BHS 2014

Session 3: Water resources management within an uncertain climate

ABSTRACTS

Oral presentations

3-1S: Modelling the effects of rural land use and management change on hydrologically effective rainfall under climate change.

T. M. Hess[1] & I. P. Holman[1]
[1]Cranfield Water Science Institute, Cranfield University, Bedford, MK43 0AL.
Phone: +44 1234 750111 Email: t.hess@cranfield.ac.uk

Climate and/or social change may stimulate rural land use and/or management changes which in turn can modify the hydrologically effective rainfall (rainfall – losses) and the partitioning between surface (quick) response and (slow) baseflow. This paper provides a modelled estimate of the effects of plausible future land use and management changes (induced by the 2050s) on average annual Hydrological Effective Rainfall (AAHER) and Potential Baseflow (PB) under present and future climates in 259 catchments across England and Wales. It concludes that climate change and land-use / land management change, in isolation or combination, can have potentially significant positive or negative impacts on average AAHER and PB, but land-use change may have the greater impact. The modelled results suggest that the sensitivity to land use and management change depends on the soil type and agroclimate - impacts are generally greater in drier parts of the country, with wetter areas being less sensitive to land-use change due to the lack of soil moisture limitations under the baseline climate. The relative magnitude of the hydrological impacts are generally greater for Potential Baseflow than for average annual Hydrologically Effective Rainfall. Changes in rural land use and/or management may have significant impacts on local water resources in some locations, whilst projected changes in climate may increase the geographical extent of these sensitive catchments.

3-2S: Capacity expansion optimisation for water supply investment decisions in England – limitations and extensions of current approaches

Silvia Padula[1], Julien J. Harou[2]
[1] Department of Civil, Environmental and Geomatic Engineering, University College London, UK. silvia.padula.09@ucl.ac.uk
[2] Department of Mechanical, Aerospace, and Civil Engineering, The University of Manchester, UK. julien.harou@manchester.ac.uk

Over the past decades in England's privatised water supply industry a single approach for water resource infrastructure expansion planning has been widely adopted. The method, called 'Economics of Balancing Supply and Demand' (EBSD) uses deterministic least cost capacity expansion optimisation models. EBSD models is formulated as a mixed integer linear programming optimisation model that selects the least cost annual schedule of supply and demand management options that meet forecasted demand over a planning horizon. Various applications and extensions to the EBSD framework are described using a South East England regional application based on public supply-demand data. 1. The model is used to evaluate the financial implications of further interconnectivity to assess the impact of water transfers beyond those currently proposed by water companies. The problem of using non-convex cost curves for inter-company transfers is overcome through piecewise linear techniques and special constraints to avoid model nonlinearities. 2. The uncertainty on supply and demand estimates are addressed via Monte Carlo simulation with two proposed iterative schemes. 3. The English price cap regulatory process and privatised water company incentive schemes are represented within a modified EBSD model formulation using a profit maximisation objective. The goal is to assess the effectiveness of current regulations by predicting water company investment decisions and assessing if they differ from least-cost socially optimal plans. Concluding, the talk reflects on the benefits and

limitations of the current EBSD approach and looks towards future applications and extensions of the method, and whether it should be abandoned for new approaches.

3-3S: Quantifying the impact of water company drought measures on water demand during the 2012 drought.

M. Zaidman[1], A. Wallis[2] & R. Critchley[3]
[1]JBA Consulting, South Barn, Broughton Hall, Skipton, North Yorkshire, BD23 3AE.
Email: maxine.zaidman@jbaconsulting.com
[2]Environment Agency, Kingfisher House, Peterborough, PE2 5ZR.
Email: angela.wallis@environment-agency.gov.uk
[3]Waterforte Consulting, 20 Vision Hill Road, Budleigh Salterton Devon, EX9 6EE.
Email: richard.critchley@yahoo.co.uk

During the 2012 drought, water use restrictions affected parts of South East England. Water companies initially used publicity campaigns to encourage voluntary restraint in water use but a formal Temporary Use Ban (TUB) was put into place in early April 2012. Fortunately the restrictions were reasonably short-lived as water resources were able to replenish rapidly due to the wet summer that followed. This paper reports a comparison of usage profiles during the 2012 drought based on restricted (observed) and unrestricted (modelled) conditions, which was used to identify if, when and by how much usage reduced as a result of the restrictions. A similar comparison was also carried out using data from the 2006 drought.

