2-4 DECEMBER 2015

NEW DELHI, INDIA

FUTURE GANGA: SCIENCE NEEDS FOR WATER SECURITY

Report of Scientific Workshop

Conclusions of a joint India-UK hydrological sciences workshop exploring the future research needs and challenges which will underpin sustainable management of the Ganga.

V1

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Convened by the:

NERC CENTRE FOR ECOLOGY & HYDROLOGY

United Kingdom

www.ceh.ac.uk

Contents

Workshop Contact

The workshop was convened by the Centre for Ecology & Hydrology (CEH) and was led by Professor Alan Jenkins, Deputy Director of CEH. The workshop organiser was:

Dr Harry Dixon
+44 (0)1491 692254
harr@ceh.ac.uk

Introduction

This document outlines the conclusions of a joint India-UK science workshop convened by the Centre for Ecology & Hydrology in New Delhi in December 2015. It outlines the aims and structure of the workshop along with the conclusions, including eight high-level scientific challenges where future India-UK collaboration has the potential to support management of the River Ganga.

Workshop Aims

The Ganga basin extends over an area of 1,000,000 km^2 and is home to over 450 million people. Rapidly increasing population, rising standards of living and exponential growth of industrialisation and urbanisation have exposed water resources across the basin to various forms of degradation. Issues such as the over-extraction of water sources and discharge of pollutants are threatening current and future water security. In 2014 the Indian Government announced the setting up of an Integrated Ganga Conservation Mission to clean up the river called "Namami Ganga". Expected to last at least 18 years, the initiative will require significant scientific inputs to support integrated solutions to manage the river.

This workshop aimed to bring together leading freshwater scientists from across India and the UK to explore the future scientific needs and challenges which will underpin the sustainable management of the Ganga. The workshop intended to develop ideas for future scientific collaborations between India and the UK which will address key knowledge gaps in our understanding of the basin's hydrology and cultivate innovations in water resources management.

Delegates

A total of thirty nine delegates attended the workshop over the three days, from a broad variety of Indian and UK organisations involved in scientific activities in the Ganga basin. Delegates included representatives of the Government of India; UK Science Coordinators; numerous Indian Institutes for Technology and Science; government sciences centres in the UK and India; universities and; Non-Government Organisations. A full list of delegates can be found below. Contact details and an overview of delegates' research interests can be found in Annex A.

Name	Institution
Prof. Alan Jenkins	Centre for Ecology & Hydrology, UK
Dr Harry Dixon	Centre for Ecology & Hydrology, UK
Prof. Bob Ferrier	James Hutton Institute, UK
Prof. Mike Acreman	Centre for Ecology & Hydrology, UK
Prof. Paul Whitehead	University of Oxford, UK
Dr Gwyn Rees	Centre for Ecology & Hydrology, UK
Mr Andrew McKenzie	British Geological Survey, UK
Prof. John Rowan	University of Dundee, UK
Prof. Adebayo Adeloye	Heriot-Watt University, UK
Mr Barry Greig	Scottish Government, UK
Prof. Pradeep Mujumdar	Indian Institute of Science Bangalore, India
Prof. Muddu Sekhar	Indian Institute of Science Bangalore, India
Prof. Vinod Gaur	CSIR Fourth Paradigm Institute, India
Prof. Rajiv Sinha	Indian Institute of Technology Kanpur, India
Dr Argha Banerjee	Indian Institute of Science Education and Research Pune, India
Dr Sharad Jain	National Institute of Hydrology, Roorkee, India
Prof. Sachchida Tripathi	Indian Institute of Technology Kanpur, India
Dr Arpita Mondal	Indian Institute of Technology Bombay, India
Prof. Vinod Tare	Indian Institute of Technology Kanpur, India
Prof. Arun Kumar	Indian Institute of Technology Roorkee, India
Prof. B.R. Chahar	Indian Institute of Technology Delhi, India
Dr Arjamadutta Sarangi	Indian Agricultural Research Institute, India
Mr Yogesh Sharma	Independent, India

Mr Vinay Shankar	Independent, India
Dr Swati Basu	Ministry of Earth Sciences, India
Dr Vijay Kumar	Ministry of Earth Sciences, India
Mr Suresh Babu	WWF-India
Dr Nafees Meah	Research Councils UK (RCUK) India
Ms Melissa Else	British High Commission, New Delhi, India
Mr Puskal Upadhyay	Ministry of Water Resources, River Development & Ganga Rejuvenation, India
Mr Hari Har Mishra	Ministry of Water Resources, River Development & Ganga Rejuvenation, India
Ms Mansi Tripathi	Ministry of Water Resources, River Development & Ganga Rejuvenation, India
Ms Priyanka Jha	Ministry of Water Resources, River Development & Ganga Rejuvenation, India
Mr Ashwin Pandya	Central Water Commission, India
Mr Vinay Kumar	Central Water Commission, India
Mr N N Rai	Central Water Commission, India
Mr M Raghuram	Central Water Commission, India
Mr Rishi Srivastva	Central Water Commission, India
Mr Jyotiraj Patra	ESPA Programme

Workshop Structure

The workshop was structured around the six key areas where scientific research is needed to underpin the future development and sustainable management of the Ganga. The topics for the workshop were:

1) Water & Ecosystems,
2) Water & Agriculture,
3) Water & Urban Areas,
4) Water & Industry,
5) Water & Energy,
6) Water & Hazards.

Each topic formed the focus of a workshop session, comprising presentations from Indian and UK experts and an interactive discussion amongst delegates. Invited topic speakers were asked to give presentations outlining:

a) Their vision for what the Ganga will/should look like (in relation to their issue) in 2050,
b) The background to the key topic issues,
c) Recent scientific developments in the basin and more widely,
d) The science required now to support catchment management,
e) The science required in future.

Discussion sessions considered the scientific needs and challenges within the basin. A full outline of the workshop Agenda and details of presentations can be found in Annex B. Presentations have been made available online with this report at:

http://www.ceh.ac.uk/news-and-media/blogs/future-ganga-science-needs-water-security

Workshop Conclusions

The workshop discussions covered a very wide range of topics from farm-scale water management to the impacts of aerosols on precipitation patterns. Delegates considered a number of thematic and cross-cutting issues drawing both high-level and supporting conclusions.

