Improving Freshwater Monitoring Frameworks for Data and Research Management

Report of User Engagement Initiative - January 2018

November 2018

INDIA-UK Water Centre
भारत-यूके जल केन्द्र

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India-UK Water Centre
www.iukwc.org
info@iukwc.org

Indian Coordination Office
Indian Institute of Tropical Meteorology
Dr Homi Bhabha Road
Pune-411008,
Maharashtra, India

UK Coordination Office
Centre for Ecology & Hydrology
Benson Lane
Crowmarsh Gifford, Wallingford
OX10 8BB, UK

Key authors:
Priya P. Joshi, India UK Water Centre, Indian Institute of Tropical, Meteoroloy, Pune
Anita Petrie, India UK Water Centre, Centre for Ecology & Hydrology, Wallingford

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NERC SCIENCE OF THE ENVIRONMENT

Ministry of Earth Sciences
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The India-UK Water Centre promotes cooperation and collaboration between the complementary priorities of NERC-MoES water security research.

भारत-यूके जल केंद्र, एनईआरसी-एमओईएस जल सुरक्षा अनुसंधान की मानार्थ प्राथमिकताओं के बीच सहयोग और सहकार्यता को प्रोत्साहित करता है।

Contents

List of Acronyms

AMBHAS	Assimilation of Multi-satellite data at Berambadi watershed for Hydrology And land Surface experiment
ATREE	Ashoka Trust for Research in Ecology and Environment
BGS	British Geological Survey
CEH	Centre for Ecology & Hydrology
CHANSE	Coupled Human And Natural Systems Environment for water management under uncertainty in the Indo-Gangetic Plain
CMFRI	Central Marine and Fisheries Research Institute
COSMOS	Cosmic-ray Soil Moisture Observing System
CWC	Central Water Commission, India
DST	Department of Science and Tecnology, Govt. of India
EMI	Enterprise Manufacturing Intelligence
EO	Earth Observation
ES	Ecosystem Services
GIS	Geographical Information System
GRACE Model	Global Responses to Anthropogenic Changes in the Environment Model
GWAVA	Global Water Availability Assessment Model
IISC	Indian Institute of Science
IITM	Indian Institute of Tropical Meteorology
IMD	India Meterological Department
IUKWC	India-UK Water Centre
IUWM	Integrated Urban Water Management
M&E	Monitoring and Evaluation
MERIS	Medium Resolution Imaging Spectrometer
MoES	Ministry of Earth Sciences, India
NERC	Natural Environmental Research Council, UK
NERCI	Nansen Environmental Research Centre
NGO	Non Governmental Organisation
NIO	National Institute of Oceanography
RS	Remote Sensing
SCADA	Supervisory control and data acquisition
SusHi-Wat	Sustaining Himalayan Water Resources in a Changing Climate
TWAD Board	Tamil Nadu Water supply & drainage board
UAV	Unmanned Aerial Vehicle
UEI	User Engagement Initiative
UK	United Kingdom of Great Britain and Northern Ireland
UPSCAPE	Upscaling Catchment Processes in Peninsular India
VIC	Variable Infiltration Capacity
WUE	Water Use Efficiency
ZOODRM	Zoom Object-Oriented Distributed Recharge Model
ZOOM	Z39.50 Object-Orientation Model

Executive Summary

This report presents an overview of the joint India-UK scientific User Engagement Initiative held in Kochi from 23rd– 25th January, 2018. The event was convened by the India-UK Water Centre co-coordinators Dr A.K. Sahai (Indian Institute of Tropical Meteorology, Pune, India) and Dr Harry Dixon (Centre for Ecology & Hydrology, Wallingford, UK). The initiative was organised by IUKWC Secretariat in collaboration with the Plymouth Marine Laboratory, UK and Nansen Environmental Research Centre, Kochi. The event aimed to engage regional-level water policy and management bodies in discussions about how the latest India-UK scientific outputs could be used to help improve freshwater monitoring frameworks and data for research and management in the southern Indian region. The event was specifically focused towards addressing four key themes:

- Water Quality - Monitoring Pollution & Treatment;
- Monitoring Aquatic Ecosystems & Biodiversity;
- Irrigation - Monitoring Availability and Consumption; and
- Water Provision : Monitoring Supply & Consumption.

The event was multi-sectoral and multi-stakeholder in nature. Representatives from organizations responsible for the development of water policy and the management of freshwater issues in Kerala, Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh and Orissa attended. Amongst others, this included the Kerala Biodiversity Board, Kerala Water Resources Department, Karnataka State Biodiversity Board, Karnataka Water Resources Department, Maharashtra Pollution Control Board, Tamil Nadu Water Supply Board, and Orissa Pollution Control Board.

Discussion focused on the theme of Improving Freshwater Monitoring Frameworks and Data for Research and Management. Scientists from UK and Indian institutions presented the state-of-the-art in joint India-UK water security research, in the areas of water supply and management, water quality, biodiversity and irrigation. Indian Institutions including the National Institute of Hydrology, Roorkee, National Institute of Oceanography, Kochi, Central Marine and Fisheries Research Institute, Kochi, Indian Institute of Technology, Roorkee, Ashoka Trust for Research in Ecology and Environment, Cochin University of Science & Technology, Indian Institute of Science, Bangalore, National Water Academy, amongst others, participated actively in the initiative. UK participants included experts from the Centre for Ecology & Hydrology, British Geological Survey, University of Stirling and University of Portsmouth.

This report outlines the structure, participation, presentation and discussion sessions undertaken during the course of the event. The report is intended for the workshop participants, India-UK Water Centre members and stakeholders.

Figure 1: Delegates of the UEI on field visit to Vembanad Lake

1. User Engagement Initiative Conveners

The User Engagment Initiaitve (UEI) was convened by the India-UK Water Centre (IUKWC) and led by

Dr A.K Sahai
Centre Coordinator IUKWC, India
Indian Institute of Tropical Meteorology
Dr Homi Bhabha Road, Pashan, Pune, Maharashtra, India
Email: sahai@tropmet.res.in

Dr Harry Dixon
Centre Coordinator, IUKWC, UK
Centre for Ecology and Hydrology
Mclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire, UK
Email: harr@ceh.ac.uk

The event was held at the Riviera Suites, Kochi, India from 23rd – 25th January 2018.

2. Aims

The IUKWC aims to support the translation and communication of outcomes from India-UK water research to users via directed UEIs. Focused on translating the results of India-UK science into policy/operational practice, UEIs are designed to bring together scientists with policy makers, regulators or commercial companies to support either:

- The translation and communication of India-UK water security science to users;
- Collect input on stakeholder needs for future research and innovation.