The water demand that would have occurred had restrictions not been in place was estimated using multivariate regression models calibrated on seasonal and meteorological factors. A stepwise generalised least squares approach was used to minimise the effects of correlation between explanatory variables and the modelling also included a, consideration of non-linear relationships and evaluated the inclusion of lagged variables. The study determined that unrestricted water use can be forecast reasonably accurately using a linear regression model based on explanatory variables related to temperature, rainfall, potential evapotranspiration, soil moisture deficit and sunshine hours. Restrictions on water use were found to significantly influence demand, particularly at peak times. However in 2012 the impact of restrictions on water use was limited as the drought quickly terminated not long after.

3-4S: Presentation of the new CEH-GEAR dataset: fine resolution daily and monthly areal rainfall estimates for the UK for hydrological use.

M. Tanguy[1], V. D. J. Keller[1], I. Prosdocimi[1], J. A. Terry[1], O. E. Hitt, S. J. Cole[1], M. Fry[1], D. G. Morris[1] and H. Dixon[1]
[1] NERC Centre for Ecology & Hydrology, Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB, UK
M. Tanguy Phone: 01491 69 2342 Email: malngu@ceh.ac.uk
V. D. J. Keller Phone: 01491 69 2399 Email: vke@ceh.ac.uk
I. Prosdocimi Phone: 01491 69 2427 Email: ilapro@ceh.ac.uk
J. A. Terry Email: julie.a.terry@outlook.com
O. E. Hitt Phone: 01491 69 2721 Email: olihit@ceh.ac.uk
S. J. Cole Phone: 01491 69 2263 Email: scole@ceh.ac.uk
M. Fry Phone: 01491 69 2287 Email: mfry@ceh.ac.uk
D. G. Morris Phone: 01491 69 2428 Email: dgm@ceh.ac.uk
H. Dixon Phone: 01491 69 2254 Email: harr@ceh.ac.uk

The Centre for Ecology & Hydrology - Gridded Estimates of Areal Rainfall (CEH - GEAR) dataset consists of 1-km gridded estimates of daily and monthly precipitation rainfall for

Great-Britain (GB) and Northern Ireland (NI), currently from 1890 to 2012. The dataset will be updated annually when new raingauge data are available.

The gridded rainfall estimates are derived by applying the natural neighbour interpolation method to the national database of raingauge observations collated by the MetOffice. The CEH-GEAR dataset complies with the guidance on estimation of areal rainfall provided in the British Standard BS7843:2012.

The CEH-GEAR dataset was primarily developed to support hydrological modelling, but is freely available to any interested user. Potential uses of the dataset include management of water resources, catchment modelling, frequency analysis, groundwater recharge and drought monitoring amongst many others.

The presentation will outline the new dataset, how to access it and some of its possible uses, including an example application of the dataset to drought monitoring.

3-5L: Citizen science for water resources management and poverty alleviation: experiences from data scarce mountain regions

W. Buytaert[1], Z. Zulkafli[2], Art Dewulf[3], David Hannah[4], Julian Clark[5], Bert De Bievre[6] & Luis Acosta[7]

[1]Civil and Environmental Engineering & Grantham Institute for Climate Change, Imperial College London, SW7 2AZ, London, UK. Phone: +44 207 594 1329 Email: w.buytaert@imperial.ac.uk

[2]Civil and Environmental Engineering, Imperial College London, SW7 2AZ, London, UK. Email: z.zulkafli10@imperial.ac.uk

[3]Public Administration and Policy group. Wageningen University, 6700EW Wageningen, NL Email: art.dewulf@wur.nl

[4]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT Email: d.m.hannah@bham.ac.uk

[5]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT Email: j.r.a.clark@bham.ac.uk

[6]CONDESAN, Lima, Peru. Email: bert.debievre@condesan.org

[7]CONDESAN, Lima, Peru. Email: luis.acosta@condesan.org

Mountain regions are complex socio-ecological systems undergoing unprecedented environmental changes. At the same time, they are some of the most data scarce regions in the world. This is especially true for remote regions such as the Himalaya and the Andes. Citizen science, potentially backed by new sensor technology, mobile networks, and cloud computing, holds a lot of promise for data collection to improve water resources and other ecosystem services in these regions.