High-Level Conclusions

During the concluding session the scientific issues were summarised into eight science challenges which were seen as key to the future sustainable management of the Ganga basin and so requiring urgent research attention. These were:

1. A unified modelling approach for the Ganga river basin needs to be developed.

   An integrated, whole-system, distributed model is considered crucial to better inform decision making. The first steps are to define the scope of the model in terms of process representation (e.g. including hydrology, ecology, geomorphology, pollution) and the most appropriate space and time scales. This latter needs to be consistent with the data currently available from ground and remote-sensing sources and commensurate with the scale at which water management decisions are taken.

2. There is a need to understand how large-scale, human-induced changes in the Ganga basin (including land use, urbanisation and climate change) feedback to the whole hydrological system.

   Understanding the hydrological cycle and the changes that may occur in the flow regime is key to management of the basin and its function. For example, there are local and basin-scale questions of immediate and longer-term concern as to how an increase in irrigated area, increasing urban areas, rising demand for energy and changing atmospheric compositions (including aerosol interactions), both individually and in combination, will affect the hydrological system.

3. Understanding of the dynamic interaction between surface and groundwater in the Ganga basin needs to be improved.

   The total water resource of the Ganga basin needs to be managed as an integrated system and in this respect, the distinction between surface and groundwater is not helpful. The surface and groundwater systems are closely linked and yet there remain large areas of uncertainty and a lack of process understanding. For example, in our understanding of the impact of leakage from canals, the performance of artificial recharge dams, changing irrigation practices and the effects of urban water use on surface-groundwater interactions.

4. There is an urgent need to define the sources, pathways and fate of environmental contaminants.

   In terms of water quality and pollution, the restoration of the Ganga requires a full understanding of source, pathway, fate and impact of a wide range of contaminants such that pollution sources can be identified and appropriate legislation implemented. For example, what are the impacts of agricultural practices on soil health and the fate of agrochemicals, what is the role of sediment in ecological functioning and pollutant transport and how do microbial loads impact on human health?

5. The amount of water required to support the ecological functioning of the Ganga and its floodplain needs to be better understood.

   The definition of environmental flows is at the forefront of discussions around the future sustainable management of the Gangs. In this respect, it is clear that we must look beyond setting a 'minimum flow requirement' to consideration of the whole flow regime in support of the ecological and hydromorphological status of the river.

6. New techniques are needed to augment traditional environmental monitoring.

   To address the complex issues identified in the future restoration and management of the Ganga, observational environmental data is crucial. In this respect, new technologies in water quality monitoring need to be tested and implemented and other novel sources of data should be considered. For example, through the use of citizen science, remote sensing and eco-genomic fingerprinting.

7. The spatial and temporal patterns of hydrologically related hazards need to be determined and the potential impact of non-stationarity in management decisions explored.

   Our understanding of the distribution and risk of extreme hydrological conditions (floods and droughts) within the Ganga basin should be improved. Current management of hydrological risks and water resources in the basin rely upon the past hydrological record as an indicator of the future. Under conditions of climate change, however, this assumption is likely to be violated and so new methodologies are required to inform risk assessment, protection and management.

8. There is a need to define how science can support development of a future vision for the Ganga.

   In order to align scientific efforts with management aspirations, it is important that Ganga stakeholders decide what sort of river they want - setting objectives and defining policy. Science should play a key role in helping stakeholders set realistic expectations and objectives for the river's rejuvenation. For example, science can help decision makers: assess options by providing quantitative assessments of the benefits of rejuvenation; identify the appropriate indicators they need to monitor their policies; inform intervention time-scales; define trade-offs, tipping points and system failures?

In addition to these eight key research questions/challenges a number of cross-cutting issues were identified. These included:

- The need to work at a variety of geographical scales, tackling issues of upscaling as well as downscaling;
- The need to reach out to other scientific, policy and governance groups as well as wider ongoing initiatives (the proposed UK-India Virtual Joint Centre for Water Research could play a central role in this regard, assisting with engagement with key stakeholders);
- The need to consider issues in a socio-ecological framework;
- The need to develop appropriate hydro-climatic services to inform research and decision making.

Supporting Conclusions

In addition to the high-level conclusions, delegates determined that in order to deliver on the eight key research challenges there were a larger number of subsidiary questions/issues which need to be tackled. These were summarised according to a number of areas as outlined below, with some cross-cutting issues. In many of these areas it was felt that there were tangible science projects which could be taken forward over the short to medium-term as India-UK collaborations or as part of larger, longer-term research programmes.

Cross-Cutting Modelling

Three important cross-cutting issues in relation to modelling were identified:

- In developing models we need ways of constraining and meaningfully conveying uncertainty of model predictions;
- We should explore the utility of ensemble modelling approaches for assessing hydrological impact;
- Coupling socio-economic models and hydrological models at the required spatial scales to inform decision making (for example, to allow agricultural decision making at a farm scale) presents major challenges which should be explored.

Data and Information

The issues of data availability and quality were considered in a number of the Workshop's sessions. While the challenges in this area are not new (or unique to India), delegates concluded that there were a number of steps which would improve the information base on which science is conducted:

- Different science initiatives/projects should work more closely to share data and evaluate common scenarios;
- There is a need to evaluate data quality/availability issues to understand barriers and opportunities for science;
- Where better monitoring of the environment is needed, we should augment existing measurements with low-cost sensors, crowd-sourced data and earth observation data;
- There is a need for a network of experimental basins/sites providing representative, good quality data that can be used for the calibration and validation of models and up-scaled to the basin scale. These sites should include natural drainage systems of sub-basins, urban catchments and agricultural areas;
- There is a paucity of data for understanding urban hydrology, particularly in relation to groundwater-surface water dynamics and this should be looked at in more detail;

- It is important to consider the socio-economic data needs – for example, the issues around obtaining demand side data need to be explored.

Resource Management

The management of water resources, including current and potential future storage models and the setting of environmental flows were discussed. It was concluded that science had a significant role to play in providing the evidence to underpin decision making in this area:

- A large variability in water availability exists across the basin and in many areas of the basin demand for water outstrips supply and as a result problems of over-use/-abstraction prevail. As a result, when setting environmental flows, different approaches may be required in different parts of the basin;
- Natural infrastructure solutions should be considered together with built infrastructure;
- Research is needed into the buffering capacity of Ganga water resource systems to understand their capacity to cope with projected climate change.