To inform the development of the first UEI, the IUKWC Secretariat tried to identify the priorities of members of its Open Network on stakeholder engagement in the Indian water sector. To achieve this, an online survey was conducted amongst members of the Centre's Open Network of India-UK Water Scientists in May 2017 The results of the survey highlighted a common opinion regarding the need for scientists to engage with regional-level stakeholders in India to raise awareness regarding the potential applicability of new scientific technologies and frameworks for improving freshwater monitoring.

Other notable messages from the survey results included:

- Although current awareness amongst stakeholders regarding recent scientific developments is low, responses suggested that many had the potential (in the form of good infrastructure and technical capacity) to assimilate scientific outputs into their operations;
- There is a common need to upgrade outdated technologies;
- The particpants raised concerns about the gap which exists in some cases between planning departments and ground level implementation bodies in water resources management;
- Respondants stressed the ongoing need to make climatic and hydrological data more widely available and to improve its quality through propagation of state-of-the-art monitoring techniques.

A more detailed report on the results of the selection survey can be found at http://www.iukwc.org/marking-target-iukwc-survey-results-developing-first-user-engagement-initiative).

On the basis of the survey, the UEI was designed to engage with regional water policy and management bodies to improving freshwater monitoring frameworks and data for research and management. Focus was placed on stakeholders at regional scale, particularly policy makers, implementers and regulators who are responsible for identification and interpretation of available scientific knowledge, whether it be to help farmers improve irrigation or to assist disaster management teams in better managing water related risks. These stakeholders need to recognize the utility of new scientific approaches/technologies and facilitate their dissemination at local level while also ensuring adherence to legal and policy devices. To achieve this they need to have a thorough understanding of the potential of the evolving scientific knowledge, as well as inherent risks and limitations. The IUKWC's UEI aimed to address this need.

3. Regional Focus and Participants

The IUKWC recently organised a workshop on "Enhancing Freshwater Monitoring through Earth Observation" at Stirling University, UK in June 2017; one of the discussion sessions led by Dr Shubha Satyendranath (Plymouth Marine Laboratory, UK) highlighted issues related to the monitoring and subsequent management of freshwater systems in Southern India region – illustrated through the case study of Vembanad Lake in Kochi, Kerala. Discussions at the workshop noted the potential for the India–UK water security science community to help address these issues by targetting improvements in monitoring capabilities in four sectors:

- Water quality;
- Water supply and management;
- Water for agriculture and irrigation;
- Water management for biodiversity and ecosystem services.

To take forward these ideas the IUKWC secretariat directed its pilot UEI initiative towards stakeholders of these sectors from the Southern Indian region including the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Odisha, Telangana and Maharashtra who not only face similar issues in management of water resources but also share water resources across administrative boundaries. The UEI was held in Kochi, Kerala, India, which is in proximity of Vembanad Lake.

Stakeholder nomination: The state level bodies involved in the water resources management of this region for the above sectors include the State Pollution Control Board, State Water Supply Sewerage Board, State Water Resources Department (irrigation) and the State Biodiversity Board. Invitations were sent to the Heads of the above bodies for all the seven states requesting nomination of representatives to participate in the UEI. Further representatives from local NGOs and universities actively working in the concerned sectors were also invited. A diversity of participating organisations is represented in Figure 2 below. Full details of stakeholders can be found in Annex B.

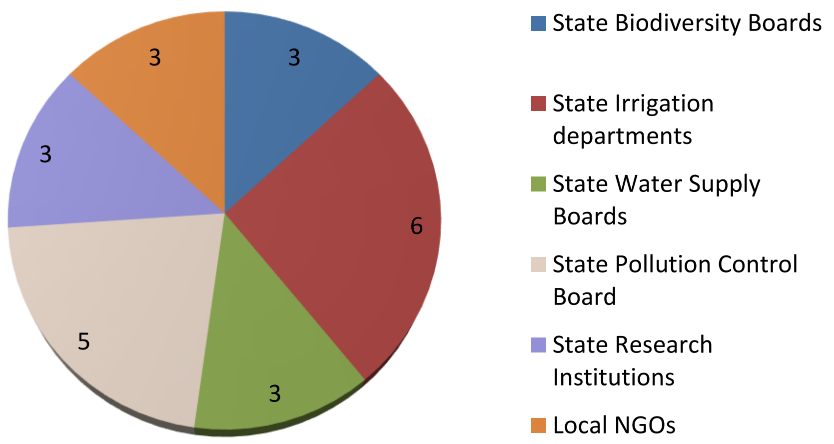

Figure 2: Diversity of participating State government organisations and representatives

Scientific expert selection: The IUKWC Secretariat used the Centre's Open Network to shortlist the scientists to be invited to the UEI based on their profile and research experience. Scientists from UK and Indian institutions were invited to present the state-of-art in joint India-UK water security research, in the areas of water supply and management, water quality, biodiversity and irrigation. Amongst others, Indian institutions including: The National Institute of Hydrology (Roorkee); National Institute of Oceanography (Kochi); Central Marine and Fisheries Research Institute (Kochi); Indian Institute of Technology (Roorkee); Ashoka Trust for Research in Ecology and Environment; Cochin University of Science & Technology; Indian Institute of Science (Bangalore) and National Water Academy (Pune), participated actively in the initiative. UK participants included experts from the Centre for Ecology & Hydrology, British Geological Survey, University of Stirling and University of Portsmouth. For details on participating scientists refer to Annex B.

The initiative was designed and organised by the IUKWC in collaboration with Plymouth Marine Laboratory and Nansen Environmental Research Centre (Table 1).

Table 1. Organising Committee

	Name	Institution
India		
1	Dr A.K. Sahai	IITM, Pune (IUKWC Indian Coordinator)
2	Ms Priya Joshi	IITM, Pune (IUKWC Stakeholder Engagement Manager)
3	Mr Anil Pandey	IITM, Pune (IUKWC Event & website Manager)
4	Ms Shanti Iyer	IITM, Pune
5	Dr Nandini Menon	Nansen, Kochi (Senior Scientist)
6	Dr Ajith Joseph	Nansen, Kochi (Director)
UK		
7	Dr Harry Dixon	CEH (IUKWC UK Coordinator)
8	Ms Anita Jobson	CEH (IUKWC Project Manager)
9	Mr Chris Bell	CEH (IUKWC Project Administrator)
10	Dr Carol Diffenthal	CEH (IUKWC Project Administrator)
11	Dr Shubha Satyendranath	Plymouth Marine Laboratory, UK

4. Structure

Brining scientists together with organisations who are faced with the day-to-day management of freshwater in India is vital to tackle the significant challenges presented by a rising population, rapid economic development and climate change. To achieve this, the activity was spread over three days and was structured to first inform the stakeholders on latest developments in joint India–UK science and to hear from them on their pressing problems and current use of scientific outputs. The programme then comprised a field session where the delegates could visualise the discussed concepts and new technologies could be demonstrated. The last day was set aside for sector specific discussions. Preparatory toolkits outlining expectations and background of the initiative were provided to both stakeholders and scientists before the workshop to promote active participation and discussion during the event[1].