Indeed, the availability of cheap and user-friendly sensors is giving participatory approach science a major impulse. This evolution holds great promise for data collection on ecosystem services. However, converting raw experimental data into useful knowledge to inform local management requires a complex process involving data processing, quality control, scenario development, scenario testing, prediction, and uncertainty analysis. For this, new advances in mobile computing, web-services and interactive visualization can be very useful.

Here, we present the results of experiments to leverage such new technologies support the collection of hydrological data and co-generation of actionable knowledge in remote communities in the Andes of Ecuador, Peru and Bolivia. As a response to rapid environmental change and stresses on water resources and other ecosystem services, local communities have taken the initiative to install rain and river gauges to generate improved evidence for better decision-making. We show how elements of citizen science can be used to transform the raw data collected by local people into actionable knowledge informing and supporting local decision.

3-6L: How far can we have a detailed understanding of catchment hydrological function?

Keith Beven[1]
[1] Lancaster Environment Centre, Lancaster University, UK, LA1 4YQ
Phone: +44 524 593892 Email: k.beven@lancaster.ac.uk

It rains. Water levels in the soil, groundwater, and streams rise, the stream network expands. And when it does not rain, water levels in the soil, groundwater and streams fall, and the stream network contracts. We have models for how catchments respond in these ways that are regularly used for water resources management, flood forecasting, catchment planning and other practical applications. Indeed, such models are often used deterministically, including in assessing the impacts of future change or management strategies, as if they reflected a true understanding of catchment hydrological function. But that understanding is limited, particularly in terms of how spatial patterns of inputs and flow pathways influence what is seen as a water level response in the streams. Distributed models have the potential to incorporate such spatial patterns but the information required to have a detailed understanding of what goes on in the subsurface is limited. This will be demonstrated by some studies of incremental discharges in small catchments that illustrate the importance of uniqueness of catchment characteristics in controlling the response. The implications for assessing uncertainty in model outputs will also be discussed.

3-7L: Influence of choice of Global Precipitation Products on hydrological modelling of a Himalayan river basin

Renji Remesan[1], & Ian Holman[1]
Cranfield Water Science Institute, College Rd, Cranfield, Bedford MK43 0AL
Phone: +44 (0)1234 750111
Email: r.remesan@cranfield.ac.uk

The Indian sub-continent is characterized with highly temporally and spatially variable precipitation patterns. The flow regime of Himalayan rivers, such as the River Beas in north west India, are influenced by the combined effects of monsoon precipitation and temperature-related snow melt. In this study, we have investigated the influence of precipitation uncertainty on both model parameterisation and predictive uncertainty in the Beas River basin using the Soil and Water Assessment Tool (SWAT) model. The model has been calibrated against measured discharge data using three different precipitation data sets: (1) National Centres for Environmental Protection (NCEP) Climate Forecast System Reanalysis (CFSR) data, (2) Asian Precipitation – Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) (3) Tropical Rainfall Measuring Mission (TRMM) 3B42 V7. The best performing model parameter sets and related uncertainties were identified using Generalized likelihood uncertainty estimation (GLUE). However, although all three models produced similar hydrological simulations, based on Nash-Sutcliffe Efficiency and Percent Bias, the parameter uncertainty range varied significantly with the precipitation data sets. The differing parameter uncertainty associated with the selection of historical weather data, and the resultant effects on hydrological process behaviour, has important implications for the use of such models in climate change impacts studies.

3-8S: Many-objective scenario optimization of regional water resource systems under uncertainty

Ivana Huskova[1], Julien J. Harou[2], Joseph R. Kasprzyk[3], Patrick M. Reed[4], Evgenii S. Matrosov[5]
[1] Department of Civil, Environmental and Geomatic Engineering, University College London, London, WC1E 6BT, UK
Phone: +44 785 660 0620, Email: i.huskova@ucl.ac.uk

[2] School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester, M13 9PL, UK
Phone: +44 161 306 4589, Email: julien.harou@manchester.ac.uk
[3] Department of Civil, Environmental and Architectural Engineering, University of Colorado, ECOT 441, UCB 428, Boulder, CO 80309, USA
Phone: +1 724 504 6084, Email: joseph.kasprzyk@colorado.edu
[4] School of Civil and Environmental Engineering, Cornell University, 211 Hollister Hall, Ithaca, NY 14853-3501, USA
Phone: +1 607 255 2024, Email: patrick.reed@cornell.edu
[5] School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester, M13 9PL, UK
Phone: +44 759 547 2938, Email: evgenii.matrosov@manchester.ac.uk

