4th BHS International Conference

Hydrologists make the water go round

30th August to 1st September 2016

Cranfield University, Bedford, MK43 0AL, UK

Abstracts

1 Managing Flood Risk - lessons from 2015/16 (1)

Vincent Auditorium 30 August 2016 10:00 – 12:30

1.1 The December 2015 floods in northern England

Peter Spencer and David Lindsay (Environment Agency)

The rainfall and flood response in northern England ranged from the minor to the unprecedented. Flows in at least three rivers exceeded the previous highest in England. Some flood hydrographs were notable for their volume as well as their peaks. Particularly in the northwest, the December 2015 floods were also remarkable for the number of rivers which experienced their highest ever flow and the number of locations flooded. A number of flood defence schemes were overtopped, including some which had been built after the 2005 and 2009 floods. This presentation will summarise the December 2015 events in northern England and compare with some previous events. It will discuss the rainfall, catchment response, flow and flooding statistics, and will put some key statistics in context.

1.2 How many 100-year floods before hydrologists lose their credibility?

Duncan Faulkner (JBA Consulting) and Peter Spencer (Environment Agency)

In 2005, Carlisle suffered a flood far higher than anything previously recorded, with an estimated return period of nearly 200 years on the River Eden. In 2009, several rivers in Cumbria experienced yet more extreme events. December 2015 exceeded both the 2005 and 2009 floods in many locations in Cumbria. The probability of at least two 500-year floods occurring at the same place within a period of 7 years is one in ten thousand. Have parts of Cumbria simply been very unlucky in recent years, or does the occurrence of two or three exceptional floods indicate that they are not as exceptional as was thought? We examine what can be learnt from, and re-inforce the importance of, longer-term history. We present compelling evidence of increasing trends in flood magnitude for some Cumbrian rivers and explore techniques of flood frequency analysis that account for these trends and for temporal clustering of flood occurrences. We will consider several alternative approaches to flood estimation, some which could be adopted with investment in tools and guidance for practitioners. The Environment Agency's FEH Local project provides some useful steps in this direction.

1.3 What do you do after major floods?

Ian Perkins and Liam Gaffney (Environment Agency) Andrew Lowe (CH2M) and Kim Hearn (AECOM)

This presentation discusses hydrological and modelling aspects of the Environment Agency's response to the December 2015 events in northwest England. We discuss how we have applied the December 2015 events to flood mapping and flood forecasting models, and assessed updating needs. The presentation shows how hydrological and hydraulic modelling has been used to review and assess a number of planned and new flood alleviation schemes. The presentation will discuss examples in more detail.

1.4 Real time modelling of 2015/2016 winter floods in the UK

Juan Duan, Caroline McMullan, Tristan Lloyd, Stephanie Higgs and Shane Latchman (AIR worldwide ltd)

Obtaining reliable catastrophe loss information quickly as an actual event unfolds has become increasingly important for insures, reinsurers, and investors. This, coupled with the opportunities available for hedging against events in real time, as well as identifying key areas to send loss adjusters makes access to timely information regarding potential catastrophe loss exceedingly valuable. As a catastrophe modelling company, AIR Worldwide provides an online subscription service – ALERTTM (AIR Loss Estimates in Real Time) providing up-to-date information and loss estimates for major natural catastrophes worldwide. A series of heavy rainfall events hit the UK during the winter of 2015/2016 which led to flooding. To help the insurance industry understand the impact of the severe flood events, AIR's ALERTTM service provided similar stochastic events identified from the existing AIR Inland Flood Model for Great Britain that cause flooding similar to that from Storms Desmond, Eva, and Frank. AIR also created shapefiles containing flood inundation footprints based on actual observations (e.g. gauge data, social media) for storms Desmond, Eva, and Frank, as well as the combined flood footprint of these three storms. A list of potentially impacted postcodes was also provided. Here we discuss how the similar stochastic events and shapefiles have been developed and how they can be used by the insurance industry for decision making in the face of real time catastrophe events.

2 Managing Flood Risk - lessons from 2015/16 (2)

Vincent Auditorium 30 August 2016 14:00 – 15:30

2.1 Boxing Day Floods 2015: Their impact on the UK canal network, and lessons to learn from the affected communities – a holistic view

Mark Heath (Canal & River Trust)

The Canal & River Trust (the Trust) manage over 2,000 miles of historic waterways across England and Wales. In normal conditions, this network has a managed water level, designed to allow boat navigation, whilst being able to cope with storm events without causing damage. However, over the December 2015 period, Northern areas of the network were subjected to unprecedented flooding with record water levels achieved, leading to widespread damage to large parts of the canal infrastructure, and neighbouring communities. Whilst there are reports covering these unprecedented events and follow-up actions, this report switches focus to investigate and report on the 'non asset' based issues, with an emphasis towards the impact on the individual (both people and property), and the community as a whole. It investigates how the Trust were viewed and what actions or improvements could be made in the case of any similar events in the future. Although it is not intended to report or suggest changes in relation to asset management, it does analyse how the Trust could link-in and utilise existing community groups to reduce the impact, both cost wise and physically to the benefit of all parties, in the course of such events. By using this approach, the findings have a strong steer from the local communities involved, allowing an insight to the feelings, desires, and requirements of the affected areas, from the time of the event, through to the later stages of the recovery process. In addition to the local views from meetings and roadshows attended, the reports also pulls together thoughts and discussions from both the Calderdale Flood Commission, and subsequent later conferences, bringing together a national viewpoint, so although the principal focus remains on the Calder Valley, the findings can be used elsewhere for similar events.

2.2 Forecasting high impact flood events during the winter of 2015/16 in Scotland

Richard Maxey, Louise Parry, Michael Cranston (Scottish Environment Protection Agency), John Mitchell (Met Office)

The winter of 2015/16 saw the most severe flooding seen in Scotland since the advent of new systems for flood forecasting five years before. The Met Office-named storms Desmond and Frank, along with other heavy rainfall events in December and January, led to a succession of flood events in many parts of the country. Fifty river gauges recorded their highest ever level. The Scottish Flood Forecasting Service issued the first ever Flood Guidance Statements containing High (red) flood risk status for some areas. Scottish Environment Protection Agency (SEPA) issued the first severe flood warnings since taking responsibility for direct warnings in 2011. Over one thousand properties were flooded, many more were evacuated and there was substantial damage to infrastructure. The Scottish Flood Forecasting Service provides forecasts and flood risk information up to five days ahead in the daily Flood Guidance Statement, based on Met Office precipitation forecasts and the national distributed Grid-to-Grid model. This presentation will summarise the winter's events and show that there has been a step change both in the breadth and quality of information used to inform these forecasts; and also in how this information is used. To cite two examples, the potential for significant flooding was identified out to forecast day 5 for Storm Frank, a timescale which is very useful for emergency responders. And secondly, in some areas Grid-to-Grid was used to inform the issue of community level flood warnings with a 24 hour lead time. These advances enabled communities to be better prepared than they were for comparable events ten years ago. We will also look ahead to future improvements in both forecasting and dissemination of expected flooding impacts.

2.3 Emerging technologies for flood extent mapping and damage assessment: using drones to map the flood events of storm Desmond.

Monica Rivas Casado (Cranfield University)

Current methodologies used for flood extent mapping and damage assessment are generally based on satellite data (SAR or optical) or aerial imagery collected from aircraft. These methods present limitations when used for urban environments. For optical imagery, low cloud-cover presence constrains data acquisition. Satellite imagery presents limitations due to its oblique viewing angle and the difficulty of separating the water signature from other urban areas. Hence, to date, robust estimation of flood extent and damage within urban areas has been challenging. With flood damage estimated to be above £3billion/event (based on 2007 flooding events) and an average house claim of £40k, flood mitigation and damage assessment are a priority in the Governmental agenda. Here, we present the potential of light-weight Unmanned Aerial Vehicles (UAVs) to address some of these limitations. UAVs offer timely and higher resolution information than comparable satellite or aircraft imagery and their operation is not constrained by low-cloud coverage. We illustrate their potential, advantages and limitations for flood extent mapping and damage assessment for the flood events over Cockermouth in December 2015.