The first day and a half comprised of talks by scientists and stakeholders; discussion focused on the crucially important theme of *Improving Freshwater Monitoring Frameworks and Data for Research and Management* specifically focusing on the following sectors:

I Water Quality - Monitoring Pollution & Treatment;

II Monitoring Aquatic Ecosystems & Biodiversity;

III Irrigation - Monitoring Availability and Consumption;

IV Water Provision : Monitoring Supply & Consumption.

Each topic included a number of scientific presentations, followed by an interactive question & answer session. The initiative also provided an opportunity to one stakeholder representative per sector to give details on management of water resource in the said sector and current uptake of scientific outputs. In all, 17 presentations on varying themes were successfully delivered during the course of the event[2].

During the second half of day 2, a visit to Vembanad Lake was organised by Nansen Environmental Research Centre (NERCI) along with local offices of Ashoka Trust for Research in Ecology and Environment (ATREE), Central Marine and Fisheries Research Institute (CMFRI) and National Institute of Oceanography (NIO). Local presenters outlined the various aspects of Vembanad lake including, the ecosystem structure and flows, anthropogenic pressures and efforts being taken for lake conservation, through informal talks. Speakers from Stirling University, UK demonstrated the state-of-the-art water quality monitoring equipment and a demonstration was provided by the Centre for Ecology & Hydrology on the SALTMED[3] model, which can be used to better understand such environments.

The third day of the initiative was dedicated to discussion sessions. These took the form of break-out discussions where the participants were divided into smaller groups led by a nominated facilitator. Three exercises were designed to encorage participants to share perspectives on various aspects of freshwater monitoring specific to a sector and the scientific knowledge available to improve monitoring (including their potential use and limitations). A copy of these exercises was provided to participants on the first day so as to give them time to prepare their thoughts for the discussions.

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[1] Toolkits are made available online at www.iukwc.org

[2] A full outline of the workshop agenda and details of presentations and posters can be found in Annex A. Copies of presentations are available online at www.iukwc.org.

3 Developed under a project on 'Systems approach to a sustainable increase in irrigated vegetable crop production in salinity-prone areas of the Mediterranean region'

The first exercise aimed to initiate discussions on two key aspects: the potential uses of previous UK-India joint research in the sector and the potential impact of using this science. The second exercise was designed to draw from discussions in exercise 1 and aimed at identifying specific factors/ barriers associated with uptake of different scientific methods. The third exercise aimed to identify the need for future collaborative work between scientific organisations and the state government bodies and the best way this could be achieved. To help streamline the discussions, the groups were asked to populate tables which were structured to specifically address the key questions for each exercise. A detailed plan for all three exercises, including the structured tables, is provided in Annex C.

Figure 3: A look at UEI discussion sessions

5. Outputs

The workshop presentations and discussions covered diverse aspects of the four sectors of freshwater monitoring. Overall the discussions focused on the suitability of various new monitoring techniques to southern Indian region. Feedback from stakeholders helped identify the current situation and potential for update. Limitations related to lack of technical capacity, capital and data sharing mechanisms were identified as key barries, which need to be overcome. Sector wise overview on discussions is presented below while key points are presented in Annex D.

5.1. Key themes arising

Session 1. Water Quality: Monitoring Pollution & Treatment

Scientific talks in this session touched upon surface and ground water pollution monitoring including monitoring of heavy metals in deep aquifer and of emerging pollutants – such as micro-plastics, which are a signfiicant problem in India but one which has not seen significant research. The session discussed the applicability of passive sampling devices to monitor anthropogenic (chemical) pollutants in India; these devices can provide lower analytical detection limits compared to spot sampling and, therefore, provide a better overall representation of water quality over time. The Pollution Control Board representative highlighted that technology which is currently available for monitoring and treatment is contractor based and noted that collaborative interaction with producers of science or technology is rare at state level. Furthermore it was noted that a lack of capital and adequate infrastructure for sewage treatment are key issues in managing sewage treatment.

To achieve comprehensive assessment of pollution in water bodies it was concluded that there is a need to integrate current monitoring of physico-chemical parameters with observation of emerging pollutants (like micropollutants) and biological indicators. Standardised experimental protocol across temporal and spatial scale was identified as the most important requirement to facilitate dissemination and uptake of collected data amongst scientific and stakeholder communities.

Table 2 outlines the key issues, perceived barriers and possible solutions with respect to water pollution management that came up in the discussion session.

Table 2: Discussions on Water Pollution: Monitoring and Management

<table>
<tr><th>Key areas</th><th>Issues</th><th>Needs</th><th>Barriers to implementation/ adoption</th></tr>
<tr><td>Monitoring</td><td>Need to switch from fragmented monitoring to holistic monitoring approach.</td><td>- Advanced monitoring systems;
- Bio-monitoring of water bodies;
- On-line monitoring systems with display.</td><td rowspan="5">- Capacity building
- Infrastructure
- Lack of availability of time series data
- Training of trainers
- Technical knowhow & technology transfer
- Budget constraints
- Standardization and integration of data
- Site/ region specific models</td></tr>
<tr><td>Drinking and irrigation water</td><td>Contaminant ingress from both point and non-point sources. Depletion of resources, conservation of resources.</td><td>- Low cost *in situ* monitoring;
- Tracer techniques for pollution source apportionment;
- New sensors from NERC/DST programme;
- Site and season specific;
- Capacity building;
- Awareness on use of resources.</td></tr>
<tr><td>Emerging contaminants</td><td>Personal care products, pharmaceuticals (anti-biotics), pesticides, microplastics, heavy metals.</td><td>- Passive samplers;
- Deep aquifer monitoring.</td></tr>
<tr><td>Re-cycling and re-use of waste water</td><td>Monitoring of contaminants.</td><td>- Low cost *in situ* monitoring;
- Real-time monitoring.</td></tr>
<tr><td>Fisheries</td><td>Declining fish stocks, fish kills and loss of diversity coupled with a lack of technological knowhow are leading to economic sustainability issues which effect the livelihoods of fishermen.</td><td>- Improved water quality models for river catchments.</td></tr>
<tr><td>Wastewater Treatment</td><td>Lack of adequate infrastructure and standardization of temporal monitoring.</td><td>- Cost effective real-time monitoring techniques;
- Integrating modelling of population growth with sewage generation to determine infrastructure need.</td><td>- Scientific capacity and collaborations
- Data
- Infrastructure investment</td></tr>
<tr><td>Watershed management</td><td>Need of a holistic approach to treatment.</td><td>- Watershed scale design of treatment process: including consideration of surface hydrology, ground water, irrigation systems, croping pattern and land capability.</td><td>- Collaborative platform
- Data sharing
- Funding</td></tr>
</table>

Key areas for future joint India-UK collaborative work and capacity building include:

- **Advanced techniques for remote monitoring:** Scientific capacity building in the form of training sessions on the use of remote sensing (RS) technology and UAVs for pollution monitoring. Ease of uptake is rated as moderate with limited assistance needed during implementation phase.
- **On-line real time monitoring:** Technology transfer oriented interventions aimed to expose implementing authorities to low cost site-specific sampling devices and sesor networks that can send real time data on pollution to monitoring stations.
- **Modelling for integration of monitoring:** Techology transfer-oriented collaborative meetings and capacity building sessions involving State pollution control bodies. There is a need for technical assistance during planning and implementation phase to ensure ease of uptake.