Climate change, population growth, regulatory changes and the uncertainties inherent in these pose a major challenge to planning of water supply systems. Using historical river flow records to predict the behaviour of water resource systems into the future is not sufficient since the hydrologic record can no longer be assumed to represent future conditions. Different approaches to planning under uncertainty are being developed in the water supply area. Because water systems are complex and need to fulfil many societal goals, many-criteria methods that accommodate multiple conflicting objectives are appropriate. Our study optimises London's future water supply system investments using multi-criteria search, an efficient water resource system simulator, and many-objective visualization. The many-objective scenario optimization combines multiple realizations of future hydrological flows with possible future demand, and sustainability reductions scenarios. We seek system robustness by constraining the frequency of failures across all scenarios in addition to many performance objectives such as cost, resilience, reliability, and environmental performance. The presentation summarises recent work where we investigate the possibility of representing investments as dynamic adaptive trajectories rather than static portfolios and discuss the challenges this poses.

3-9S: A review of Scottish snow cover related to the North Atlantic Oscillation index.

M. Spencer[1], R. Essery[1]
[1]Grant Institute, School of GeoSciences, King's Buildings, University of Edinburgh, Edinburgh, UK, EH9 3JW
Phone: +44 131 650 5916 Email: m.spencer@ed.ac.uk

The phase of the North Atlantic Oscillation (NAO) has been suggested by many researchers to affect snow cover in Europe. Relating the two is of use to those using snow or managing water resources as it could allow them to estimate the duration of snow cover from measurements taken early in winter. In this study we look at three datasets describing snow cover from sea level to above 1200 m: the Bonacina snow index, the Met Office UKCP09 snow cover grid (MO grid) and the Snow Survey of Great Britain (SSGB), and relate them to the NAO index derived by the University of East Anglia Climatic Research Unit. The relationship between NAO and the Bonacina index, which subjectively describes snow cover across Britain, gives a significant ($p<0.05$) trend of negative NAO index leading to snowier winters. A Pearson correlation between NAO index and the days of snow cover MO grid during DJF indicates a strong ($r>0.7$) relationship in the East and West away from main mountain areas. The relationship between the SSGB and NAO index suggests that observation period has an impact on the correlation: when NAO is compared month by month to snow cover duration the best correlations are found at lower elevations, but when NAO is averaged over DJF then the best correlations are found at higher elevations. This suggests that snow cover at higher elevations are less susceptible to short term changes in

weather patterns. There is an indication that the days of annual snow cover may be forecast using early winter values of NAO.

3-10S: Can land use and land management make a difference to water availability?

H.A. Houghton-Carr[1], D.B. Boorman[1] & K.M. Heuser[1]
[1]Centre for Ecology & Hydrology (CEH), MacLean Building, Crowmarsh Gifford, Wallingford, UK OX10 8BB
Phone: +44 1491 692332 Email: hahc@ceh.ac.uk

Evidence Reviews are a systematic approach to understanding the state and quality of data and information available on specific issues. They involve taking stock of what has been produced and reviewing it in a systematic way to address specific questions, and identifying knowledge gaps and further data and information needs. Increasingly, they are being used by the UK Government to inform policy and practice, with the assurances of transparency and objectivity increasing acceptance of the results by stakeholders, the scientific community and the public. This paper presents a critical analysis of the Evidence Review process, illustrated with reference to a Rapid Evidence Assessment (REA) commissioned by Defra in 2013 to answer the question "Can land use and land management make a difference to water availability?" based on published evidence, not hearsay and personal perception. Draft guidance produced by Defra was utilised to develop a protocol for conducting the REA. The REA concluded that it may take many decades for the impacts of land use/management practices on surface and groundwater resources to become apparent, and that impacts that are observed are generally localised, with what appear to be large changes at the field, plot or sub-catchment level manifested as only small changes at the catchment or basin level. In order to generate a larger body of UK-specific evidence, there is a need for coordinated, targeted research and long-term monitoring to investigate the water-related impacts from the most important land use/management interventions, across a variety of catchment types.