Urban Environments

A number of issues specific to urban environments emerged from the Workshop, including:

- We need to explore what hydrological process are important in urban areas and should be included in a systems model;
- Key research is needed into how urban development alters groundwater dynamics and the impact of urban development on floodplain processes;
- Science is required to underpin urban planning. For example, helping to explore how urban drainage design can be improved to support groundwater recharge, the environment (for example, constructed wetlands) and human health.

Water Quality

Water quality/pollution is a significant threat to water availability, and poses some of the most important science challenges and questions in the basin.

- Water quality issues related to traditional pollutants (such as agro-chemicals, organic loading) and emergent pollutants (such as oestrogen, nano-particles) are not yet fully understood and require research;
- In relation to arsenic and nitrate contamination from intensive agricultural practices, science could provide better predictive tools and/or low-cost treatment options;

- It would be useful to consider if the European Water Framework Directive approaches offer a template for mapping point/diffuse pressures and informing river basin management planning.

Ecosystems

While most issues discussed throughout the Workshop (and outlined in this report) have impacts on the river's ecosystems, the following additional points were made:

- Issues of lateral- as well as longitudinal-connectivity of rivers are key and should be explored in detail;
- We should consider the river as an ecological entity and value the ecosystem services it provides. We should think in terms of Environment Opportunity Assessment instead of Environmental Impact Assessment.
- Biomonitoring methods present significant opportunities to establish base-line status and track evolution (for example, assessing the impact of hydropower on ecosystems);

Hydrogeomorphology

Issues around our understanding of sediment generation and transport in the Basin and the related impacts were highlighted, including:

- We should explore how to define the resilience and threshold of the geomorphic system to floods and its relationship to other river processes such as river dynamics and bank erosion. Amongst other things this will help to assess the impact of floods on ecological services.
- The knowledge of sediment dynamics in high and middle mountains and the linkages with basin properties need to be improved so we can identify the impacts on infrastructures;

Agricultural Water Use

Agricultural productivity is a key water use within the basin and one which is expected to continue growing significantly in coming years. The following points were made:

- We should aim to develop models based on different physiographic climatic conditions to inform intelligent application of irrigation water (for example, through understanding crop requirement, rotation options);
- There are knock-on challenges around how to operationalize the resulting 'intelligent' irrigation systems, based on soil moisture, soil health, rainfall, discharge availability and current storage. New soil moisture data sources should be explored to support improvements in agricultural water resources management. For example, using earth observation data and

crops as sensors to inform and optimise precision irrigation, maximising the crop yield and conserving energy;

- Low cost water measuring devices and soil moisture sensors may provide opportunities to inform irrigation decisions by farmers;
- Methods of irrigation application (such as sprinkler *vs.* drip and managed groundwater recharge) require more research;
- We do not fully understand how crop yields may be impacted by changing a climate and water availability in the Ganga basin;

Industrial Water Use

Issues around industrial water use were considered, with the Workshop concluding the following:

- India represents an emergent BRIC economy with a growing industrial base and agro-business driving socio-economic development presenting scientific challenges around rising water demand (e.g. for power, processing, cooling, supply-chains) and impacts from wastewater/atmospheric emissions (e.g. aerosols);
- Research into the interdependency of energy, food and ecosystem services, could help inform the assessment of options and trade-offs which will be key to finding sustainable solutions;
- The effects of industrial emissions on regional/local hydro-meteorology are should be explored;

Hydropower

The water-energy nexus in the basin presents a number of scientific challenges, particularly in relation to hydropower development. Delegates highlighted that:

- Freshwater science can help inform decision makers in respect to hydropower development by providing information on water availability in ungauged catchments, flood risk estimation and forecasting methods, and seasonal forecasts. We should look to tailor models and techniques from other parts of the globe to the Indian requirements/conditions.
- Scientific support is required to aid considerations of where to develop hydropower schemes (for example, whether to delineate only a sub-set of tributaries for development);
- There is significant potential to develop hydrological climate services for energy provider. For example assessing the likely climate change impacts on water availability and runoff regimes in the basin;
- Understanding sediment production and transport in the basin is a key challenge.

Flood Risk Management

Floods pose a significant hydrological hazard in some parts of the basin. Delegates concluded the following:

- We need to consider whether and how long traditional hydrologic design concepts assuming stationarity remain valid under rapid human and natural changes;
- There is a need for a unifying framework for assessment and communication of risk under non-stationarity, taking into consideration the associated uncertainties, and socio-economic aspects. Challenges exist in relation to how proposed concepts could be adapted to large and complex river water systems such as the Ganga;
- Scientific research is needed to explore how flood risk assessment and forecasting can be translated to improvements on the ground. For example, considering how best to inform the setting of building codes and how to provide flood warning information to aid real-time management (looking at issues around organisation *vs.* technology).

Next Steps

In light of the scientific conclusions, the workshop discussed a number of key short-term/immediate initiatives which could be taken forward to maintain the momentum of India-UK collaboration for Ganga science. The following were suggested:

1. The publication of a short paper(s) or commentary outlining a future scientific vision for the Ganga and the key challenges and questions which have been identified.
2. A joint India-UK workshop specifically on modelling. This should be a technical workshop aimed at modelling scientists and consider the scope of any future unified model for the basin; the barriers and opportunities for rapid development; data and skills requirements and a plan for developing a modelling framework.
3. A stakeholder engagement event designed to collate the views, aspirations and demands of key stakeholders in the Ganga basin.

Annex A: Delegate Research Interests

Prof. Alan Jenkins	Deputy Director and Director of Water & Pollution Science, Centre for Ecology & Hydrology, Wallingford, UK jinx@ceh.ac.uk	
Alan Jenkins is Deputy Director of CEH and Director of CEH's Water and Pollution Science. Alan's research focus is hydrochemical modelling, in particular the development of models for predicting the impact of air pollution on soils and surface waters. He worked for many years to develop the MAGIC model and this now forms a focus for the assessment of the efficacy of international agreements on emission reductions. His wider interests include diffuse pollution and the transport of chemicals from soils to surface waters. Alan is Chair of the UK Committee for National and International Hydrology, Head of the UK Delegation to the UNESCO International Hydrology Programme and Hydrological Adviser to the UK Government with the World Meteorological Organization.		