2.4 Delusions and deluges – public engagement with physical modelling of flood mitigation measures

Peter Metcalfe (Lancaster University), Keith Beven (Lancaster University, Uppsala University), Barry Hankin (JBA Consulting) and Rob Lamb (JBA Trust, Lancaster University)

Given the increasing frequency of events of the magnitude of storms Desmond and Frank, there is now general recognition that traditional downstream approaches to flood mitigation are inadequate. Within the general public and policy makers, however, there remains a lack of knowledge of run-off processes or a good evidence base that could inform identification of the most effective alternatives. For example, dredging to improve channel conveyance can be shown to have localised benefits but at a catchment scale is almost invariably ineffective. It is, however, frequently proposed as a solution to flooding problems. Some Natural flood Management Schemes (NFMS) were highlighted in the media, but none were stressed by either of the storm events. We implemented a simple physically-based model hillslope run-off and hydraulic channel routing model which, given minimal data, can be quickly set up for most catchments. It can incorporate in and out of channel run-off attenuation features (RAFs) and predict their effects on the flood response. The model is easily applied to demonstrating the effects of increasing channel conveyance by dredging and of the effects of installing a NFMS. Associated routines were developed to animate the spatio-temporal progress of a storm event through a catchment and the approximate extent of overbank flow. Results for a local flood event were were well-received when demonstrated at a catchment stakeholder meeting in North Yorkshire. We demonstrate these applications for a representative catchment. We suggest there is a need for physical flood models that can be quickly and cheaply applied to a range of catchments without detailed morphological data. We propose that to have maximum impact these models should be developed in tandem with visualisations that can easily disseminate with catchment stakeholders their comparative effects.

3 Keynote Debate: Flood risk and uncertainty

Vincent Auditorium 30 August 2016 16:00 – 18:30

Charles Vorosmarty (CUNY Advanced Science Research Center, USA)

Roger Falconer (Cardiff University)

Nigel Goody (Scottish Environment Protection Agency)

4 Flood Hydrology

Stafford Cripps (SC2) 31 August 2016 09:00 – 10:45

4.1 A Bayesian based updating process for improving probabilistic radar Quantitative Precipitation Forecasts

Arshan Iqbal (University of Exeter), Guangtao Fu (University of Exeter), David Butler (University of Exeter)

There is an increasing trend in improving radar Quantitative Precipitation Forecasts (QPF) for hydrologic modelling, particularly for flood prediction. Radars have become popular for producing QPF data as it allows high temporal and spatial resolutions covering large spatial areas. However, due to the operational aspects of radar technology it can produce inaccurate rainfall values. Furthermore, the uncertainties associated with radar rainfall forecasts pose a major challenge in producing reasonably accurate estimates of precipitation forecasts. Whilst deterministic methods have been explored to improve rainfall forecasts, a probabilistic framework has recently been investigated in order to produce ensembles of the deterministic QPF data that represent the uncertainty structure of the forecast. This study investigates the change of uncertainty structure using the most recent rainfall data with an aim to improve the accuracy of probabilistic forecasts. This is achieved by applying a Bayesian based updating process to initial probability distributions where the probability of observing a rainfall amount conditioned on recent data is calculated in a posterior predictive distribution. These updated values would alter the initial probability distributions and can therefore be used to produce more accurate forecast ensembles. Preliminary results show that the updated QPF ensembles values more closely match the corresponding radar QPE data compared to those ensembles produced from initial probability distributions. This comparison would especially be useful for studying the predictive abilities of the probabilistic framework for rainfall in different seasons. This approach can be applied to a real time flood warning system to improve the accuracy of flood forecasting.

4.2 How to use tape measures, lichens, zirconium and boulders for design flood estimation

Duncan Faulkner(JBA Consulting), Sean Longfield (Environment Agency), Mark Macklin (Aberystwyth University), Tim Hunt (Environment Agency), Chrissy Mitchell(Environment Agency)

The Environment Agency's FEH Local research project has investigated ways of incorporating "local data" into flood frequency estimation. Two examples of local data are measurements of channel geometry and evidence from palaeoflood deposits. Both provide physical evidence of the occurrence of past floods. Both require geomorphological as well as hydrological skills to interpret. We present research showing how channel width can provide useful extra information, alongside catchment descriptors, for the estimation of the median annual flood on ungauged catchments. We outline two case studies in which palaeoflood data has been used to estimate a flood frequency curve: one using boulder berm deposits for an ungauged upland catchment in mid-Wales and the other using floodplain sediment cores on the River Severn. These are thought to be the first applications of palaeoflood data for flood frequency estimation in the UK. The research findings and case studies have been incorporated into guidelines for practitioners, alongside information on other types of local data such as long-term flood history, river level records, temporary flow gauges, photographs of flood impacts and information obtained from field visits. Remaining challenges are to improve the accessibility of local data, to develop software to allow practitioners to estimate flood frequency curves using historical data, and to continue encouraging clients and practitioners to avoid a "click-button" approach to flood frequency estimation.

4.3 Snowmelt flooding and the risk to impoundment infrastructure

Mike Spencer (University of Edinburgh)

September in SE England feels a long way from snow and mountains, but as the calendar year draws to a close many people will be thinking of winter breaks to enjoy the white stuff. However, snow isn't just fun; it can bring benefits and hazards. Across places like the western US and Canada snow is a vital store of water for the dry summer months. On steeper slopes, snow sits precariously and can avalanche, which causes deaths each year. The second largest flow recorded on the River Thames was from a rain on snow event (March 1947). Snowmelt is annually part of river flows in colder regions, in the UK these are invariably located in northern and mountainous terrain. In Scotland the uplands are often used for water storage, e.g. for hydro-power and water supply. In this talk I'll discuss the risk snowmelt poses to impoundment infrastructures used for water storage in Scotland and how this compares to the fixed daily melt rate laid out in the Flood Studies Report (1975). This analysis is based on the results of a degree-day snowmelt model run over a sixty year period (1945 - 2006) and calibrated against daily observations of snow cover, observed as part of the Snow Survey of Great Britain.

4.4 Harmonic- Periodic Wave Model Application in Flood Hydrograph Routing

Mohammad Reza Beheshti (Islamic Azad University, Tehran), Elham Mina (Tarbiat Modares University, Iran)

One of the most common challenges in river hydrologic systems analysis is the estimation of a flood hydrograph at any given location in a river during the course of a flood event. The problem is solved by the techniques of flood routing. If there are no gauging stations on a particular river and therefore no measurements of discharge, the engineer may have to make do with stage measurements for. In such circumstances, it is usually the flood peaks that have been recorded, and indeed it is common to find the people living alongside a river have marked on a wall or bridge pier the heights reached by notable floods. Hence the derivation of a relationship between peak stages at upstream and downstream points on a river reach may be made when it is known that the floods are caused by similar notable conditions. This is a very approximate method, and there should be no major tributaries between the points with the stage measurements. On the other hand, the empirical methods of flood routing are based on a large collection of observed data for a discrete reach of river and are only applicable for that reach. To overcome this problem, a new mathematical scheme has been developed in this research for flood routing in such rivers based on the harmonic-periodic wave equation. To compute the coefficients values of the proposed model, partial differential equations solved simultaneously by implicit and explicit numerical schemes. The significant characteristic of this model in comparison of other hydraulic flood routing models is its independency to geometrical characteristics (cross section shape, bed slope, etc.) of the flood passage way. Also the main characteristic of proposed model in respect to other hydrological routing models is its non-linear estimation of flow storage.

4.5 Fast 2D Flood Simulation and Risk Assessment

Yuntao Wang (University of Technology Dalian, China & University of Exeter), Guangtao Fu (University of Exeter), Albert S. Chen (University of Exeter), Mike Gibson (University of Exeter), Slobodan Djordjević (University of Exeter), Chi Zhang (University of Technology Dalian, China), Dragan A. Savić (University of Exeter)

Flood simulation and risk assessment in a growing number of mega cities have gained increased attention in recent years due to substantial flood impacts. However, computational efficiency remains a huge challenge for researchers and practitioners involved in flood risk modelling. In this paper, a two-dimensional model based on cellular automata principles is developed and applied to assess flood risks for the whole London. This approach was implemented in a parallel environment, which enables flood risk modelling over the entire area (1,572 km^2) to be undertaken while also considering a large number of storm events. The use of the Graphical Processing Unit (GPU) approach significantly improves computational performance, while achieving required accuracy. Flood risk is calculated as a product of the multiple storm events with different maximum flood depths and probabilities. Flood simulations were run at a 5m x 5m resolution, resulting in a total of 62.9 million computational cells. The simulation time for the entire London area is about 20.3 hours (Intel Xeon 3.20GHz, 18GB of main memory and GeForce GTX TITAN graphics card with 3072 cores and 12GB of memory). Maps are generated to reveal the spatial distribution of flood risk, which can help the local governments and residents to understand the risks and consider appropriate risk mitigation strategies. From the maps, we can learn that threats from flood for Kings Cross, Waterloo and so on are significant. The results obtained indicate that the model is capable of flood simulation and risk assessment in mega cities.