Poster presentations

3-1P: The use of acoustic flow determination devices and velocity index ratings – a hydrometrist's delight or another potential source of uncertainty in the hydrological record!

S Child[1], M. Dibley[2] & N. Whalley[3]
[1] Hydro-Logic Services LLP, The Corner House, 18 - 20 West End Road
Mortimer, Berks RG7 3TF Tel. 0118 9331325, Email: schild@hydro-logic.co.uk
[2] Hydro-Logic Services LLP, Suite 1, The Old Cattle Shed, Lower Town, Sampford Peverell, Tiverton, Devon. EX16 7EG. Tel. 07771865864, Email: mdibley@hydro-logic.co.uk
[3] Hydro-Logic Services LLP, Suite 1, The Old Cattle Shed, Lower Town, Sampford Peverell, Tiverton, Devon. EX16 7EG. Tel. 07717 204364, Email: nwhalley@hydro-logic.co.uk

Over 60% of the primary flow measurement network in England is comprised of structures. Recent legislation has resulted in increased pressure to provide fish passage at, or removal of, flow measurement structures in the UK. This could have a significant impact on the quality and consistency of the UK's flow measurement records.

Hydro-acoustic Doppler and radar technologies provide a means of estimating continuous discharge by determining a velocity component together with the stage-area relationship at the measuring cross-section. They are frequently considered as viable and cost effective replacements for flow measurement structures and alternatives to transit time ultrasonic systems.

A number of practitioners have installed such devices because of their ease of installation and relatively low costs and in doing so have lost sight of the ongoing commitments and in particular the need to develop relationships between the measured (index) velocity (V_i) and the mean velocity ($\overline{V}$). At some sites it is possible to readily develop simple velocity index ratings, whereby $\overline{V} = fn(V_i)$. However, at more complex locations, particularly where variable backwater occurs it is often necessary to develop relationships which also include stage (h) as a parameter, of the form: $\overline{V} = fn(V_i, h)$. Even these types of relationship can be unstable at some sites. It is therefore essential that the perceived benefits are balanced against the accuracy and stability of the velocity-index rating and the resulting uncertainties in the flow determinations.

The paper draws on the authors' considerable experience of using both structures and acoustic devices to demonstrate their applications, attributes and limitations, including the potential for introducing greater uncertainty to hydrological records.

3-2P:Thermal patterns in a lowland stream during seasonal and supra-seasonal droughts in the UK using Fibre-Optic Distributed Temperature Sensing

S. Folegot[1], David Hannah[2], W. Buytaert[3] & S. Krause[4]
[1]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT
Email: SXF356@student.bham.ac.uk
[2]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT
Phone: +44 (0)121 41 46925; Email: d.m.hannah@bham.ac.uk
[3] Faculty of Engineering, Department of Civil and Environmental Engineering, Imperial College of London, 335 Skempton Building South Kensington Campus
Phone: +44 (0)20 7594 1329; Email: w.buytaert@imperial.ac.uk
[4]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT

Phone: +44 (0)121 414 5535; Email: s.krause@bham.ac.uk

The effects of climate change and increasing human adaptation and intervention are expected to affect the global water cycle over the 21st century, with increased drought frequency and severity (Prudhomme et al., 2013). An intensified hydrological cycle could threat freshwater biodiversity (Jacobsen et al., 2012), alter water availability and impact the delivery of ecosystem services (Terrado et al., 2014). Decreasing precipitation and changes in runoff generation and groundwater recharge have the potential to increase relative proportions of groundwater contributions to stream discharge with implications for stream temperatures, metabolism and ecosystem performance. Water temperature is a key variable and natural tracer to assess groundwater-surface water (GW-SW) exchange. Fibre-optic Distributed Temperature Sensing (FO-DTS) is a novel sensor technique that permits high-resolution, continuous monitoring of T patterns at the GW-SW interface. In this study, FO cables will be installed along stream reaches and vertically within the stream bed sediments. In combination with numerical modelling approaches, FO-DTS will help quantifying water and heat fluxes at the GW-SW interface under drought conditions to understand energy and water exchange processes. We furthermore aim to develop and validate a model-based risk assessment framework to improve predictive capacity for the quantitative assessment of thermal responses to drought under assumption of different climate projections and groundwater abstraction rates.