Session 2: Irrigation - Monitoring Availability and Consumption

Irrigation water-use efficiency and water budgeting for agriculture dominated the discussions in session two. Water intensive irrigation practices like surface and flood irrigation were reported to be widely practised by paddy and fodder cultivators in India. This severely affects water availability and lead to excessive runoff and pollution of surface water bodies, ground water and even deep aquifers. The use of farm level lysimeters coupled with water balance models was shown to help determine water losses (due to runoff and deep percolation) resulting from excessive irrigation in one of the studies discussed. The potential use of scintillation and COSMOS sensors to improve irrigation water efficiency, by informing farmers on exact crop water requirements and avoiding water stress, was demonstrated.

Irrigation Board representatives reported that state-built irrigation schemes are underperforming and in many cases not providing reliable and timely availability of water at a farm level. Additionally, there is a lack of use of modern science and technology and a high dependence on traditional methods for monitoring and management. It was highlighted that to increase crop productivity the focus needs to shift from maximizing productivity per unit of land area to maximizing productivity per unit of water consumed.

The need for blending modern design principles with existing irrigation infrastructure was discussed as an efficient way to make use of existing infrastructure and ensure cost effectiveness. Scientific interventions to increase distribution and conveyance efficiency, diversification of agricultural practices, site/region specific crop water demand models and strategies, coupled with provision of trained trainers were identified as the most important aspects requiring attention.

Table *3* highlights the key issues, perceived barriers and possible solutions in irrigation management that came up in the discussion session.

Table 3: Discussions on Irrigation: Monitoring Availability and Consumption

Key areas	Issues	Needs	Barriers in implementation/adoption
Water availability & supply	- Intermittent spatial and temporal availability of water; - Unreliable water and power supply; - Poor water conveyance systems (including problems of seepage, sedimentation); - Equitable distribution of water (amongst casts, tribes, fiscal capacity, etc.); - Design and maintenance of irrigation schemes.	- Site/region specific models/techniques for predicting water availability through various sources; - Developing *in situ* techniques for water storage, ground water recharge and power generation; - Designing better water conveyance systems for water supply and consumption at farm level; - Result based Monitoring and Evaluation (M&E) of completed schemes.	- Diversity (in terrain, agro-climatic conditions and agricultural practices); - Funds (inadequate, delayed release); - Efficient communication of scientific outputs to stakeholders; - Bureaucracy & political will; - Awareness about the importance of demand based scientific interventions and research; - Preference of stakeholders for traditional methods as opposed to belief in modern technology.
Water use efficiency (WUE)	- Over abstraction/ irrigation; - Runoff & pollution; - Competition amongst different uses/users; - Lack of awareness of efficient water use; - No standardised indicators to monitor WUE.	- Monitoring extraction and use; - Automated pump and irrigation measures; - More reliable water supply; - Runoff/ wastewater treatment, reuse and recycling; - Awareness on sustainable irrigation practices; - Development of standardised methods on data collection and development of region specific indicators of WUE; - The need for centralised and readily available databases for research at the start of projects.	
Agriculture practices	- Unsustainable irrigation practices; - Lack of crop diversification; - Lack of maintenance of existing infrastructure; - Excess fertilization and pesticide application leading to contamination of associated water bodies and storage units.	- Crop specific water demand; - Diversity in agriculture and irrigation practices; - Introduction of affordable irrigation systems; - Awareness on sustainable irrigation practices.	
Infrastructure and maintenance	- Maintenance of reservoirs and storage units; - Maintenance of water conveyance systems.	- Periodic siltation monitoring and removal; - Periodic monitoring for seepage losses; - Better operation of infrastructure;	

		- Cost effective modernisation of existing infrastructure.	
Capacity Building	- Lack of trained trainers; - Lack of funds; - Lack of continued engagement with ground level stakeholders; - Lack of Infrastructure & equipment for demonstration; - Lack of involvement of educational/ scientific institutions in capacity building, promoting demand based research.	- Training of trainers by professional academic and research institutions; - Mapping of all stakeholders and ensuring their engagement; - Ensuring long term funding to conduct engagement initiatives and monitor adoption at ground level; - Making modern instruments and infrastructure available for demos along with trained demonstrators; - Funds for pilot initiatives; - Mandate for researchers to undertake at least one application oriented project; - Communication outputs in a simplistic manner.	
Investments & Policy instruments	- Redundant focus of existing finance instruments; - Lack of political will; - Lack of corporate involvement; - Government schemes look good on paper but fail on ground.	- Reframing of definitions and design of financial instruments to increase outputs/ productivity; - Awareness amongst all sectors of government / hierarchy and corporate sector; - Collaborative work to develop site specific schemes.	

Key areas for potential India-UK collaborative work and capacity building included:

- **Improving water conveyance and water-use efficiency through cost effective technology:** A need to design and promote co-designed research projects that would be of value to end users, as well as, a centralised and readily available database with information on current water use and cropping patterns, was identified as key to achieve this, by the scientific participants. Knowledge transfer projects aimed at modernising exisiting equipment and introduction of *in situ* low cost technology would help in addressing issues at the ground level, particularly if such projects were designed and implemented in collaboration with State irrigation departments. Development of new methods for monitoring the functioning of water conveyance systems, like canals, are also important.
- **Capacity building and continued engagement:** There is a need to map key stakeholders and design an ongoing programme of simple capacity building and technology transfer sessions customised to their specific needs. Provision of trained trainers to allow wider dissemination was also disscussed as a key aspect in ensuring success of capacity building initiatives. Instruments to ensure better and continued engagement from the stakeholders needs to be in place.