5 River Restoration

Stafford Cripps (SC3) 31 August 2016 09:00 – 10:45

5.1 Drought impacts on river ecology

Cedric Laize (Centre for Ecology and Hydrology)

With hydrological drought foreseen as more frequent and severe, a key element of any adaptation strategy is to know what and where would be the likely impacts. The paper presents early assessments of the impact of future droughts on river ecology carried out as part of the NERC-funded 'Managing the risks, impacts and uncertainties of drought and water scarcity' (MaRIUS) project. Three approaches are used: (i) hydrological alteration; (ii) discharge-biological index modelling; (iii) eco-hydraulic modelling.
Hydrological alteration: All aspects of the flow regime matter to the riverine ecosystems, any major departure from usual conditions is therefore associated with an impact risk to the system. Adapting the Ecological Risk due to Flow Alteration (ERFA) method, we assessed quantified and mapped departures from normal conditions of predicted future droughts.
Discharge-biological index modelling: The biological (i.e. river invertebrate index) response to discharge is modelled using observed biological records. Flows for drought events are then run through model to simulate future values of the invertebrate indicator. Summary metrics and maps are produced.
Eco-hydraulic modelling: River organisms react indirectly to discharge but directly to river hydraulics in terms of: (i) available physical habitat (i.e. depth, velocity) (ii) river longitudinal connectivity (i.e. less opportunity to explore food sources, or to find most suitable conditions if connectivity is broken). Based on a wide geographical coverage of hydraulic geometry models, we quantify typical habitat loss during drought years, and map catchment fragmentation due to longitudinal connectivity.

5.2 The effect of a fine sediment pulse on invertebrate surface, longitudinal and vertical distributions in stream mesocosms

George Bunting (University of Worcester)

The amount of sediment entering rivers has increased dramatically over the last century and is now recognised as a leading cause of water quality impairment. However, the exact mechanisms driving this impairment are not yet fully understood. The present study used twelve outdoor flume mesocosms to identify the impact of a fine sediment pulse on hyporheic sediments and the dispersal pathways (i.e. surface, longitudinal and vertical) of benthic and hyporheic invertebrates. A further aim of the experiment was to identify the influence of substrate porosity and interstitial habitat availability on the response of benthic and hyporheic invertebrates to a fine sediment pulse. The channel bed of each mesocosm was divided in to two, one half consisting of a fine substrate and the other half a coarse substrate. The benthic and hyporheic invertebrate communities (at 5, 11 and 18 cm depths) in each mesocosm section were sampled before, during, immediately after, 30 days after and 60 days after a fine sediment pulse. In addition to this, invertebrate drift, sediment deposition, depth of oxygen penetration and water quality were analysed on each sampling occasion. Initial results of this experiment will be presented, as well as a discussion of the methods used.

5.3 Geomorphic changes and hydrological responses to the 2015 'Storm Frank' flood event at a river restoration site on the upper River Dee.

Stephen Addy, Mark Wilkinson and Susan Cooksley (The James Hutton Institute)

Removing embankments to allow rivers to freely interact with their floodplains is seen as a key method to improve the ecological integrity of rivers and their floodplains and also reduce downstream flood risk through Natural Flood Management. However, large scale case studies in a UK context are rare. In October 2015, an artificial embankment was deliberately breached to reconnect part of the floodplain of the upper River Dee in

Aberdeenshire at a catchment scale of 370 km2. The main aims of the restoration project were to remove waste and improve morphology and floodplain connectivity. Monitoring of the floodplain water table (and depth of water on the floodplain during a flood) and geomorphology commenced in summer 2013 and have continued after the restoration work was undertaken. This paper reports on initial findings of the geomorphic and hydrological monitoring following a series of winter floods that occurred after the floodplain reconnection was undertaken. The flood of the 30th of December 2015 ('Storm Frank' flood) was the most significant of the events that happened during this period. The flood mainly generated by an intense rainfall event and wet antecedent conditions, was exceptional in its magnitude. Although comparison is prone to uncertainty, the event may have been the most significant flood since the 300-1000 year recurrence interval 1829 'Muckle Spate' flood. At the restoration site, maximum deposition of up to 1 m in the main channel and the deposition of gravel over the floodplain were the dominant responses. These findings are discussed in the context of the history of river management, flooding and geomorphic changes in the River Dee. In addition, the process undertaken by the Dee Catchment Partnership to achieve the restoration action is presented to provide context to the study.

5.4 Prioritising river restoration for multiple benefits at the catchment scale: applying the correct approach considering the potential for geomorphic work

Hamish Moir (cbec eco-engineering UK Ltd)

For successful delivery of river restoration for the reinstatement of natural physical processes, a strategy for implementation must be considered at the catchment scale, at least. With limited funding available for such work, there requires to be an objective assessment of the optimal benefit to a suite of identified objectives (e.g. rehabilitation of natural physical processes, WFD targets, biodiversity, NFM, socio-economic factors etc) across entire catchments. Furthermore, restoration measures cannot be applied with a 'one size fits all' type of approach. Different types of river environment and degree of constraint of natural processes require the application of different approaches to delivering restoration. Specific river restoration measures must reflect the imposed physical controls at a site (i.e. those inherited from upstream, catchment-scale processes), these controls defining a range of general approaches to implementation; i.e. with increasing degree of intervention, 'do nothing' – 'assisted recovery' – 'initial condition design' – 'functional design', associated with gradients of increasing physical constraint and decreasing potential for geomorphic work. However, to date, there have been few attempts to quantitatively define this type of framework and apply it at the catchment scale, using existing data-sets. In this paper we present an application of such an approach on the River Leven catchment, Scotland. Catchment-wide data on the degree of engineering pressure (based on SEPA's MImAS 'capacity used' score, used to define WFD 'ecological status') and indicators of the potential for geomorphic work (combining information of specific stream power and unit sediment supply and storage) are integrated to provide a standardised metric that, 1) prioritises restoration for greatest cumulative improvement to physical processes and WFD benefit (i.e. relating to 'morphological pressures'), and, 2) identifies the type of general restoration approach appropriate for prioritised areas. Subsequent evaluations consider additional benefits in terms of NFM potential associated with specific restoration works, improvements to biodiversity and specific habitats and socio-economic factors to provide an objective and integrated assessment of an optimal restoration strategy at the catchment scale.

5.5 The opportunities and constraints of river restoration from a water company perspective

Simon Whitton and Di Hammond (Affinity Water Limited)

The abstraction of water for potable supply is one of the many pressures on rivers, negatively affecting their ecological quality. In our enhanced status Business Plan, Affinity Water has a commitment for "making sure our customers have enough water whilst leaving more water in the environment". Working with the Environment Agency (EA), we have identified damaging abstractions which we are now evaluating. In our Central Area (including parts of Buckinghamshire and Hertfordshire), abstraction in seven chalk stream catchments is being reduced by 42 Ml/d (5% of our total groundwater abstraction) in AMP6 (2015-20), whilst further reductions of 17.8 Ml/d will take place in AMP7 (2020-25). The water supply deficit thus created is being offset by a comprehensive water saving programme with our customers, the rolling out of metering to every household and an intensification of reducing leakages. An ambitious programme of morphological and habitat improvement work is concurrently being developed in six of the seven catchments subject to reduced abstraction. In conjunction with the EA, an agreed list of prioritised projects has been compiled, which includes channel narrowing, re-meandering, re-alignment (into the natural course), fencing to exclude livestock, the removal or bypassing of weirs and the thinning of trees to allow more light into the channel. These projects are focussed to help the rivers meet the requirements of the Water Framework Directive. Multi-faceted monitoring started in 2014 and will continue until 2020. Results will be analysed to determine any changes in flow, species, geomorphology and habitats that have been brought about by the reductions in abstractions and / or the morphological works. The work involves a great deal of engagement with a wide range of stakeholders, including landowners, farmers, anglers, community groups, and we need to be aware of the diverse interests, needs and aspirations of all these groups.