Dr Harry Dixon	Senior Hydrologist, Centre for Ecology & Hydrology, Wallingford, UK harr@ceh.ac.uk	
Harry Dixon is a Senior Hydrologist at CEH specialising in the measurement, management and assessment of hydrometric data. Harry has an active involvement in water-related intergovernmental hydrology programmes under the UN framework, primarily with the WMO and UNESCO. Through this work he has experience of international-scale research and operational projects and policy development. Harry's research interests span hydrometry, hydrometric data processing and analysis. He is Head of the UK's National River Flow Archive and has extensive experience of working in the UK and internationally on projects related to the collection and management of hydrological data and information.		

Prof. Bob Ferrier	Director of Research Impact, James Hutton Institute, Aberdeen, UK Bob.Ferrier@hutton.ac.uk	
Bob Ferrier is Director of Research Impact at the James Hutton Institute and is responsible for the development and delivery of the Institute's research portfolio, associated knowledge exchange, and income generation strategies. He is also the Director of the policy-research Centre of Expertise for Waters (CREW). He has over 20 years experience in water resources management in particular the hydrological, hydrochemical and ecological consequences of environmental change; in particular land use and management, and climate change. His own research interests centre on the potential role of policy and land use change on water resources and the development of systems-based approaches and frameworks for sustainable management. He has been a champion for catchment management and in particular, addressing the global challenge of diffuse pollution.		

Prof. Mike Acreman	Science Area Lead for Natural Capital, Centre for Ecology & Hydrology, Wallingford, UK man@ceh.ac.uk	
Mike Acreman is Science Area Lead for Natural Capital at CEH and visiting Professor at UCL. He joined the Institute of Hydrology in 1984 as a hydrological modeller and worked at NERC HQ coordinating terrestrial and freshwater sciences. In the 1990s he was the freshwater management advisor to the IUCN-The World Conservation Union. He has worked in numerous countries worldwide for DFID, the World Bank, European Commission and IUCN on hydro-ecological processes in wetlands and the ecological flow requirements of rivers. He is joint Editor of Hydrological Sciences Journal. He leads a collaboration with National Institute of Hydrology in India on environmental flows.		

Prof. Paul Whitehead	Professor of Water Science, University of Oxford, UK paul.whitehead@ouce.ox.ac.uk	
Paul Whitehead is Professor of Water Science, Oxford and has over 35 years of experience in managing 47 research projects, worth £37million, funded by NERC, EPSRC, ESRC, EU, Defra, DFID, EA, WORLD BANK, Water Companies, WWF, UKWIR, River Ganges Commission, consultancy organisations such as Atkins and the Royal Geographical Society. He has published 187 papers in international journals, has 3850 citations and an H Index of 28. He is currently Director of the £10.5 million NERC Macronutrient Cycles programme and has worked extensively on Asian projects in India, Nepal, Bangladesh, Thailand, China and Taiwan. He has been the PI in Oxford on the NERC/ESRC/DFID funded ESPA DELTAs project, jointly with Professor Sinha. He has been responsible for developing the INCA flow and water quality model, which has been applied extensively to the Ganges, the Brahmaputra, the Meghna and several upland rivers in Nepal. The model has been used to evaluate climate change impacts on flows and water quality and also used to assess socio-economic impacts of the Ganga river system.		

Dr Gwyn Rees	Science Area Lead for Water Resources, Centre for Ecology & Hydrology, Wallingford, UK hgrees@ceh.ac.uk	
Gwyn Rees is Science Area Lead for Water Resources at CEH. Gwyn is a hydrologist who specialises in regional low flows, droughts, water resources and mountain hydrology. His hydrological expertise has been gained through his involvement in a wide range of commercial research projects in Europe and South Asia, for such clients as DFID, Defra, EA, the European Commission, the European Environment Agency, Eurostat, Unilever and the World Bank. Gwyn maintains a strong interest in environmental informatics and hydrological data management.		

Mr Barry Greig	Hydro Nation Manager, Scottish Government, UK Barry.Greig@gov.scot	

Mr Andrew McKenzie	Manager of Groundwater Information, British Geological Survey, Wallingford, UK aam@bgs.ac.uk	
Andrew McKenzie is a hydrogeologist and specialist in groundwater information management. He runs the UK's national databases of groundwater data, covering abstractions, groundwater level and quality across the UK. These collections provide the basis for NERC's continuous reporting on water resources and likely trends, are used in publishing monthly and annual recharge estimates for UK aquifers, and in providing on drought and flood incidents. He was the senior expert on hydrogeology and information systems for the India Hydrology 2 project, and a co-investigator on the NERC Hydroflux project looking at interactions between water and climate in the Ganges.		

Prof. John Rowan	Professor of Physical Geography, University of Dundee, UK j.s.rowan@dundee.ac.uk	
John Rowan is Dean of the School of Social Sciences at the University of Dundee. His research has an emphasis on water and sediment dynamics, and more generally the sensitivity and resilience of environmental systems to perturbations including climate change. The most significant contributions range from new conceptual frameworks linking lake behaviour to landscape setting; use of innovative modelling approaches including Bayesian, data-based mechanistic and minimum information models; use of environmental radionuclides for sediment fingerprinting and dating long-term landform development, and more recently new hydromorphological assessment and decision-support tools. A conscious move towards systems-based approaches is reflected in current projects which explore the utility of ecosystem-based adaptation the ecosystem services concept with respect to natural flood management; development of cross-sectoral indicators of climate change adaptation; exploring the linkages between soil erosion and biodiversity in agro-ecosystems, and elucidating the biophysical linkages between hydromorphological pressures and ecological response – increasingly using remote sensing techniques.		

Prof. Adebayo Adeloye	Professor of Water Resources Management, Heriot-Watt University, Edinburgh, UK A.J.Adeloye@hw.ac.uk	
Adebayo Adeloye is Professor of water resources management at Heriot-Watt University, Edinburgh. The main focus of his research is the development of robust tools for the sustainable planning and management of reservoirs. He also researches the assessment of climate change impacts and its uncertainties on water resources and flooding. His research has been extensively published. Professor Adeloye has wide-ranging experience of working in India; he is the PI for "MICCI" jointly funded by the UK-NERC and India-MOES and focused on the Himalayan Beas basin. How MICCI experience could inform the management of the Ganga will be explored in his presentation.		

