the 2030 BHS National Symposium?

Looking backwards over an equivalent interval there have been many significant technical advances including Earth Observation of water-balance components, drones for hydrological surveillance in remote and/or hostile environments, partial opening of national river archives, data-mining and machine learning, planetary-scale runoff modelling, and even extra-terrestrial hydrology. Computing power increased 50-fold, hydroinformatics emerged as a sub-discipline, R and Python replaced FORTRAN as the hydrologist's programming languages of choice, whilst support for field hydrology waned.

By 2030 there could be another 40 mm of sea level rise, incrementally raising the threat of coastal and estuarine flooding during storm surges. Global population could be about 8.5 billion reducing *per capita* renewable water resources by ~10% if all else remains the same. Degradation and biodiversity loss continues to be most rapid in freshwater environments. And yet we might still be discussing how to attract more students to water-related, inter-disciplinary degree programmes!

In response to these multiple, interconnected challenges, this talk imagines the following themes for a 2030 BHS agenda:

- (1) Detecting climate-driven tipping points and peak water;
- (2) Model integration and interoperability;
- (3) Funding, planning and new standards for long-lived water infrastructure;
- (4) Hydro-meteorological hazard forecasts in your hand;
- (5) Decade of drought: (when) will it end;
- (6) Ground-truthing and historical hydrologies for data-sparse places.

Craft wines could figure prominently at the conference dinner – thanks to a run of hot/dry summers. The field excursion may be to a village-sized hydrocosm experiment.....