6 Soil Hydrology

Stafford Cripps (SC2) 31 August 2016 11:15 – 12:45

6.1 Innovative means of assessing the relative permeability of a soil type for inclusion in a small catchment flood study

David Price (Jacobs, Glasgow)

In the UK the Hydrology Of Soil Types (HOST) has over the last 25 years been the principal source of catchment permeability information for hydrological flood studies. This paper describes an investigation into the adequacy of the permeability of HOST Class 4 linked to a particular soil type found in the north west of England. Concerns had been raised previously within the reservoir community that HOST Class 4 permeabilities were too low for inclusion in reservoir flood safety studies – resulting in potentially dangerous underestimation of design floods with implications to downstream risk and safety. This study describes how a blend of at-site environmental interpretation and thematic datasets was used to assess the relative permeability of the target soil to other soils in five reservoired catchments in the north west of England. The threads of evidence include interpretation of vegetation, land use, hydrological features, channel characteristics, channel density, soils, hydrogeology, presence of springs and artificial drainage; together with out-of-bank flood evidence along watercourses from the extremely wet 2015\2016 winter that caused dramatic flooding in large areas of northern England and Scotland. Findings were collated using an innovative summarising technique enabling the relative permeabilities of different soil types to be compared. In doing so the study exposes inadequacies with the current means of obtaining reliable catchment permeability indices from the HOST dataset for small catchments in general, pointing to a real need for the refinement of the existing HOST data set.

6.2 The impact of macropores on heavy metal retention in Sustainable Drainage Systems

Ruth Quinn and Alejandro Dussaillant (University of Greenwich)

Numerous laboratory and field experiments have found that rain gardens exhibit excellent retention of heavy metals (>88%). However, none examined the influence of macropores on retention; this was established as a key factor in heavy metal capture in previous landfill leachate experiments. Therefore, the aim of the experiments detailed in this paper was to investigate the effect of a single artificial macropore on heavy metal retention in a layered soil column (with similar soil layout to a rain garden). The findings of these experiments indicated that although macropore flow did not impact the hydraulic performance of the columns, retention of the most mobile of heavy metals, copper, was decreased in one case. The retention of the columns was still high at a value in excess of 99% for copper, lead and zinc. This indicates that macropores are not detrimental to heavy metal retention in rain garden systems. However in shallower systems such as green roofs, heavy metals and other pollutant retention may be impacted by the existence of preferential flow and more research into this area is needed.

6.3 A soil moisture accounting-procedure with a Richards' equation-based soil texture-dependent parameterization

Simon Mathias (Durham University), Todd Skaggs (US Salinity Laboratory, California), Simon Quinn (AMEC Environment & Infrastructure), Sorcha Egan (Durham University), Lucy Finch (Durham University), and Corinne Oldham (Durham University)

Given a time-series of potential evapotranspiration and rainfall data, there are at least two approaches for estimating vertical percolation rates. One approach involves solving Richards' equation (RE) with a plant uptake model. An alternative approach involves applying a simple soil moisture accounting procedure (SMAP) based on a set of conceptual stores and conditional statements. It is often desirable to parameterize distributed vertical percolation models using regional soil texture maps. This can be achieved using pedotransfer functions when applying RE. However, robust soil texture based parameterizations for more simple SMAPs have not previously been available. This article presents a new SMAP designed to emulate the response of a one-dimensional homogenous RE model. Model parameters for 231 different soil textures are obtained by calibrating the SMAP model to 20 year time-series from equivalent RE model simulations. The results are then validated by comparing to an additional 13 years of simulated RE model data. The resulting work provides a new simple two parameter (% sand and % silt) SMAP, which provides consistent vertical percolation data as compared to RE based models. Results from the 231 numerical simulations are also found to be qualitatively consistent with intuitive ideas concerning soil texture and soil moisture dynamics. Vertical percolation rates are found to be highest in sandy soils. Sandy soils are found to provide less water for evapotranspiration. Surface runoff is found to be more important in soils with high clay content.

6.4 Quantifying the impact of hedgerows on soil hydrology

Victoria Coates, Ian Pattison and Graham Sander (Loughborough University)

Farming practices have changed significantly over the past century. This is particularly evident in arable fields, where the use of larger machinery has led to the removal of hedgerows and 20-40% decrease in field density. Hedgerows are a widespread feature in the rural English landscape and have been shown to play an important ecological role in providing shelter, changing the local climate and reducing erosion. However, their impact on soil hydrology has not been widely studied. The national-wide change in the rural landscape is thought to be responsible for longer slope lengths, increased runoff velocities and greater potential for connectivity, which may be responsible for an increase in flood risk at the catchment scale. However there is a lack of physical evidence to support this theory. This paper provides evidence of the impact of a hedgerow on the partitioning of rainfall-runoff by modifying the soil hydrology at the local scale. Field experiments were conducted at a field site in the River Skell catchment, in Yorkshire, UK. A hedgerow was monitored for a period of 15 months to capture information on soil-water interactions. Results show that soil moisture levels next to the hedgerow rise earlier and fall quicker, than the probes further from the hedgerow, where levels rise gradually and fall slowly. Over the whole period of monitoring soil moisture levels were significantly lower in the area up to 1 meter away from the hedgerow. This is due to higher soil porosity (5-15%) next to the hedgerow, compared to 1-10m away and because of the root system that extends 1m horizontally from the structure and helps the soil to drain better. These results indicate that hedgerows could be used to soak up large quantities of water from the surrounding soil, cause disconnections across fields and reduce runoff.

7 River Restoration Workshop

Stafford Cripps (SC3) 31 August 2016 11:15 – 12:45

8 Water resources for a growing population (1)

Stafford Cripps (SC2) 31 August 2016 13:30 – 15:00

8.1 Meeting increased demand for a growing population through inter-basin transfers: A case study of the Trent Witham Ancholme River Transfer Scheme

Daniel Burbidge (Environment Agency)

The Trent Witham Ancholme River Transfer Scheme is one of the largest inter-basin water transfers in the UK and plays a vital role in supplying water to people and industry and conserving it for the environment. Up to 182 million litres of water a day is pumped along an 800m pipeline from the River Trent at Torksey to the Fossdyke Canal, which in turn flows into the River Witham. We then transfer up to 156 million litres a day from the River Witham using our pumping station at Short Ferry, downstream of Lincoln. The pumps force water through a 17km underground pipeline until it reaches the River Ancholme at Toft Newton. An Environment Agency reservoir stores water at Toft Newton for emergency release. Transfers typically occur every summer usually from May to September. The transfers are used for public water supply, meeting the needs of industry and spray irrigation for agriculture. The scheme also supports navigation and fishing and flushes out salt water from the lower Ancholme into the Humber. This presentation will describe: how the scheme is run; the use of models to optimise transfers and the improved use of hydrological forecast; the benefits of the scheme for public water supply, industry, agriculture and navigation; use in drought along with potential drought orders; the environmental risks of the scheme including transfer of invasive species and changes to the natural flow regime and the work done to mitigate the risks; potential for increasing transfers from the Trent to support growth and the environmental and economic limitations; planning for emergencies;

8.2 Water transfer by canals – improving UK water resource resilience

Mathew Wells (Canal & River Trust) and Fiona Tarrant (Black & Veatch Ltd)

Following the drought event of 2011-12, and with the prospect of a third dry winter, a range of collaborative water transfer schemes using canals were discussed and considered by a number of water companies, Water UK and the Canal & River Trust (the Trust), formerly British Waterways, in early 2012. The exceptionally wet weather in late spring and the remainder of 2012 reduced the urgency to develop viable drought schemes for water transfer during winter 2012/13. In the period since the drought, the Trust continued to develop support from several water companies for an extended water transfer feasibility study. In May 2016 Black & Veatch (BV) completed an assessment of a range of water inputs and canal transfers that would benefit United Utilities, Severn Trent, Anglian Water, Affinity Water and Thames Water. The stated objective of the feasibility study was to scope the engineering works required, and to develop high level estimates of associated capital and running costs for schemes to transfer up to 200 Ml/d of water. It is hoped that the study will lead to one or more water companies taking forward canal transfer schemes into their subsequent Water Resource Management Plans as 'preferred options' for more detailed investigation. If any of these transfer schemes are selected as preferred options then a second phase of comprehensive investigations (covering a detailed hydraulic modelling assessment, and appraisal of environmental, ecological and legal/planning matters, plus more detailed costings) will follow. Small extent field trials will also be carried out in phase 2 to verify key assumptions. A third phase of investigations would involve detailed analysis of preferred water transfer routes (including more geographically extensive and longer duration field trials and refinement of previous assumptions) before detailed design and eventual construction.