Dr Nafees Meah	Director, Research Councils UK (RCUK) India Nafees.Meah@rcuk.ac.uk	

Ms Melissa Else	Energy & Resource Security, British High Commission New Delhi, India M-Else@dfid.gov.uk	

Prof. Pradeep Mujumdar	Professor, Department of Civil Engineering and Chairman, Interdisciplinary Centre for Water Research, Indian Institute of Science Bangalore, India ppmujumdar@gmail.com	
Pradeep Mujumdar is currently serving as a Professor in the Department of Civil Engineering at IISc Bangalore and as Chairman, Interdisciplinary Centre for Water Research. His area of specialization is Water Resources with a focus on climate change impacts on hydrology/water resources, statistical downscaling of GCM outputs, urban flooding, planning and operation of large-scale water resources systems, and uncertainty modelling. His recent research contributions include detection and attribution of hydrologic change, development of downscaling models, uncertainty combination in climate change impacts and reservoir operation for adaptation to climate change. He has served as the Chairman of the Water Resources Management section of the International Association for Hydro-Environment Engineering and Research (IAHR), and as a reviewer for the Assessment Report 5 (AR5) of the IPCC.		

Prof. Muddu Sekhar	Professor, Department of Civil Engineering & Interdisciplinary Centre for Water Research, Indian Institute of Science Bangalore, India sekhar.muddu@gmail.com	
Muddu Sekhar's research areas including groundwater hydrology, agro-hydrology, satellite hydrology and urban hydrogeology. In particular, he works on modelling the groundwater systems in hard rock aquifers of South India and performs integrated geochemical & hydrological studies in nested experimental watersheds in the Kabini river basin. He is working on a framework to develop a spatially distributed agro-hydrological model using field experiments, remote sensing and data assimilation as part of the Indo-French project "Adaptation of irrigated agriculture to climate change". As a member of the NERC-MoES CWC project, 'Hydrometeorological feedbacks and changes in water storage and fluxes in northern India', he performed studies on evapotranspiration and groundwater in Ganges basin.		

Prof. Vinod Gaur	Honorary Emeritus Scientist, CSIR Fourth Paradigm Institute, India gaur@cmmacs.ernet.in	

Prof. Rajiv Sinha	Professor and Head of Department of Earth Sciences, Indian Institute of Technology Kanpur, India rsinha@iitk.ac.in	
Rajiv Sinha has worked on various aspects of the Ganga river system. His main research interests include river dynamics and floods, fluvial remote sensing, and river response to climate change. Some of his major contributions in the Ganga basin research include source area classification, hydro-geomorphic approach to understanding floods, and paleohydrologic and paleoclimatic reconstructions using sedimentary archives and drill cores. Professor Sinha led the fluvial geomorphology group of a very large project on Ganga River Basin Management Plan sponsored by MoEF. He is currently involved in several projects in the Ganga basin related to river health, environmental flows, hydrological and sediment transport modelling, and flood risk assessment.		

Dr Argha Banerjee	Assistant Professor Earth and Climate Science, Indian Institute of Science Education and Research Pune, India argha@iiserpune.ac.in	
Argha Banerjee is a glaciologist working on problems relevant to Himalayan glaciers. He has used simple zero and one dimensional models of glacier dynamics to investigate climate-glacier interactions, glacier response properties and mass balance processes in the Himalaya, mostly focusing on the debris covered glaciers that are abundant here. His present and future research goals include developing models of debris-ice coupled dynamics, developing simple and numerically efficient glacier models that can be integrated with hydrological models, investigating climate signals hidden in mass balance variability and the fluctuations of Himalayan glaciers. He is involved in detailed field and modelling studies of glaciers in the upper Alaknanda basin.		

Dr Sharad Jain	Scientist G and Head (Water Resources Systems Division), National Institute of Hydrology, Roorkee, India s_k_jain@yahoo.com	
The topics of interest of Dr Jain include hydrological modelling, application of emerging techniques, Eflow assessment, impacts of climate change on water resources, water governance, etc. Dr Jain is involved in hydrological studies for Interlinking of Rivers in India and integrated operation of a system of hydro-projects. He has organized numerous short-term courses and has developed a web-based course under NPTEL program of Government of India. His group has developed a software package to perform a range of analyses related with sizing, flood routing, yield estimation, and operation of a system of reservoirs that may be encompassing multiple basins. The group led by Dr Jain has carried out distributed hydrological modelling, completed a scoping project on Eflow assessment, and are in the process of setting an instrumented experimental basin, all for the Upper Ganga basin. He has also authored chapters on Ganga basin for the Handbook of Applied Hydrology (forthcoming) and for a book on Ganga basin (being published by IWMI).		

Prof. Sachchida Tripathi	Rajeeva and Sangeeta Lahri Chair Professor, Department of Civil Engineering, Indian Institute of Technology Kanpur, India snt@iitk.ac.in	
Sachchida (Sachi) Nand Tripathi currently holds Rajeeva and Sangeeta Lahri Chair Professor position in Civil Engineering Department and is an adjunct Professor in Earth Sciences at Indian Institute of Technology, Kanpur. As an atmospheric scientist, Sachi could blend his knowledge to scientifically tackle environmental problems affecting society and thus influencing the policy makers. Sachi's research emphasis has been on the interface of environment and climate change. He has contributed to numerous high-profile scientific investigations, such as showing how aerosols are affecting the radiation over the Gangetic basin, how they are interacting with fog and causing cloud invigoration thus modulating rainfall rates, and ways to mitigate them. Sachi provided first estimates of climate forcing of biomass-generated Brown Carbon aerosols over Gangetic basin. His research findings have led to corrective measures achieving climate change mitigation of Gangetic basin.		

Dr Arpita Mondal	Assistant Professor, Department of Civil Engineering, Indian Institute of Technology Bombay, India arpita567@gmail.com	
Arpita Mondal's research interest includes detection and attribution of hydrologic change, spatio-temporal modelling of hydroclimatic extremes, uncertainty modelling, climate change impacts, frequency analysis of floods and droughts, and risk assessment under non-stationarity. Her published work includes analysing the causes of observed regional hydroclimatic changes including extremes, for possible identification of human-induced climate change signals, investigation of non-stationarity in intensity, duration and frequency of regional extreme rainfall and detection of change in return levels of floods and droughts. She is also working on assessment and communication of risk under changing conditions that challenge the tradition assumption of stationarity in hydrologic designs.		