Session 3: Monitoring Aquatic Ecosystems & Biodiversity

The focus of talks and discussions in the third session was on exploiting the use of earth observation (EO) and RS techniques in order to improve monitoring of aquatic ecosystems. The potential to use EO to improve monitoring for management and protection of water ecosystems was discussed, particularly in light of the spatial and temporal heterogeneity of many water body. The use of EO technology such as Airborne Hyperspectral imaging, MERIS validation for lakes, optical classification of water bodies, use of UAV/drones and near real-time reservoir storage monitoring with GRACE data was discussed. The main barriers to uptake of EO were thought to be algorithm stability, challenges of optically complex waters, and rapidly growing capability which makes it difficult for stakeholders to keep up.

Other key topics covered in the session included the diversity in pollution sources of Vembanad lake and their impact on the unique ecosystem along with proposed initiatives to support the lake's revival involving various monitoring techniques (RS, laboratory experiments, modelling studies, *in situ* measurements and citizen science). The importance of maintaining environmental flows to support ecological diversity and to maintain local livelihoods was also discussed. Further, impacts of developmental activities like hydropower and river interlinking and associated dredging activities on riverine ecosystems were highlighted. Success stories from multi-disciplinary studies into policy, mitigation and management responses to address the issues at hand, were presented.

Stakeholder presentations during the session focused on freshwater biodiversity and the associated threats and challenges in Kerala. The protocol, parameters and technology used for monitoring and managing biodiversity in the State were outlined. Key gaps identified included: a lack of structured data on biodiversity (composition, diversity and community structure); poor multi-institutional networking; insufficient quantification of carbon cycling/sequestration and; lack of a standardised sampling approach.

Table 4 highlights the key issues, perceived barriers and possible solutions in biodiversity management that came up in the discussion session:

Table 4: Discussions on Monitoring Aquatic Ecosystems & Biodiversity

Key areas	Issues	Needs	Barriers to implementation/ adoption
Data	- Lack of baseline data - Gaps in existing data - No compilation and repository - Standardization - Inter- sectoral integration - Fish species specific data for key / indicator species	- Compilation & repository - Collaborative activities for ease of data sharing & multi sectoral integration - Trainings and incentives for standardization - Site specific technology for identification & tracking of key species/ indicator species - Geospatial literacy at all scales - Improved use of citizen science approaches - Field taxonomy guides/ mobile applications - Data democracy	- Conflicts in data sharing - Political will - Funding/ economic feasibility - Motivation amongst stakeholders/ scientists - Inhibitions wrt collaborating with NGOs - Lack of trained trainers - Lack of state-of-the-art demonstration equipment - Lack of motivation for Action oriented research - Communication gaps between science producers and users - Policy instruments and mandates for sustaining business practices like tourism, etc. - Dependence upon third party to initiate inter sectoral/ multi stakeholder collaborative activities
Ecosystem services (ES)	- Remotely sensed surrogates for Ecosystem health linked to ground observations - Climate change / variability impact on phenology magnitude & distribution - Human health implications of ES - Quantification of ES - Site and region specific indicators - Social & economic aspects	- Institutional capacity for quantification - Specialist workshops RS/ GIS / detection techniques - Linking ecosystem health to human wellbeing - Develop baseline database for RS and Modelling - Youtube/online platform for training - Conflict resolution - Scientist – public interaction	
Developmental activities	- Barrage operations with no downstream ecological measurements / ecosystem response studies - Unsustainable tourism - Agricultural runoff: lack of time series data/ site specific modelling	- Site specific management plans - Cost effective *in situ* sensors and monitoring equipment - Subsidies and incentives - Training and awareness - Corporate involvement	

Key areas for potential India-UK collaborative work and capacity building included:

- **Research projects:** New projects to develop site/species/issue/stakeholder specific monitoring technology to address the issues identified in the table above were thought to be key. This technology should be easy to uptake at the ground level preferably with use of RS. To monitor aquatic ecosystem health, development of monitoring techniques for key indicator species through RS detection, capture and recapture methods were suggested. The need for furthering research into the quantification of ES and mapping of fish migration were also highlighted
- **Collaboration around data:** A need for improved collaboration across institutions, stakeholders, NGOs, universities, etc. to facilitate data sharing was identified; facilitation through training sessions and collaborative projects for data standardization was discussed as effective ways to facilitate data sharing. Improved awareness of the benefits which can be realised through data sharing, along with provision of incentives to stakeholders, was thought to be key to motivating more collaborative work. Development of taxonomic fieldguides to facilitate data collection through citizen science initiatives was discussed. Development of a baseline database for better use & integration of RS and modelling outputs was identified as key.
- **Action oriented research:** There is a need to generate motivation amongst the scientific community to pursue action based or demand-driven research. Institutional, funding and policy instruments were thought to be key in achieving this. Further training of scientists in relation to communication with stakeholders/NGOs and identification of their scientific needs was also identified as important.
- **Capacity building & training:** Training for use of RS & GIS techniqies is important in building monitoring capacity across all stakeholders and scientists. Specialised training courses are needed for specific issues and on model integration. The use of online platforms and social media to ensure cost effectiveness of training programmes was suggested.

Session 4: Water Provision - Monitoring Supply & Consumption

Integrated Urban Water Management (IUWM) and management of groundwater for the water provision sector were the key themes discussed in session four. Better integration of various sub-systems including: catchment management (including surface and groundwater), water supply systems, wastewater treatment, water allocation, decentralised treatment and storm water harvesting, in order to design fit-for-purpose approaches was highlighted as the key need. Issues associated with impurity of source water, poor quality infrastructure, cross-contamination, increasing demand and mismanagement of supply were identified as the main efficiency barriers in current water provision systems.

Techniques and lessons from joint India-UK projects like Hydroflux[4] (model which integrates climate, land use, surface water and groundwater models), UPSCAPE[5], CHANSE[6] and SusHi-Wat[7] were presented to stakeholders. A need for better engagement with stakeholders to increase the applicability of project outputs was highlighted.