8.3 Optimising Monitoring Strategies for Changing Water Resource Management Priorities

R. Gosling (Scottish Environment Protection Agency), C. Malcolm (Scottish Water) and R. Morris (Scottish Environment Protection Agency)

Long-term hydrometric data and a robust monitoring strategy are essential for successful water resource management. Well-established hydrometric networks provide hydrologists with an empirical basis for calculating the long-term averages and extremes in hydrological conditions; the understanding of which is fundamental to managing water resources. In recent times, much of the focus of hydrological endeavour, including water resource management, has shifted from data collection to modelling approaches. Nevertheless, the basis of these modelling approaches is nearly always empirical, and reliant on long-term hydrometric data. A challenge facing water resource practitioners today is that changing water resource management priorities do not always align with the design of existing benchmark hydrometric networks. Nor do the time scales associated with setting up and running new long-term monitoring sites often align with those programmes which seek to resolve water resource issues such as River Basin Management planning cycles or capital investment programmes. Finally, financial constraints mean that hydrometric networks have been under pressure in recent years, rather than expanding to meet changing needs in water resource management. To address the disparity between the changing needs of water resource managers and the misalignment with traditional monitoring networks, this paper presents case studies from Scotland, where medium and short-term gauging stations have been installed to address gaps in the existing hydrometric network, to meet the needs of specific water resource projects. A methodology is presented to show how temporary sites can be optimally located to maximise their data utility. The case studies also show how consideration is made of the length and quality of record required to provide sufficient confidence in the management decisions made as a result of collecting these data. Finally, data sharing and collaboration between different organisations to create an integrated monitoring network is shown to be key a component of further optimising hydrological knowledge of data sparse regions.

8.4 A trend analysis on the updated UK Benchmark Network of river flow stations

Shaun Harrigan (Centre for Ecology and Hydrology)

Climate change is expected to intensify the hydrological cycle thereby increasing the likelihood of extremes such as floods and droughts. Observational trend analysis is a key tool for tracking emerging changes in the flow regime and for placing shorter-term trends into their longer-term historical context. However, human disturbance within catchments, for example land-use change, water abstraction and river engineering, can introduce artificial changes therefore confounding any underlying climate-driven signal. The UK Benchmark Network was originally defined in the early 2000s and comprised a sub-set of National River Flow Archive (NRFA) stations that were considered near-natural and thus appropriate for identification and interpretation of hydrological trends. Here, the original benchmark network is updated to remove inactive stations and to incorporate stations that had previously met the criteria but were too short. Additionally, the importance of including stations suitable for analysis of extremes is acknowledged more strongly; the current version of the network provides user guidance on the suitability of each station for the assessment of low, medium, and high flows. A comprehensive trend analysis will be presented on the updated UK Benchmark Network with a focus on high and low flow variables. Such a quality assured observational dataset is the foundation of many scientific research efforts to better understand the changing nature of the hydrological cycle which is necessary for improved water management.

9 Workshop: ‘Sediments in rivers: opportunities for improving our understanding’

Stafford Cripps (SC3) 31 August 2016 13:30 – 15:00

10 Lorch Lecture: Observations and thoughts on water resources research

Vincent Auditorium 31 August 2016 17:00 – 18:00

Ximing Cai, University of Illinois at Urbana-Champaign, USA

Water science has been shifting its focus over the past century to support water governance evolving from engineering development, demand management, water quality protection, and ecosystem restoration to building sustainable water systems. Meanwhile a gradual shift towards a holistic water management approach has already been evident in many countries and regions. The future of the world can be challenged by dramatic environmental change and increasing human population, which may stress the world's water resources at local to global scales and from single sector to multiple sectors (e.g., food-energy-water-environment nexus). In order to handle the complex and complicated water systems problems, technology innovation will be called upon to move us from segmented methods to seamless methods integrating all necessary components to solve real-world water problems, from physical to cyber-physical infrastructural support, and from human domination to human-nature harmony. Water has been playing a growing role to unify nature and humanity, and the target of water science in the 21st century must be ambitious to ensure that humans and our planet co-evolve sustainably. This talk will provide a historical review of water resources research and discuss the pressing research issues and directions for future studies, which call for a paradigm shift to deal with the challenges of sustainable water resources management.

11 Hydrology in cities

Stafford Cripps (SC2) 1 September 2016 09:00 – 10:45

11.1 An assessment of property development on the floodplain during the last 100 years

Ian Pattison (Loughborough University)

Flood risk is perceived to be increasing in the UK. This is not only due to the physical hazard potentially becoming more frequent and severe, but that urbanisation, and particularly building on floodplains has increased exposure to flooding. A study by the Climate Change Committee in 2012 found that building in the floodplain had increased by 12% over the previous decade, compared to a 7% increase outside the floodplain. This equates to 21,000 residential properties per year being built on the floodplain. 80% of these are built behind flood defences, which may result in a false sense of security and also increases the cost : benefit ratio for investing in flood defences. However, 20% of these properties is at significant flood risk under the current climate. This paper presents an assessment of property development on the floodplain since 1900. Combining open access datasets of housing age by decade and flood risk zones, allows the number of properties built in flood risk areas to be estimated. This is determined at the spatial resolution of Lower Super Output Areas, which have on average 650 properties within them and there are ~35,000 LSOA's in England and Wales. This analysis highlights both the temporal increase of building on the floodplain over time, and also the spatial distribution of where this is the biggest problem.

11.2 Influence of building density on surface water flooding

D. Green, I. Pattison, D. Yu (Loughborough University)

Surface water (pluvial) flooding occurs when rainwater from intense precipitation events is unable to infiltrate into the subsurface or drain via natural or artificial drainage channels. Surface water flooding poses a serious hazard to urban areas across the world, with the UK's perceived risk appearing to have increased in recent years due to increases in precipitation due to climatic changes, population growth and changes in land-use. An increase in impermeable surfaces (e.g. tarmacked/paved surfaces and buildings) and a reduction in vegetated, permeable surfaces within urban regions may lead to city regions being at greater surface water flood risk when subjected to high intensity precipitation events. To investigate the influence of urbanisation on surface water flooding, building density scenarios were conducted using a novel physical modelling environment. Physical modelling experiments were conducted within a $9m^2$, two-tiered 1:100 physical model consisting of: (i) a low-cost rainfall simulator component able to simulate consistent, uniformly distributed (<75% CUC) rainfall events of varying duration and intensity, and; (ii) a fully interchangeable, modular plot surface. Experiments within the physical modelling environment were subjected to a 45-minute simulated rainfall event applied uniformly throughout experimentation and building density was altered systematically (0%; no buildings, up to 25%; 225 building coverage across the 9m2 surface) to investigate the influence of building density on surface water flood outflows and depths. Results from the closed, controlled physical modelling experiments suggest that an increase in building density across the urban model catchment leads to: (i) a more rapid rising limb; (ii) higher peak discharges; (iv) a reduction in the total hydrograph time, and; (v) a faster falling limb, with the dense building scenario having a 22% increase in peak discharge and a 60% shorter experiment time when compared to the no building scenario.

11.3 Housing and hydrology: comparing the rainfall runoff behaviour of two residential catchments in north Swindon

Tom Redfern (Centre for Ecology and Hydrology)

Urbanisation can dramatically alter the hydrological functioning of streams, rivers and groundwater; with potentially negative consequences for flood risk management, hydro-ecology and water resources. A large and increasing proportion of urban areas is composed of housing and residential development, therefore understanding the hydrology of residential areas is important for hydrological modelling, flood risk and environmental management. By comparing the physical surface and rainfall-runoff behaviour of two small residential catchments of north Swindon constructed during different decades of the 20th century (1950s and

1990s) this study demonstrates that the hydrological behaviour of housing is highly sensitive to design. As the design of housing has changed over the 20th century, so the potential impacts of residential development on hydrology have increased. A reduction in public vegetated space, increased provision of private car parking spaces and an increase in the connectivity of storm water drains have all dramatically altered the hydrological response of the modern residential development in comparison to the development built only a few decades before. The implications of this may mean it is harder to re-engineer the hydrology of modern developments to pre-development conditions emphasising the need to incorporate storm water management technologies into residential development during the design and construction phases.