3-3P: The Sizing of New Dams Affects Food-Energy Security Trade-offs – Application to Blue Nile infrastructure investment

Robel T. Geressu[1], Julien J. Harou[2]
[1]Department of Civil, Environmental and Geomatic Engineering, University College London, Chadwick Building, Gower Street, London, WC1E 6BT, UK
Phone: 07473333676 Email: robel.geressu.12@ucl.ac.uk
[2]Department of Mechanical, Aerospace, and Civil Engineering, The University of Manchester, Manchester M13 9PL, UK. Email: julien.harou@manchester.ac.uk

This study proposes a multi-criteria screening approach for selecting the best performing infrastructure configurations and operation strategies for multi reservoir systems that meet many objectives under climate change uncertainty. We use a water management simulation model to track hydropower and irrigation supply benefits of the different combinations of four proposed hydropower dams in Ethiopia and two existing multipurpose dams in Sudan on the Blue Nile River. Linking the simulator to a many-objective search engine enables exploring the decision space efficiently to identify the most promising system designs from different stakeholder perspectives. Results take the form of Pareto-optimal trade-offs where each point on the curve or surface represents the design (in this case combination of reservoirs and their sizes) and management policies (operating rules) with the highest achievable performance. In our case-study trade-offs between five objectives including minimizing capital costs of dams, maximizing energy output and the reliability of energy and water supply for irrigation in Ethiopia and Sudan, are derived and plotted using interactive visual analytic tools. Promising combinations of investments that offer viable win-win balances between different stakeholder objectives are suggested. The approach fulfils decision-makers desire to see the link between future plans (system designs) and allocation of benefits between different sectors and users.

3-4P: Vulnerability of water resources to climate change and human impact: a scenario analysis of the Zayandeh-Rud river basin, Iran.

S. Javadinejad[1]; Stefan Krause[2] & David M. Hannah[3]
[1]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT
Phone: +44 121 4145682 Email:sxj228@bham.ac.uk

[2]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT
Phone: +44 (0)121 414 5535Email:s.krause@bham.ac.uk3
[3]School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, UK, B15 2TT
Phone: +44 (0)121 41 46925 Email: d.m.hannah@bham.ac.uk

Currently, water resources are facing severe challenges particularly in semi-arid and arid regions where trends of reduced precipitation and increasing temperature are in conflict with increasing human water demands. Drought events are recurrent phenomenon with consequent significant impacts on socio-economic and environment systems. Water allocation decisions and water resources planning are part of complex, multi-disciplinary processes overarching a wide range of stakeholders with different interests, expertise, knowledge and priorities. Successful planning needs effective Integrated Water Resource Management models that can address these complex problems. The purpose of this study is to develop framework for effective and systematic risk management of water resources during periods of drought. This management framework integrates hydrological, agricultural and water planning models. The methodology has three sections. First, the statistical properties of drought are analysed and thresholds of drought alert are defined to evaluate triggers for management actions. Second, water demand for agriculture, industry and domestic are specified during the normal and drought periods. Third, a water planning model (WEAP) is used to integrate water availability and demand and evaluate the range of possible adaptation management actions that reduce the risk of water deficits. This methodological approach links the dynamic aspects of water availability and demand and its statistical properties needed for risk analysis to operational aspects of water management at the basin level. The methods are tested the Zayandeh-Rud river basin in Iran. The results of the study will try to show its applicability for integrated analysis of drought that incorporate a demand analysis approach and the evaluation of climate change scenario and other possible scenarios. So for the evaluation of drought impacts on water management the Standard Precipitation Index (SPI) is calculated for accumulated precipitation every 12 months for every meteorological station and the threshold level for drought identification has been set to -1, this means that these years that present precipitation values below the average precipitation minus one standard deviation are the ones identified as drought years. In the Zayandeh Rud basin the upper stations show less coincident drought events with the rest of the basin, confirming the climatic differences between mountainous and the flat areas. Drought periods characterized in the rest of the basin are more similar. Also the result analysis shows for all the hydrological areas in the basin where each of the SPI values selected as thresholds for drought management stages there is association with decreases of inflows.