The representative from the Water Supply and Drainage Board informed delegates of the institutional, operational and instrumental setups currently in place at the district and state level for water supply management. Discussions identified an urgent need to frame and implement scientific interventions to address issues associated with the supply:demand gap, salinity, recycling, data collection, climate vulnerability & increasing resilience, and improving water supply grids

[4] Hydroflux Model: http://paramo.cc.ic.ac.uk/india / http://gtr.ukri.org/projects?ref=NE%2FI022590%2F1

[5] UPSCAPE: http://www.iukwc.org/upscape-upscaling-catchment-processes-peninsular-india

[6] CHANSE: http://www.iukwc.org/chanse-coupled-human-and-natural-systems-environment-water-management-under-uncertainty-indo

[7] SusHi-Wat: http://www.iukwc.org/sushi-wat-sustaining-himalayan-water-resources-changing-climate

Table 5 highlights the key issues, perceived barriers and possible solutions in monitoring water supply and consumption that came up in the discussion session

Table 5: Discussions on Water Provision: Monitoring Supply & Consumption

Key areas	Issues	Needs	Barriers to implementation/adoption
Consumption/ Resources	- Water budgeting and the demand supply gap - Modelling approaches focussed on groundwater recharge. - Modelling approaches focussed on surface-groundwater interactions. - Basin modelling - Monitoring/modelling of soil moisture, land use ET from space - Space borne measurements of water quantity and quality - Climate modelling	- Scientific tools: groundwater exploration/artificial recharge and rainwater harvesting/revival of water bodies. - Alternative water resources (desalination, wastewater reuse). - ZOODRM model: groundwater recharge - Linked groundwater & surface water models .e.g VIC/AMBHAS as used by Hydroflux, UPSCAPE and CHANSE can be used to model groundwater surface water interaction. - GWAVA model: used at basin scale; test different water resource management options against demand - SALTMED Model: used to assess field level hydrology/ model irrigation systems to test optimum technology, crop choice etc. - IISC soil moisture and ET model, 5km gridded data time series, near real time. - RS to assess reservoir stage from space - IISC soil moisture and ET models Almost all CWC/SWR projects are using climate projections. Monsoon mission.	- Data Availability - Model deployment moderately difficult, requires training of staff/ skilled staff - Model deployment: moderate difficulty with accessible data requirements, requires specialist staff skills - Data available on request; easy to obtain - Technology, methodology, exists, calibration potentially complex , - Issues of model confidence. Multiple sources and complexity of data access
Water allocations/ Sharing	- Overall	Water sharing and conveyance across boundaries. Conflicts inter-state, inter-community and inter-sector - Understanding groundwater recharge can contribute to	- Social science skills not often available in govt institutes, silos

	- Modelling approaches focussed on groundwater recharge. - Basin modelling - Modelling of soil moisture. / land use ET from space	better understanding of shared resources - GWAVA model can be used at basin scale to model allocation of resources - SALTMED Model can be used to help resolve irrigation efficiency questions as a way of informing users. - IISC soil moisture and ET models (real time) can be used to identify areas of minor irrigation	- Model deployment is considered moderately difficult, with accessible data requirements but requires specialist staff skills. Likely to be politically sensitive (Difficult) - Applicability to resolving inter sectoral issues untested
Energy	- Conservation. Energy efficient utilities (TWAD Board spends 60% of its budget on energy).	- Modelling approaches focussed on groundwater recharge: ZOOM model developed by BGS has been used with other datasets to calculate energy usage for groundwater pumping spatially. - Understanding of Energy Water Nexus: Ongoing work at Dundee as part of hydroflux focussing on this.	- Data availability - Model deployment is complicated by availability of data.
Material	- Water conveyance systems and infrastructure	- Water transport, design of pipes and transfer efficiency improvements. Control valves and flow/pressure monitoring: Currently outside NERC/MoES scope but expertise exists in India & UK	- Main issue in accessing expertise will be cost
Control/ EMI, SCADA	- Lack of in-situ measurements and real time consumption monitoring methods	- Smart water devices, including flow measurement for smart billing. - Smart water grids - Currently outside NERC/MoES scope but expertise exists in India & UK.	- Main issue in accessing expertise will be cost
Water Safety	- Lack of means of ensuring water source quality	- Development of water safety plans - Quality monitoring and rectification of safety failures. - Modelling approaches focussed on groundwater recharge: Understanding groundwater recharge important for identifying pathways to pollution - Modelling approaches focussed on surface gw interaction: VIC/AMBHAS as used by Hydroflux, Upscape and CHANSE can be used to model gw surface water interaction pollution pathways. - New water quality sensors including: BGS Tryptohan sensors give near real time e-coli in field, being used on	- Issues around resources for implementing and monitoring plans

		projects in Bihar, Karnataka. - Passive water quality monitoring: Portsmouth passive sensors can be used for surveillance and tracking contamination sources, emerging contaminants, have been deployed in Karnataka - Space borne measurements of water quantity and quality: RS to assess water quality in reservoirs from space - Seasonal forecasting: Seasonal forecasting operational in UK. Capabilities exist in IMD IITM. Stakeholder workshop previously run by IUKWC.	- Technique is simple; Cost of field kit can be a moderate barrier - Cost of analysis, analytical skill (moderate issues) - Cost of analysis, analytical methodology exists, but needs testing operationally; can be considered a significant barrier - User concern over accessibility and actionability of forecasts. Moderate barrier
Climate	- Climate vulnerability risk assessment. - Disaster management plans. - Climate resilient infrastructure	- Use of models discussed above like Hydroflux, ZOODRM, Aquimod , IISc model for soil moisture and ET , VIC/AMBHAS, etc to address: - Modelling approaches focussed on groundwater recharge/ on surface groundwater interaction/ Basin modelling / Climate modelling and seasonal forecasting	- expertise, need to understand confidence of projections - User concern over accessibility and actionability of forecasts - Multiple sources and complexity of data access a barrier to casual user
Pricing	- Water pricing and tariffs are usually not considered in scientific studies	- Integration of Economic aspects in smart monitoring systems	- Main issue in accessing expertise will be cost

Key areas for potential India-UK collaborative work and capacity building included:

- **Data & code sharing:** Availability of data amongst all stakeholders needs to be documented and advertised widely. A common platform for all data is essential. Similarly a repository of codes for running models, including instructions, should be made easily accessible to users.
- **Pilot projects and exchanges:** Pilot projects aimed to take joint India–UK research outputs to the ground-level in collaboration with state government bodies, this would include customising of models and techniques to the region and integrating stakeholder feedback. Promoting India to UK exchanges for a better exposure to outputs was proposed, ensuring the implementation of learned techniques in India should be given due attention. A pilot project to develop and apply mining of time series data for a given location was suggested.
- **New research & collaborations:** Research to integrate different aspects of the water supply system as discussed in Table 5 including the less addressed issues of pricing and consumption monitoring were discussed to have scope in new research projects. To achieve this it is essential to arrange long term inter-sectoral communication platforms and meetings. Further, research to recognise application of RS and EO technology, increasing energy efficiency, smart water supply systems, source to consumer analysis, resilience of infrastructure to extreme events in this sector, is needed.

Field visit: Vembanad Lake

The representatives of the local research organisations organised a visit to Vembanad Lake where the delegates were introduced to the ecosystem of the lake along with multiple anthropogenic factors severely affecting its health. Talks by study area experts were also delivered. The lake was reported to be a source of drinking water, water for irrigation, and nutrition in the form of aquaculture to the neighbouring communities. However, it is suffering heavily from industrial pollution, agriculture runoff, tourism related pollution including discharge from lakeside resorts and houseboats, which has resulted in severe deterioration of the lake.