11.4 The effects of a changing climate and urbanisation on river flows in the Thames basin – a hydrological modelling approach

N. J. Rickards (Centre for Ecology and Hydrology), J. Fidal (University of Bath), T. R. Kjeldsen (University of Bath), A. Hagen-Zanker (University of Surrey), M. G. Hutchins (Centre for Ecology and Hydrology), J. D. Miller (Centre for Ecology and Hydrology), C. S. Rowland (Centre for Ecology and Hydrology), C. Prudhomme (Centre for Ecology and Hydrology) and M. Tanguy(Centre for Ecology and Hydrology)

The UK population is set to increase by 16% by 2035; it is therefore increasingly important to understand the impact this may have on urban populations, and in turn how this will affect river flow regimes and water quality in urban areas. A growing population is likely to lead to an increase in urban land use and impervious surfaces, the implications of which are not yet fully understood for issues such as future flood risk. The aim of this paper is to develop a greater understanding of the impacts of both an increasing population and urban extent, and to assess the effect this may have on urban streamflow regimes and water security in the future. Flows are modelled for selected catchments in the Thames basin using the URBMOD model. URBMOD is a lumped rainfall runoff model that is able to represent both pervious and impervious surfaces, reducing infiltration in catchments where there is a greater urban extent. The model is calibrated using the GEAR (rainfall) and CHESS (evapotranspiration) datasets, and using long-term river flow records from the NRFA. Historic satellite imagery is used to train cellular automata land use models, which are then applied under different scenarios of urban development up to 2035. These changes in land use are combined with a range of climate change scenarios to give an indication of how urban flow regimes may be altered in the Thames basin over the next 20 years, and the key drivers behind such changes. By identifying the main drivers of change, the fine-scale impacts of urbanisation on water resources can be better understood. The findings from this research will also be used to inform a regional-scale model, coupling water quantity and quality and providing insight to urban planners and stakeholders regarding the future of the urban hydrological regime.

11.5 Predicting future change in water flows and quality in urbanising catchments

M. G. Hutchins (Centre for Ecology and Hydrology), G. Bussi (University of Oxford), S. Dadson (University of Oxford), J. Fidal (University of Bath), A. Hagen-Zanker (University of Surrey), O. Hitt (Centre for Ecology and Hydrology), J. Jones (Environment Agency), T. R. Kjeldsen (University of Bath), M. Loewenthal (Environment Agency), S. J. McGrane (University of Glasgow), J. D. Miller (Centre for Ecology and Hydrology), I. Prosdocimi (University of Bath), C. Prudhomme (Centre for Ecology and Hydrology), N. Rickards (Centre for Ecology and Hydrology), C. S. Rowland (Centre for Ecology and Hydrology), M. Tanguy (Centre for Ecology and Hydrology), G. Vesuviano(Centre for Ecology and Hydrology)

Despite substantial improvements in the recent past brought about by investment in treatment of sewage and industrial wastes, and various incentives and regulations to reduce diffuse pollution, water resources in the UK are facing considerable future pressures. For example, previous modelling work in the River Thames suggests incidence of “undesirable” water quality will become more frequent in the future. Furthermore, these predictions were made without considering the impact of population growth. Here, we present a combination of approaches to evaluate impacts of urbanisation on water resources in the Thames basin. Empirical analysis of two years of monitoring data in intensely monitored sub-catchments reveal the degree to which spatial variability of hydrological and water quality response can be explained by indices of impervious area. Statistical detection and attribution techniques are used to assess long-term river data, and these highlight strong signals of urban growth after climate variability is accounted for. High-resolution continuous monitoring puts the extreme periods of storm conditions in winter 2013-14 in the context of annual cycles of water quality. We illustrate how the high-resolution monitoring programme is used to simulate river hydrochemistry, and in particular to indicate how far downstream of urban areas the influence of those areas persist. At the basin scale, analysis of satellite imagery reveals landuse changes since the mid-1980s, signals used to train cellular automata models which then are employed for predictive purposes under different scenarios of urban development. We show how parametrically-parsimonious models of hydrology, sediment delivery and water quality are driven by the future landuse data to refine the existing predictions of future change in water resources across the whole Thames basin.

12 Catchment management for water quality

Stafford Cripps (SC3) 1 September 2016 09:00 – 10:45

12.1 Analysing hydropower production in stressed river basins within the SEEA-W approach. The Jucar River case

Abel Solera, María Pedro-Monzonís, Joaquín Andreu, Teodoro Estrela (Universidad Politécnica de València, Spain)

Hydropower generation represents an important contribution to meeting the challenges of today's increasing world energy needs. It uses about 44% of water in Europe, and it is the main user of water in most OCDE countries. But the fact is that energy sector is not a water consumer. The largest part of these withdrawals are immediately returned into the environment, being able to be used by other sectors, including other hydropower stations, without competing with other water users. Only in Spain, in 2014, the contribution of hydropower to the national electricity power accounted for 15.5%, with a total of 35,860 GWh. An important part of this contribution was destined for the regulation of electricity sector, generating electricity to help meet the hourly demand peaks. In order to understand the nexus water-energy and the challenges facing environmental requirements and other users, the European Commission proposed the use of water accounts in order to measure the influence of each water user, infrastructure and management decision to the total economic value of water resources in a given basin. In this sense, the SEEA-W is the most well-known approach of hybrid accounting and it is developed in many European countries as it provides a standard approach in order to compare results between different regions. This research analyses hydropower generation in Jucar River Basin (Spain), which is currently water-stressed by consumptive demands, within the SEEA-W approach. In systems like this, the hydropower sector only turbines the water withdrawals for other water uses located downstream. Moreover, hydropower stations can turbine water in cyclical systems, pumping and turbining the same volume of water several times in one day. The inclusion of water abstracted by energy sector can distort water balances, since the volume abstracted is often bigger than the rest of uses in the river basin.

12.2 Drivers of hyporheic exchange across spatial scales

Chiara Magliozzi (Cranfield University & The River Restoration Centre), Gianpaolo Coro (Istituto di Scienza e Tecnologie dell'Informazione "Alessandro Faedo", Italy, Robert Grabowski (Cranfield University), Stefan Krause (University of Birmingham), Martin Janes (The River Restoration Centre)

Recent field and modelling research has acknowledged the hyporheic zone as connecting interface between river and groundwater systems, and its functional significance to river ecosystems. However, our understanding of the interacting factors driving hyporheic exchange at large scales (i.e. from segment to landscape) is fragmentary and further evidence is needed to link local hyporheic exchange flows across scales. Therefore through a critical review of recent literature, we have developed a conceptual model of the hyporheic exchange that details how drivers operating at catchment, valley and reach scales are responsible for spatial and temporal variations in exchange. This work is based on a conceptual understanding of surface-groundwater interactions from published reviews and field studies on hyporheic exchange placed within a hierarchical river processes framework. First the factors that influence the presence and hydraulic functioning of the hyporheic zone were identified, and evidence gathered on their cumulative impact at stream and catchment-scale. Then, data across 8 UK catchments were collected from public and private repositories and analysed in order to identify indicators of hyporheic exchange.. Statistical tools such as Principal Component Analysis and clustering technique were used to develop unsupervised decisional systems that define potential hyporheic exchange at different scale. This approach was tested using field-site information from recent literature studies. The outcomes of the study will benefit fundamental research in hyporheic zone by providing an integrated approach of the drivers of hyporheic exchange across spatial and temporal scales. It will also benefit river restoration and catchment management through the identification of areas characterized by hyporheic exchange sites and therefore defining the methods and criteria for maximizing hydrological and ecological benefits. Finally the hierarchical approach will help foster a cross-scale perspective of the hyporheic zone that will highlight possible catchment-scale solutions to reach-scale problems.

12.3 The effect of tillage intensity on sediment and nutrient loads in waterbodies

S Cooper and Jane Rickson (Cranfield University)

The EU Water Framework Directive requires waterbodies to be in 'good ecological status', but 81% of UK waterbodies are failing to meet this target. This is partially due to diffuse pollution from agriculture. It is estimated that over 70% of sediment load and 43% of phosphorus in watercourses originate from agricultural land. Better land management is needed to control these sources of pollution. The SOWAP project ("Soil and surface water protection using conservation tillage in Northern and Central Europe") aimed to demonstrate the environmental and ecological benefits of reduced tillage practices, including improvements in catchment water quality. Field scale plots were installed on contrasting soil types (a clay and a sandy clay loam) in Leicestershire and Somerset to monitor the runoff, sediments and nutrients generated from three tillage treatments of varying degrees of soil disturbance: conventional (inversion tillage); conservation (non-inversion, direct-drill tillage); and 'farmer preference' (non-inversion, minimum tillage). The volumes of runoff generated under the three different tillage treatments were not significantly different. However, sediment loads were affected by tillage type: On the clay soil, the use of the conservation tillage actually increased sediment load, but the opposite was true for the sandy clay loam. On the clay soil, nutrient loads in the runoff and sediment were significantly different for the different tillage types, but only for N and P, and not for K. On the sandy clay soil, significant treatment differences in nutrient loads were found in the sediment, but not in the runoff. The results show that the effects of different soil management treatments on water quality are site/soil specific. Consequently, universal conclusions regarding the impact of conservation tillage on soil, water and nutrient losses are not possible. Also, to be meaningful, better understanding is needed of connectivity between the field and the watercourse (source-pathway-receptor).