Prof. Vinod Tare	Professor of Environmental Engineering & Management, Indian Institute of Technology Kanpur, India vinod@iitk.ac.in	
Vinod Tare is a Professor of Environmental Engineering and Management at the Indian Institute of Technology Kanpur and also holds Sir M Visvesaraya Chair Professor established by Ministry of Water Resources, Government of India. He is a Civil Engineer, obtained his Masters and Doctoral degrees in Environmental Engineering from IIT Kanpur. He has guided numerous masters and doctoral dissertations. Prof. Tare is consultant/advisor to many government organizations, NGOs, industries, and institutions. He also developed environment friendly toilet system, and has led a consortium of seven IITs in preparing Ganga River Basin Management Plan 2015 for the National Ganga River Basin Authority chaired by the Prime Minister of India.		

Prof. Arun Kumar	Chair Professor (Renewable Energy) and CSO, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, India aheciitr.ak@gmail.com	
Arun Kumar a civil engineer with specialization in water resources and hydropower by education is working at AHEC, IIT Roorkee since 1981. He has been awarded MNRE Chair Professor and served as CLA for Hydropower on Special Report on Renewable Energy Sources for IPCC – working group III during 2009–11. He has been appointed by Government of India as the Director NHPC. He has completed CIA studies of hydropower projects on river Ganga, Yamuna and Satluj in recent years. He appraises the project proposals on pollution abatements and RFD works for MOEF, Government of India and National Mission for Clean Ganga regularly. He has over 34 year experience of R&D, extension and teaching SHP and environmental management of river and lakes.		

Prof. B R Chahar	Indian Institute of Technology Delhi, India chahar@iitd.ac.in	

Dr Arjamadutta Sarangi	Principal Scientist, Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India asarangi@iari.res.in	
Arjamadutta Sarangi works in the field of hydrological modelling of watershed systems, impact of climate change on hydrologic responses, development of protocol for water foot print estimation of Gomti basin of river Ganga and Betwa basin of river Yamuna, application of GIS and RS tools and soft computing models for integrated watershed management, development of decision support systems for soil and water conservation measures and enhancing water productivity of crops. Crop growth and yield simulations and integration with climate generators for prediction of future irrigation water requirement for sustaining crop growth, geospatial tools and techniques for predicting the spatial variability of rainfall, evapotranspiration, soil texture etc. in basin scales. Ground water modelling under irrigated cropping environment and water budgeting studies under different rice cultivation methods.		

Mr Yogesh Sharma	Independent, India yogesh-mef@nic.in	

Mr Vinay Shankar	Independent, India vinayshan@gmail.com	
The Ganga Action Plan of the Ministry of Environment and Forest aimed to improve the water quality of Ganga so that it could become suitable for the humans to take a bath. Vinay Shankar functioned as Project Director for three years from 1992 to 1995. He has been associated with IIT Roorkee in preparing and reviewing Detailed Project Reports for the conservation of rivers and lakes, with the evaluation of the components of the GAP and with framing of guidelines on various aspects of the River Conservation Programmes. He has also been associated with the training programmes organised by IIT Roorkee.		

Dr Swati Basu	Adviser, Ministry of Earth Sciences, India swati.basu@nic.in	

Dr Vijay Kumar	Scientist -F, Ministry of Earth Sciences, India rdeas.crhy@moes.gov.in	

Mr Suresh Babu	Director - Rivers, Wetlands and Water Policy, WWF-India, India suresh@wwfindia.net	

Mr Puskal Upadhyay	Additional Mission Director, National Mission for Clean Ganga, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India pupaghyay@nic.in	

Mr Hari Har Mishra	Director, National Mission for Clean Ganga, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India mishrahh@nic.in	

Ms Mansi Tripathi	Research Officer, National Mission for Clean Ganga, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India	

Ms Priyanka Jha	Research Officer, National Mission for Clean Ganga, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India	

Mr Ashwin Pandya	Chairman, Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India Chairman-cwc@nic.in	

Mr Vinay Kumar	Chief Engineer (HSO), Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India cehydrl@nic.in	

Mr N N Rai	Director, Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India	

Mr M Raghuram	Director, Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India	

Mr Rishi Srivastva	Director, Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India	

Mr Jyotiraj Patra	Regional Evidence Advisor – South Asia, Ecosystem Services for Poverty Alleviation (EPPA) Programme asiaimpact@espa.ac.uk	

Annex B: Agenda

Day 1: Wednesday 2 December 2015 Room: Longchamp	
12:00-13:30	Arrival, Registration and Lunch
13:30-13:40	**Welcome and Introduction to the Workshop** Speaker: Alan Jenkins
13:40-13:45	Presentation Topic: **Scottish Government Hydro Nation International Fellows Programme** Speaker: **Barry Greig**
13:45-14:00	Presentation Topic: **Address by the National Mission for Clean Ganga** Speaker: **Puskal Upadhyay**
14:00-14:15	Presentation Topic: **Address by the Central Water Commission** Speakers: **N.N.Rai**
14:15-14:45	Presentation Topic: **Science and Water Management Challenges in the Ganga Basin** Speaker: **Vinod Tare**
14:45-15:00	**Discussion**
15:00-15:30	Tea
	Session 1: Water & Ecosystems Chair: Gwyn Rees
15:30-16:00	Presentation Topic: **Water management for the environment in India – can UK experience help?** Speaker: **Mike Acreman** Abstract: Water is essential for most aspects of our lives including drinking and washing, growing food, generating power and driving industry. People also benefit from a healthy environment for protection from hazards, health, natural resources, recreation and spiritual /cultural meaning. Allocation of water to river ecosystems provides important benefits to people and is essential to achieve the Sustainable Development Goals (particularly no. 6). But determining how much water a river needs is a difficult scientific problem that begins with a social process of defining what sort of river is desired and undertaking research to quantify the water needed to deliver that desired condition. Although from a different climate and cultural setting, the river Thames has been through many of the steps in the process of recovery from a degraded river to one that provides multiple benefits. These steps have required a range of actions including

	understanding expectations of people, making a clear vision with realistic objectives and time scales, defining concepts and taking-on new ways of thinking, collecting good data that links water and ecosystems, undertaking good studies and projecting the future. The story of the Thames can provide useful advice for restoration of the Ganga and other Indian rivers.
16:00-16:30	Presentation Topic: **Scientific inputs for Ganga rejuvenation** Speaker: **Sharad Jain** Abstract: The Ganga basin covers an area of more than one million km^2 and supports more than 600 million people, about 9% of the world population. The main river and some of its tributaries are in poor health at many places. This presentation will identify the major causes of declining ecosystem and health of the Ganga river and its tributaries. Rejuvenation of the rivers in the Ganga basin will require a host of scientific and regulatory inputs, infrastructure development, beginning with a basin management plan. All these topics will be discussed in the presentation.
16:30-17:45	Discussion of Session 1 Vision. Focused on: 1) Priority science challenges 2) Areas of possible UK-India collaboration Chair to report back in Wrap-up Session on Day 3.
17:45	Close