The delegates were encouraged to consider how the technology discussed in the first four sessions of the UEI could be applied on ground to mitigate the impacts on the pristine ecosystem. To further this discussion there were demonstrations of the efficiency of *in situ* instruments like WISP–M, passive sesors for monitoring of optical and qualitative parameters from the lake and a demonstration of the applicability of SALTMED model as a tool for efficient use of water, crop, and fertilizers to the delegates (copies of the model software were also provided to the delegates).

Figure 4: Field visit

6. Conclusion

The need to identify and engage stakeholders acting at different levels of a particular sector in action-oriented research was a recurring theme in discussions. Events like this UEI and platforms like the IUKWC were seen as useful in promoting engagement between scientists and stakeholders
But there is a need for an active forum to ensure continuation of discussions after such events. There were many areas where delegated could see the potential to work together to implement recent India-UK science into operational practices, but a major challenge exists in relation to the lack of mechanisms to taking forward ideas. A summary of key points arising for all sectors is presented in Table 6; for a detailed look at participant feedback in connection to the UEI refer to Annex D.

Table 6: Summary of key points

Data	A need for a common open repository for baseline and other datasets from diverse sector along with promoting sharing and advertising of available data
Demand-Driven research	Collaboration between scientists & stakeholders to design scientific outputs based on the need of stakeholders
Remote sensing / modelling outputs	Furthering research in application of RS outputs integrated with modelling outputs to provide for ground-level operations
Stakeholder Engagement	Interaction between stakeholders present at every operational level / across sectors to better understand the scope of the problem at a deeper and wider scale
Capacity building & Training	Capacity building is needed at ground-level through specialised training courses in GIS, science communication and others areas
Cost effective technology	Modernisation of existing infrastructure coupled with low cost *in situ* sensors for monitoring quantitative, qualitative and economic aspects of water resources
Site /region specific scientific outputs	Research outputs focused towards specific issue and specific region are needed
Inter-sectoral integration	There is a need for collaborative work amongst stakeholders from different sectors, scientists, water businesses
Funding for pilot projects	Funds for pilot projects to test the scientific outputs on ground; promoting knowledge exchange between India and UK for the implementation of the same

7. Remarks & Feedback

Overall the UEI structure and design was very well received by participants; the sector specific approach was appreciated especially as irrigation requirements often dominate discussions over urban water supply in the water security sector. The UEI participatory engagement tools designed to streamline the discussions on day three were successfully able to capture the current scientific capacity of stakeholders, recent joint Indo–UK science outputs and their applicability on the ground. Such engagement tools can be easily modified to fit different stakeholders and issues and IUKWC welcomes the water security community to use and test these (refer to Annex C).

At the conclusion of the Workshop a feedback form was circulated to participants who were asked to provide comments on:

- the Workshop content;
- the meeting venue and organisation;
- networking opportunities; and
- an overall score out of 10 for the workshop.

83% of participants returned the form, with anonymous responses. Participants fed back positively on the content of the workshop (including the inclusion of breakout discussion sessions); cross disciplinary theme and focus areas, the mix of participants (researchers/stakeholders and differing scientific backgrounds) and the tools and techniques (discussed by participating scientists). They reported that possible changes to enhance the workshop might include more time dedicated to networking opportunities (poster sessions and group discussions), increased participation of stakeholders and inclusion of more talks from stakeholders. Video highlights/bites of the workshop were also recommended to circulate the key outputs of the workshop and stakeholder views.

Logistical organisation and delivery of any workshop are of high importance to participants' enjoyment and participants at this workshop were on the whole complementary about the meeting space, field trip arrangements and hospitality provided. The participants immensely appreciated the metal water bottles that IUKWC circulated to reduce the consumption of plastic bottles at the workshop.

A key goal of the India-UK Water Centre is to provide a platform for bringing together users, researchers and stakeholders in water science; it was thus pleasing to note that 100% of the respondents stated that they had made new contacts as a result of the workshop with potential opportunities for future collaboration with the new contacts.

Participants identified ways in which the IUKWC could further assist in building joint UK-India capacity in the four focus areas of the UEI (see Annex D), these included:

- Establishing an ongoing platform for dialogue between authorities of states sharing water resources and scientists (along with social/ policy experts);
- Supporting collaborative projects between scientists and state-level authorities; and
- Training of trainers.

More immediate methods the IUKWC could use to facilitate continued (and increased) linkages between the stakeholders and scientists who attended the event included:

- continued direct interactions for knowledge dissemination,
- further events similar to UEI (along with workshops, exchanges and training opportunities).

Overall participants scored the workshop on average 9/10.

8. Annexes

ANNEX A: Agenda

Day 1 – 23rd January 2018

Time	Agenda item
8:30	Registration
9.00 - 9.10	Welcome and introduction to IUKWC: Dr A.K. Sahai
9.10 – 9.20	About UEI + Structure of the workshop: Dr Harry Dixon
9.20 – 11.05	Session 1: Water quality: Monitoring Pollution & Treatment
	Goundwater quality monitoring in northwest India *Dr Gopal Krishan, National Institute of Hydrology, Roorkee*
	The use of passive sampling devices to improve the monitoring of anthropogenic pollutants in river catchments in India *Dr Gary Fones, University of Portsmouth*
	Microplastics: An Emerging contaminant - polluting water bodies - less studied in India *Dr E.V. Ramasamy, Mahatma Gandhi University, Kerala*
11.05 – 11.25	Tea Break
11.25 – 13.10	Session 2: Irrigation - Monitoring availability and consumption
	Deep Percolation from Water Intensive Irrigated Crops *Dr K.S.H.Prasad, IIT Roorkee*
	Increasing Water Use Efficiency and Productivity using new technologies *Dr Ragab, Centre for Ecology & Hydrology*
	Emerging Concepts of Irrigation Water Management & its Suitability in Southern Indian States *Mr. Sunil Kumar, National Water Academy*
13.10 – 14.10	Lunch Break
14.10 – 15.50	Session 3: Monitoring Aquatic Ecosystems & biodiversity
	Water quality of Vembanad Lake: A proposed case study using remote sensing, modeling and *in situ* observations *Dr Anas Abdulaziz National Institue of Oceanography, Kochi*
	Exploiting EO capability to monitor status and change in the quality of freshwater environments *Dr Andrew Tyler, Stirling University*
	Future of India's rivers: Challenges and Opportunities *Dr Jagadish krishnaswamy, ATREE*
15.50 – 16.10	Tea Break
16.10 – 17.20	Session 4: Water provision: monitoring supply & consumption
	Integrated Urban Water Management Prof. Mohan Kumar, IISC, Bangalore
	Groundwater and water resources – UK India collaborations under the Newton Bhaba initiative *Dr Andrew Mckenzie, British Geological Survey*
20.00 – 21.30	Workshop Dinner & end of Day 1