3-5: Using remotely sensed products for improved hydrological models in high mountain hydrological regimes

F. Mhenga[1], H. Fowler[1] & R. Gaulton[1]
[1]School of Civil Engineering & Geosciences,
Cassie Building, Newcastle University,
Newcastle Upon Tyne NE1 7RU, UK
Phone: 0191 222 7113, Email: f.d.mhenga@newcastle.ac.uk

About 16.7% of the World's population relies on water supplied by high mountainous catchments. The hydrological regimes of these high mountain regions are complex and characterized by extreme seasonal and annual variations. It is thus very important that we have appropriate and efficient tools to support our understanding of the current and future state of our water resources. However, these tools require extensive data sets and parameters to produce reasonable results. Unfortunately, these input parameters and

variables are mostly available as point measurements i.e. weather parameters. The spatial distribution of these parameters is derived by interpolating between point measurements which sometimes leads to poor model outputs. Again, large parts of the world are facing challenges of in-situ data availability for hydrological modelling. The situation is more severe in high mountain catchments where monitoring stations tend to decrease with an increase of elevation. Integrating remotely sensed products into hydrological models seems to be a solution. Remote sensing products can be used to improve model performance, either by optimizing model parameters or by correcting the state produced by the model. Lack of ground data especially over high mountain catchments; and the need for comprehensive understanding of the current and future state of water resources is the primary motivation for this proposed work. Therefore, the main focus of this study is to develop a modelling approach/tool that will use less ground observed data and more remotely sensed data as a solution toward decreasing availability of ground data, especially in developing countries.

3-6: Canal & River Trust's Water Resource Strategy: delivering long term security of water supply to our canals

D. J. Mould, M. Wells
Water Management Team, Canal & River Trust, Canal Lane, Hatton, UK, CV35 7JL
Phone: +44 01926 626148 Email: david.mould@canalrivertrust.org.uk

The Canal & River Trust is the charity that cares for England and Wales' legacy of 200 year-old waterways. The Trust has responsibility for 2,000 miles of canals, rivers, docks and reservoirs. The Water Management Team provide the business with technical advice on all aspects of water management including flood and drought response, efficient use of water resources and infrastructure design. The team strives where possible to align with the industry requirements of our closest analogues – water companies – and effectively plan for future water resource pressures. The process for defining our Water Resource Strategy mirrors some of our values of being open, engaging with stakeholders and achieving technical excellence.

Within the Strategy, definitions for 'drought' and 'level of service' are derived with discussion of associated implications for CRT. The network is categorised into distinct 'hydrological units' with their boundaries/interfaces delineated. Consistent, robust baseline water balances are derived for those units where CRT have sufficiently detailed information; a timetable for the remaining hydrological units is set out.

As part of the Strategy, it is critical to also assess the role of future pressures on water resources. Bespoke approaches to modelling the impacts of on the network are derived for: climate change; investment and associated asset management; water availability (from regulatory reform), and increased usage of CRT's network. The impacts are assessed against baseline modelling for the period to 2080, in order to drive water resources investment. All work is related to a delivering given levels of service.

3-7P: Modelling abstractor behaviour under weather and climate uncertainty.

E.K. Weatherhead[1] & C. Henriques[2]
[1]School of Applied Sciences, Cranfield University, UK, MK43 0AL
Phone: +44 1234 758368 Email: k.weatherhead@cranfield.ac.uk
[2]School of Applied Sciences, Cranfield University, UK, MK43 0AL
Phone: +44 1234 750111 ext. 3336 Email: catarina.c.henriques@gmail.com

Understanding the relative benefits of alternative water uses is fundamental to rational water resource allocation and modelling abstractor behaviour. This becomes particularly important as water scarcity increases under climate change, and the performance of alternative future allocation systems such as water trading and investments such as reservoirs need to be assessed under climate uncertainty.

A farmer (abstractor) has to decide each week whether to irrigate. When ample water was available, benefits could be simply compared to costs. Under water shortage limitations

however, for example using a reservoir or an abstraction licence, the farmer must also consider the risk and cost of running out of water later in the season. With multiple crops, soils and water sources, the decision can become highly complex, particularly if the farmer also has the option of trading water. A simple model was required to represent farmer behaviour within an agent–based water allocation and trading model, intended to study catchment water management under current and future climates.

A probabilistic approach was developed which values the remaining resource by considering rainfall uncertainty over the rest of the season. Typically, the value drops as the season progresses for a given remaining volume, but rises if the remaining water is used up too fast. This value can then be used to allocate water between crops, between immediate and later use, and for evaluating options to buy or sell water. The model outputs and implication for catchment water resource management under uncertainty will be discussed.