Day 2: Thursday 3 December 2015 Room: Villa Medici	
08:45-09:00	Arrival
	Session 2: Water & Agriculture Chair: Arun Kumar
09:00-09:30	Presentation Topic: **The hydrological links between groundwater dynamics and land-energy feedbacks in the Ganges basin** Speaker: **Muddu Sekhar** Abstract: In tropics, apart from climate change, land use changes are expected to have a significant impact on the hydrologic cycle, creating changes in freshwater resources, land cover and land–atmosphere feedbacks. Maxwell and Kollet (2008) have examined the response of groundwater interplay between water and energy flows in the significant groundwater extracted from the Southern Great Plains basin in the USA and investigated the effects of climate change with groundwater flow integrated with a land-surface model. Over the past decades the Indian subcontinent has undergone one of the largest environmental changes in human history. India's green revolution, besides the ubiquitous benefits, has resulted in large-scale changes in land-cover and a significant increase in the exploitation of water resources. In this work, we examine the links between the groundwater storage changes and evapotranspiration (ET) in the Ganges basin of 650,000 km^2, which mostly belong to the plains. The results present an idea of the magnitude of water lost to the atmosphere due to groundwater abstraction and the spatial signatures of such spots in tropical river basins such as the Ganges basin. Looking ahead, these results would be useful for validating coupled models of groundwater and land surface, which can be used to simulate the water cycle changes occurring in the Ganges basin.
09:30-10:00	Presentation Topic: **Assessing climate change impacts on water resources in the Beas Basin and possible lessons for future management of the Ganga** Speaker: **Adebayo Adeloye** Abstract: A recent study to assess the impacts of predicted climate change on Beas Basin and its Pong Reservoir has thrown up some interesting results that can inform the future management of other major Indian Basins including the Ganga. The study revealed that higher rainfall produced more runoff and *vice-versa*, while increasing the temperature caused the runoff to increase due to additional runoff generated by the melting of the seasonal snow and Himalayan glaciers. When the runoff response was used to simulate the Pong Reservoir, a major hydropower and irrigation facility in the Basin, the reservoir vulnerability deteriorated significantly as the runoff reduced. This vulnerability disappeared with improved operational practices involving hedging. This shows that existing water resources systems have inherent buffering capacity that can be harnessed

	through improved systems operation, thus cushioning the effect of climate change and removing the need for new builds to adapt to climate change. The Ganga Basin shares many features with the Beas, e.g. seasonal snow and glaciers, monsoon, and reservoirs that make this study relevant to the Ganga. The presentation will outline the main results of the Beas study and proffer suggestions on how they could inform the science for the future management of the Ganga.
10:00-11:00	Discussion of Session 2 Vision. Focused on: 1) Priority science challenges 2) Areas of possible UK-India collaboration Chair to report back in Wrap-up Session on Day 3.
11:00-11:30	Coffee
	Session 3: Water & Urban Areas Chair: Mike Acreman
11:30-12:00	Presentation Topic: **Pressures on groundwater: handling the impacts of urbanisation** Speaker: **Andrew McKenzie** Abstract: Much of the focus and debate around water in the Ganga basin is on water quality in the river system, and on the availability of water for irrigation, but a rapidly urbanising population means that it is inevitable that the proportion of sustainable groundwater resource consumed by cities will increase. The growth of urban groundwater abstraction leads to large drawdowns, which are both a management challenge, and an opportunity to study aquifer behaviour under stress. Intense use is coupled with large inputs of effluent, compromising water quality, especially disadvantaging poorer communities that make more use of shallow groundwater. Intensive pumping may also lead to unanticipated changes in water quality as shallow and deep groundwaters mix, especially in coastal areas and areas affected by geogenic pollutants such as arsenic. Local management actions have often concentrated on artificial recharge of shallow aquifers, and it is hard to assess their utility without a good understanding of both vertical and horizontal flows; and clear identification of which aquifers will benefit from recharge. Addressing these issues will require new networks of sensors and observations to characterise urban aquifers in three dimensions, and enable more realistic and detailed simulation of processes within the complex urban environment.

12:00-13:00	Discussion of Session 3 Vision. Focused on: 1) Priority science challenges 2) Areas of possible UK-India collaboration Chair to report back in Wrap-up Session on Day 3.
13:00-14:00	Lunch
	Session 4: Water & Industry Chair: John Rowan
14:00-14:30	Presentation Topic: **Modelling flow and water quality in the Ganga catchment: Impacts of pollution control strategies and climate change** Speaker: **Paul Whitehead** Abstract: The dynamic and process-based INCA Model has been applied to model the Ganga River system using a 70 model reach set-up incorporating all tributaries and the whole land surface. The model incorporates land use based on a fine grid, effluent discharge points, agricultural diffuse runoff and has been set up using historical data from 1970 through to 2015 to assess changes in flow and water quality. Climate data from the UK Met Office Regional Model has been used to predict future flows and water quality under at range of climate scenarios and also using a set of socio-economic/industrial scenarios. The impacts of these will be presented.
14:30-15:00	Presentation Topic: **Coupling between climate change and the river quality of Ganges ecosystem: Paving the road ahead** Speaker: **Sachchida Tripathi** Abstract: The Ganga is the lifeblood of several hundred million people, supplying not only a source of water for consumption and crop irrigation, but also spiritual inspiration. Human activities are increasingly putting pressure on the Ganga through a variety of pathways including runoff from human and industrial waste, fertilizers and pesticides from agricultural practices, and trash/refuse disposal to name a few. In addition, increasing air pollution over the Indo-Gangetic plain (IGP) can contribute significantly in contaminating the Ganga. Air pollutants also have the ability to alter climate across the IGP, that in turn influences the hydrological cycle and the water supply to the river. Growing usage of antibiotics in humans & animals and unregulated disposal from hospitals and industrial effluents has significant impact on water quality and biotic components of the river. It seems that all these factors are contributing to the deterioration of purifying properties of Ganga, impacting microbiome and human health in particular. Ancient scriptures decree the holiness of the Ganga and the purifying properties of its waters, a belief many hold today. Although the extent to which the Ganga is able to cleanse itself of pollutants is not well understood, it is clear that its waters are under siege from an ever increasing flow of pollutants, as are the people living in the Ganga basin. At this time our understanding of the pollutants