12.4 Integrating records of agricultural change for modelling catchment soil erosion and lake sedimentation

Hugh Smith (University of Liverpool), Andrés Peñuela Fernández (University of Liverpool), Heather Sangster (University of Liverpool), Haykel Sellami (University of Liverpool & Centre for Water Research and Technologies, BorjCedria, Tunisia), Richard Chiverrell (University of Liverpool), John Boyle (University of Liverpool), Mark Riley (University of Liverpool)

Agricultural change has caused significant environmental impacts with the onset of modern practices and intensification over the past century. In response, many current policy and management initiatives aim to reduce soil erosion and excess fine sediment supply to streams and lakes. However, such initiatives lack detailed, longer-term baseline information extending beyond the instrumental record against which to measure the success or otherwise of these efforts. Here, we provide an overview of an approach for reconstructing impacts from past agricultural changes based on physical and social records from the last ca. 100 years coupled with simulations of soil erosion in lake catchments. This period represents a compromise between length of record and data availability for model parameterisation. We aim to simulate changes in soil erosion and sediment input to the lakes under historic climatic variability and land cover using variants of the RUSLE and Morgan-Morgan-Finney models. The study focuses on six lake catchments in Britain spanning a range of agricultural environments. Land use reconstructions are based on historic aerial photography and satellite-derived land cover maps (1940s-2000s) in combination with annual records of parish-level agricultural census data (1890s-1970s) and farmer interviews. These datasets form the basis for generating sets of synthetic land cover maps with randomised field classification (arable or pasture) to capture uncertainty in spatial arrangement for each simulated period. Preliminary results from the land cover reconstructions and model simulations will be presented and compared with dated sediment records for selected catchments. This combination of social and environmental records, soil erosion modelling and lake sediment chronologies provides a unique platform against which to compare the effect of current or future land management initiatives designed to reduce soil erosion and improve water quality in agricultural environments.

12.5 Increasing drought risk in a heavy rainfall region: causes, impacts and challenges in adaptation and mitigation

K. Shadananan Nair (Nansen Environmental Research Centre, India)

Unsustainable use of land and water resources, changes in temperature and in rainfall characteristics and inefficient water management create seasonal droughts in the state of Kerala that receives more than 3000mm annual rainfall. Rainfall in the state is becoming more seasonal and intense. Long gap in rainfall, especially the decreasing trend in pre-monsoon rainfall makes the water resources dry during a part of the year. Droughts occur even in years of large positive anomalies in rainfall. Certain types of seasonal plants are facing extinction. Slight increase in rainfall in certain parts is not able to compensate for the loss in soil moisture due to rise in temperature. Increasing convective activity in the hill region results in heavy downpour with large droplets that erodes the topsoil in the mountain forests that has already been degraded by anthropogenic activities such like encroachment for plantation agriculture, hill tourism and hydropower development schemes. More than 30 % of the wetlands including the network of canals and ponds in Kerala were lost in last 50 years. Because of various socio-economic reasons vast areas of farmlands have been abandoned. These fertile lands are now being converted into industrial plots and residential complexes, in spite of rules and regulations to prevent it. Area under paddy cultivation has declined by 60% in the last 30 years. The paddies once contributed much to the groundwater recharge. Groundwater level in the state has been receding by nearly 1 metre per decade. In the industrial area, it is falling at an alarming rate because of over exploitation. Number of bore wells is multiplying every year. There is no balance between the recharge and extraction. Rapid urbanization results in more runoff and less recharge. Sand mining from rivers and watersheds also make the groundwater resources dry. Reluctance to traditional water conservation practices, especially the groundwater recharging methods during northeast monsoon, end of the rainy season has also affected the groundwater storage. Seven once perennial rivers in the state have become seasonal in five decades and five more are in the same path. Droughts lead to several socio-economic issues including hiking price of water, food and energy, competition for land and water, migration and unrest in society. It halters the economic development. Weakening trend in northeast monsoon rainfall and shift in regional climate may worsen the drought situation in future. This study is an investigation on the various factors leading to seasonal droughts in Kerala, and an assessment of their impact on different sectors. Trends in rainfall and aridity, shifts in regional climate and proneness to drought have been analysed. Current policies, regulations, management practices have been critically reviewed to suggest guidelines for mitigation and adaptation.

13 Water resources for a growing population (2)

Stafford Cripps (SC2) 1 September 2016 11:15 – 12:45

13.1 Improving international management of leakage - the hidden resource

Allan Lambert, Past President of BHS

After 30 fascinating years working in hydrology and water resources management, conjunctive use of resources, reservoir yield assessment and other techniques to optimise raw water resources management, it had become increasingly clear to me that water resources engineers needed to understand much more about how to quantify and improve the management of leakage in public water distribution systems. So, 'changing horses in mid-stream', for the last 25 years I have specialised in leakage management, working with international experts of the Water Loss Task Force (now the Water Loss Specialist Group, WLSG) of the International Water Association. Since 2000, a number of systematic, structured and innovative practical concepts developed through the IWA WLSG have been applied internationally, leading to sustained reduction of the wasted hidden resource of leakage in many cities and Utilities around the world. Several of these practical concepts are based on modifications of classic hydrological concepts, and a relatively small number of hydrologists have now also become expert in leakage management, Unfortunately, most of this knowledge has not yet successfully re-crossed the artificial boundary between water resources management and leakage management. Inclusion of leakage management as a sub-set of traditional raw water resources management has much to offer in improved management of water resources for growing populations. If you are stimulated by water conservation as a water resources engineer/hydrologist, you will also find the learning curve of leakage management just as intellectually interesting, and not too steep. This presentation will present an overview of: myths, legends and misinformation about how and where leakage occurs; how to quickly quantify technical leakage management performance; numerous successful international applications of modern leakage management; where to obtain freely available information on leakage management, on the web.

13.2 Securing water supply in remote indigenous communities – the challenge for Wilcannia, NSW, Australia

Amy Bentley (Director, Jacobs)

Wilcannia is located on the Darling River in far western New South Wales, Australia. The town has a population of approximately 700 people and has a large Aboriginal community, being the traditional home of the Barkindji people (Barkindji meaning "people of the river"). Following growth in development across Australia in the early part of the 20th century competition for water was fierce. Increases in abstractions combined with long periods of drought resulted in Wilcannia struggling to have sufficient water to support the town. Historic records show that the Darling River has ceased to flow on many occasions due to drought. As a solution, the Wilcannia Weir was first constructed in 1942 to provide a weir pool from which water could be extracted during these periods of cease-to-flow conditions in the river system. However, the weir was last refurbished in 1988 and while still providing some storage for use as a community water supply, the weir is in a state of disrepair. As a result, the town is frequently on water restrictions and sourcing its water from emergency water bores. The NSW Government over a number of years have been investigating options for the weir including a new replacement weir. As the management of the Murray-Darling River Basin becomes even more contentious, this paper presents the key findings from the latest investigations to replace the weir at Wilcannia. The paper specifically raises some key issues on water supply and security, the cultural importance of the river to the community and how an understanding of the hydrology, watercycle and the relationship of water to people is at the heart of the project being a success.

13.3 Climate change impacts on urban water and sanitation services

Richard Opoku Boakye, Alison Parker, Paul Hutchings and Keith Weatherhead (Cranfield University)

Two billion people worldwide do not have access to improved sanitation facilities and a billion do not have access to potable water. Climate change is exacerbating problems in the WASH sector especially in developing countries. There is therefore the need to assess the impacts of climate change on WASH services and look at ways of climate proofing it. There is a current research project underway in Cranfield University to understand the types of responses that are already used to minimize risk and build resilience and workable measures that can be put in place to climate proof WASH services across Ghana's ecological zones. To achieve this, semi structured questions were posed to various WASH services' stakeholders. This was in line with the Rapid Climate Adaptation Assessment (RCAA), a rapid research methodology use to assess climate change impacts and help stakeholders to come up with ways of climate proofing water and sanitation services. Ghana was chosen to understand this problem because of its location in Sub-Saharan Africa - home to half of the people in the world living without access to improved water sources and fast changing climate. The climate change awareness of the WASH stakeholders in Kumasi (1of the 3 cities) was assessed. Though interviewees were aware of climate change, they had not incorporated it into their management plans. Two scenarios of less available water and localized flooding were developed. These scenarios will increase pipe burst, leakages and change the rate of emptying of septic tank. In adapting to climate change, specific adaptations were developed for various stakeholders.