	that effect both humans and the river are not well understood. Before strategies can be developed to improve Ganga health, a clear assessment is needed of the key environmental pollutants impacting it. Multi-disciplinary teams capable of determining the critical pollutants impacting the health of the Ganga and humans living across the IGP consisting of experts with a variety of emphases including climate modelling, hydrology, air and water quality, microbiology, exposure assessment, climate modelling and epidemiology are needed for untangling such a highly multi-disciplinary, complex problem.
15:00-15:45	Discussion of Session 4 Vision. Focused on: 1) Priority science challenges 2) Areas of possible UK-India collaboration Chair to report back in Wrap-up Session on Day 3.
15:45-16:15	Tea
	Session 5: Water & Energy Chair: Muddu Sekhar
16:15-16:45	Presentation Topic: **River Ganga: Energy and environment** Speaker: **Arun Kumar** In spite of the Ganga Action Plan, the National River Conservation Plan and the National Mission for Clean Ganga, the water quality and quantity in the river Ganga has not been found suitable even for bathing, especially in many stretches, and aquatic life and biodiversity has been affected. In the absence of regulations on minimum flow, one storage dam and several diversion barrages/dams on the river Ganga in upper reaches have resulted in flow variability and almost dry stretches during lean periods respectively. Steep slopes, on one the hand, has high hydropower potential (over 10 GW) and on the other hand unregulated flow in the diverted stretch, poor governance and monitoring of construction activities are in conflict. In the plains from Haridwar onwards the river Ganga enters in plain and stretches up to the Bay of Bengal where high abstractions occur to meet water requirements for irrigation and drinking. The untreated and poorly treated waste water from industries, towns and cities make the matter of low flows even worse. Work on power potential, cumulative impacts and management plans in the upper reach of the river Ganga have been studied and presented and have been debated widely. The issues related to the rejuvenation of the river Ganga which are multi-dimensional involving activities in social, economic, management, infrastructure, scientific and technological issues are discussed and presented. Generating awareness, a regulatory framework covering land use of flood plains, uninterrupted power supply to treatment plants, land acquisition, monitoring and integrated approach for conservation are proposed.

16:45-17:15	Presentation Topic: **Science and hydropower** Speaker: **Gwyn Rees** Abstract: Reliable sources of energy are essential to sustain India's economic growth. India, under pressure to reduce carbon emissions, has committed that 40% of its total power capacity will be based on renewables by 2030. Whilst the majority of this will be from solar and wind energy, hydropower, with an estimated useable potential of 148 GW, remains an important potential source of future energy. However, a series of failed investments, extreme floods and earthquakes, along with concerns over climate change, have resulted in a slow-down in hydropower development. This presentation will prompt discussion on how freshwater sciences can help India realise its hydropower potential.
17:15-18:00	Discussion of Session 5 Vision. Focused on: 1) Priority science challenges 2) Areas of possible UK-India collaboration Chair to report back in Wrap-up Session on Day 3.
18:00	Close

Day 3: Friday 4 December 2015 Room: Diwan-I-Khas	
09:00-09:15	Arrival
	Session 6: Water & Hazards Chair: Rajiv Sinha
09:15-09:45	Presentation Topic: **Water and hazards: Hydrologic extremes and risk assessment under non-stationarity** Speaker: **Arpita Mondal** Abstract: Hydrologic extremes such as floods and droughts constitute complex water problems that affect societies through direct and indirect interactions with natural and man-made systems. Tail quantiles of such extremes such as the n-year return level (for example, the proverbial '100-year flood') and the associated uncertainties, estimated from the historical observations under assumptions of stationarity and used in current hydrological designs, may change in future because of non-stationarity induced by rapid climate change or human interventions. In this study, through individual case-study applications, we investigate whether and when, the future return levels of floods and droughts, under climate change, are likely to be significantly different from the observed return levels, taking into account the associated uncertainties. Additionally, robust assessment and communication of risk is crucial to ascertain water security. Reformulations are suggested in recent literature to account for non-stationarity in hydrologic designs. This study also presents a comparative analysis of design flood levels under non-stationarity based on time varying annual exceedance probabilities, waiting time of a hazardous event, number of hazardous events and probability of failure. Considerable disagreement is found between the design magnitudes of flood obtained by the different definitions of hydrologic risk under non-stationarity. Additionally, some critical points on the assumption of a deterministic non-stationary model for an observed natural process are also discussed. The findings highlight the necessity for a unifying framework for assessment and communication of hydrologic risk under transient hydro-climatic conditions. This is particularly important for the flood-prone reaches of the Ganga river basin.
09:45-10:00	Presentation Topic: **Water and hazards** Speaker: **Rajiv Sinha**
10:00-10:40	Discussion of Session 6 Vision. Focused on: 1) Priority science challenges 2) Areas of possible UK-India collaboration Chair to report back in Wrap-up Session.

10:40-10:45	Presentation Topic: **Thoughts and Suggestions** Speaker: **Vinay Shankar**
10:45-11:15	Coffee
	Wrap-up and Close Chair: Alan Jenkins
11:15-11:30	**Key science issues in the Ganga – Some conclusions for discussion** Speaker: Bob Ferrier
11:45-12:45	**Conclusions from workshop** Speakers: 5 minutes feedback presentation (1 slide) from each Session Chair followed by discussion
12:45-13:00	**Closing Remarks** Speaker: Alan Jenkins
13:00-14:00	Lunch
14:00	Close

Convened by the:

NERC CENTRE FOR ECOLOGY & HYDROLOGY

United Kingdom

www.ceh.ac.uk

Centre for Ecology & Hydrology

NATURAL ENVIRONMENT RESEARCH COUNCIL