13.4 Multi-scale climate control on groundwater risk: A synthesis

Will Rust (Cranfield University & Atkins)

Groundwater resource assessment in the UK has long been based on the premise that understanding response to annual fluctuation in groundwater recharge is sufficient for both managing future resource use and understanding risk. Typical resource risk assessments, such as those for abstraction licensing purposes, focus on groundwater store resilience to changes in annual-scale variability in climate (i.e. whether recharge in any given year is above or below the long term average). The response of a groundwater store to lower frequency, periodic climatic signals (for example, those produced by the North Atlantic Oscillation) is generally considered to be negligible, if not stationary. Despite this assumption, there is a growing body of evidence suggesting that groundwater stores can exhibit significant non-stationary signals of extra-annual (4 – 8 year) to multi-decadal (10 – 16 year) variability. In some cases, these signals have been found to be stronger than annual fluctuations. Such evidence could allow improved understanding of groundwater resilience to droughts which is not currently captured by existing approaches. At present, it is not clear how climate variability exhibits a systematic control at these scales, or how these signals propagate throughout an aquifer. Here, a synthesis of existing research in this field is provided, leading to the development of a new conceptual model of how signals found in climatic variability may progress through the water cycle to groundwater stores and ultimately discharge variability. Knowledge gaps are identified and the implications of these signals for groundwater risk management, and water resource planning, are discussed.

14 Resilient water use in agriculture & food production

Stafford Cripps (SC3) 1 September 2016 11:15 – 12:45

14.1 The importance of hydrology to future food supply

David Evans

In England & Wales only 1% of water abstraction is for agriculture, and its significance is perceived accordingly. But agriculture is by far the biggest consumer of our rainfall. For example, summer evapotranspiration in eastern England is some 400mm, mostly from crops. For comparison, total water supply in Anglian region over the same period is equivalent to only 12mm. Climate change will act on the whole of the 400mm (not just on the 1% deficit), with disproportionate impact on agriculture, and on the environment. And eastern England has no spare summer water to start with. In the rest of the world typically 70-80% of abstraction is for agriculture. Add the rain-fed component, and it is unquestionably the dominant water use. It is also problematic. Nature commonly gives us water in the wet season but little or none in the dry season, making dry-season water, and hence food supply, heavily dependent on storage even in normal years; even more so in time of drought. And yet all of the world's major water stores are in some kind of trouble: Aquifers; many of which are being unsustainably mined; Glaciers; most of which are melting; Seasonal snowmelt; all of which is under threat from climate change; Reservoirs; which can have problems of pollution, siltation and acceptability. In addition, evapotranspiration will increase in a warmer world, making global agriculture's need for water progressively bigger whilst the storage to meet it diminishes. There are problems enough already, and population is rising. So just where is the dry-season water going to come from to grow enough food in the decades ahead?

14.2 Using drought indices to assess impacts on UK irrigated agricultural production

Jerry Knox, David Haro and Ian Holman, (Cranfield University)

Droughts rank first among all natural hazards when measured in terms of the number of people and businesses affected and differ from other natural hazards in several ways: (i) droughts are a slow onset phenomenon, with their temporal and spatial boundaries difficult to determine as well as their impacts, (ii) the lack of a universal definition of drought often leads to confusion between water planners and abstractors; (iii) drought impacts are normally non-structural and spread over large geographical areas, and (iv) droughts may be triggered or exacerbated by human activities such as poor farming practices, deforestation, over-abstraction and other activities that reduce the availability of water resources within a system. High value irrigated agriculture is particularly sensitive to drought, not only in semi-arid areas, but also in temperate countries where irrigation serves to improve both yield and quality. Of particular importance is a farmers need to meet retailer demands for premium quality produce. Therefore, understanding the relationship between drought occurrence and its impacts on crop production is crucial to minimise future business risk. This research explores the utility of using various climatic drought indices in combination with agronomic aspects of irrigation to anticipate the occurrence of impacts in irrigated agriculture, with reference to potatoes, the most important irrigated crop in the UK. Recent long term climatic data covering the 20th century were used to derive a historical time-series of drought indices for different spatial and temporal aggregation scales. These datasets were also used to assess yield responses for potatoes over the reference period and to identify relationships between productivity, irrigation demand and drought risk. The findings have important implications for water resource planners managing irrigation abstractions, for the farming community growing high-value crops in an uncertain future climate, and for the fresh produce supply chain in understanding farm business adaptation options and responses to drought.

14.3 Effects of climate change on the likelihood of irrigation abstraction restrictions in the UK

Ian Holman and Dolores Rey (Cranfield University)

The use of abstracted water for irrigation and on-farm reservoir fill is globally important for the agricultural industry. In the UK, irrigation is supplemental to rainfall but can be crucial for achieving high quality crops. Water abstraction from surface waters for agricultural irrigation can be restricted by the Environment Agency during droughts, based on abnormally low river flow levels and rainfall forecast, causing significant economic impacts on irrigated agricultural production. The aim of this study is to assess the impact that climate change may have agricultural abstraction in the UK within the context of the abstraction restriction triggers currently in place. The trigger restrictions used by the Environment Agency under Section 57 of the Water Resources Act (1991) have been applied to the 'Future Flows hydrology' database to assess the likelihood of increasing restrictions on agricultural abstraction in the future by comparing the probability of voluntary and compulsory restrictions in the baseline (1961-1990) and future period (2071-2098) for 282 catchments throughout the whole of the UK. The results of this study show a general increase in the probability of future agricultural irrigation abstraction restrictions in the UK in the summer, particularly in the South West, although there is significant variability between the 11 ensemble members. The results also indicate that UK winters are likely to become wetter in the future, but could be associated with a small increased probability of abstraction restriction in the reservoir refilling winter months (November-February) in some catchments. An increasing frequency of drought events due to climate change is therefore likely to lead to more water abstraction restrictions to protect aquatic ecosystems, increasing the need for irrigators to adapt their businesses to increase drought resilience.

14.4 D-Risk, a resilience-building webtool to support irrigated agriculture under conditions for abstraction licensing reform

David Haro, Ian Holman, Jerry Knox (Cranfield University)

Irrigation is an essential component of crop production to meet supermarket and retailer demands for premium quality produce when rainfall is insufficient. Under drought conditions, the ability to provide sufficient irrigation can be constrained by abstraction licence conditions, with consequent important impacts on crop yield and quality and farm revenue. As part of the abstraction reform process, the Environment Agency is proposing to change the conditions of agricultural time-limited licences as they are due for renewal. These conditions would reduce the amount of water licenced for abstraction in order to meet objectives set by the Water Framework Directive. This will represent a major business water risk to the soft fruit, field vegetable, salads and potato growing businesses in regions that are dependent on direct abstraction. It is vital for irrigated farmers to understand the implications of these changes to their abstraction licences, to their risk management and to the competitiveness and economic viability of their businesses. This paper presents D-Risk, a web based decision support system developed together with agribusinesses in order to provide them with useful data that will allow them to evaluate: 1) how the proposed abstraction licence reforms will affect their licensed volumes; 2) how the reduced licensed volumes will impact on current farm business plans; and 3) how best to adapt their farm business plans and activities (through changing irrigated area or crop mix; investment in reservoirs; etc.) to achieve an acceptable level of drought risk under their reduced licenced volume. D-Risk uses a mixture of farm data, historical re-constructed weather data covering the whole of the twentieth century long-term climatic datasets, and pre-existing modelling tools that relate crop type to irrigation need. Through a case study example application of D-Risk, we will show its potential utility for agribusinesses and explain how the model will help increase farmer understanding of drought risk and resilience planning.

15 Penman Lecture: Managing the water limitation in agriculture under future scenarios

Vincent Auditorium 1 September 2016 14:00 – 15:00

Elias Fereres (Institute for Sustainable Agriculture and University of Cordoba, Spain)

Current trends in population growth, diet changes, and economic development suggest that there will be an increased demand for more food in the future, up to 70% more by 2050 in some scenarios. Consequently, agricultural productivity will have to increase and, given the close association between crop production and water use, agriculture will have to produce more with less water than it uses now. This is a difficult challenge because, contrary to common belief, water use efficiency in food production has increased remarkably in recent decades. Future efficiency enhancements in agricultural water use will be modulated by changes in the environment, crop genotypes, and by management interventions. The lecture will discuss the possible roles that genetic improvement, environment and management will play in further enhancing the productivity of water in future food production. In the short term, optimal management of a limited amount of water appears to be the best option. This is a problem that can easily be solved theoretically, but that in the real world becomes multifaceted thus demanding many more tools and skills to arrive at viable solutions.