Day 2 – 24th January 2018

Time	Agenda item
08.30 – 08.40	Welcome & recap of Day 1
08.40 – 10.15	Stakeholder talks
	Freshwater Supply Management at State level *Dr C N Maheswaran, Managing Director, Tamil Nadu Water supply & drainage board*
	Water quality monitoring and Management a state level *Dr Yashwant Sontakke, Joint Director Maharashtra Pollution Control Board*
	Faunal Diversity of Selected Wetlands- Status and Challenges *Dr Bijoy Nandan, Professor, Cochin University of Science and Technology*
	Increased Water Use Efficiency for Irrigation projects in Kerala through innovative Environment friendly techniques: The need of the hour *Anil Kumar Gopinath, Retd. Chief Engineer & Superintending Engineer Irrigation Dept. Govt of Kerala*
10.15 – 10-.30	Tea Break
10.30 – 17.00	Field visit to Vembanad Lake
	Introduction to Vembanad Lake*: Dr Nandhini (Nansen Environmental Centre, Kochi; Dr Grinson George, Central Marine and Fisheries research Institute, Kochi*
	Demo of SALTMED Model : *Dr Ragan Ragab*
	Demo of WISP- 3: *Dr Andrew Tyler & Dr Evangelos Spyrakos, University of Stirling*
	Talks by study area experts: Dr Bindu, Regional Agricultural Research Station & University of Kerala; Mr Jojo, Ashoka Trust for Research in Ecology and Environment, Dr Anas Abdulaziz, National Institute of Oceanography, Regional centre, Kochi
18.00 – 21.00	Workshop Dinner and end of Day 2

Day 3 – 25th January 2018

Time	Agenda item
8.45 – 9:00	Introductions to the day and exercise
9:00 -11.45	Group Discussions: - What are the potential uses of previous UK-India joint research in the sector? - What would be the impact of using this new science? - What further research is needed to enable the sector to make use of the science? /What other solution would they like to see developed for the sector? - What is the best way to achieve the above needs (options for collaboration?)
11.45 – 12.00	Tea Break
12.00 - 13:45	Plenary and panel discussion
13.45 – 14.00	Wrap-up and conclusions: Dr Harry Dixon
14:00	Lunch and close of UEI

ANNEX B: List of Stakeholders

	Name	Designation	Institution	State
1.	Dr Jayakara Bhandary	Associate Prof (Non official board member)	Karnataka State Biodiversity board	Karnataka
2.	Dr Somasekhar Rao	Director (Technical)	Karnataka Water Resources department: Advanced Centre for Integrated Water Resources Management	Karnataka
3.	Dr Pundarika Rao	Deputy Director & Water Resources Management expert		Karnataka
4.	Dr Preetha N	Technical Associate	Kerala Biodiversity Board	Kerala
5.	Dr Anil Kumar Gopinath	Retd. irrigation officer	Kerala Water resources department	Kerala
6.	Shri Shukoor,	Executive engineer, Major Irrigation		Kerala
7.	Smt. Geetha Devi	Executive engineer, Minor Irrigation.		Kerala
8.	Dr Bijoy Nandan	Professor	Cochin University of Science & Tech	Kerala
9.	Dr Bindu L	Assistant Professor	Regional Agricultural Research Station & University of Kerala	Kerala
10.	Dr T. Jojo	Project Coordinator	Ashoka Trust for research in Ecology and Environment	Kerala
11.	Dr C.N Mahesvaran	Managing Director	Tamil Nadu Water supply board	Tamil Nadu
12.	K. Vivekanandan	Joint Chief Engg		Tamil Nadu
13.	Dr Eugin Lily Mary	Asst Exe Engg		Tamil Nadu
14.	Mohandas Kayarat	IFS, PCCF, mem sec TN wetland authority	Tamil Nadu biodiversity board	Tamil Nadu
15.	Javeed Basha	EE, Regional office	Andhra Pradesh Pollution Control Board	Andhra Pradesh
16.	R Veerendra Kumar	JSO, Zonal Office		Andhra Pradesh
17.	Yesu Babu	Deputy Ex engg	Andhra Pradesh Water Resources Department	Andhra Pradesh
18.	Dr B.N. Bhol	Sr. Environmental. Scientist	Odisha Pollution Control Board	Odisha
19.	Dr Yashwant Sontakke	Joint Director	Maharashtra Pollution Control Board	Maharashtra
20.	Mr. D.B. Patil	Regional officer		Maharashtra
21.	Dr Nandini Menon	Senior Scientist	Nansen Environmental Research Centre	Kerala
22.	Dr Ajith Joseph	Principal Scientist and Executive Director		Kerala
23.	Dr Grinson George	Senior Scientist	Central Marine Fisheries Research Institute	Kerala
24.	Dr Anas Abdulaziz	Senior Scientist	National Institute of Oceanography	Kerala

ANNEX C: List of Indian & UK Scientists

Name		Organisation
Scientists : India		
1.	Prof. Mohan Kumar	Indian Institute of Science, Bangalore
2.	Dr Gopal Krishan	National Institute of Hydrology, Roorkee,
3.	Dr Jagadish Krishnaswamy	Ashoka Trust for Research in Energy and Environment, Bangalore
4.	Dr K.S.H.Prasad.	IIT, Roorkee
5.	Dr Sunil Kumar	National Water Academy, Pune
6.	Dr E.V Ramasamy	Mahatma Gandhi University
7.	Dr A.K.Sahai	Indian Institute of Tropical Meteorology
8.	Dr Anoop C K	Viswajyothi College of Engineering and Technology
Scientists : UK		
9.	Dr Andrew Mckenzie	British Geological Survey
10.	Dr Gary Fones	University of Portsmouth
11.	Dr Richard Allan	The James Hutton Institute
12.	Dr Shubha Sathyendranath	Plymouth Marine Laboratory
13.	Dr Evangelos Spyrakos	Stirling University
14.	Dr Andrew Tyler	Stirling University
15.	Dr Ragab Ragab	Centre for Ecology and Hydrology
16.	Dr Harry Dixon	Centre for Ecology and Hydrology

ANNEX C: Participatory exercises for UEI

Based on the information that has been shared on day one and two, participants are encouraged to discuss some of the opportunities and challenges related to freshwater monitoring and the outputs of joint India-UK water research. To help this process a series of questions and exercises have been developed. These exercises are designed to get a keen perspective into the various aspects of freshwater monitoring specific to a sector and scientific knowledge available to monitor those aspects, their use and limitations

Exercise 1

The following questions will be addressed as follows for each sector

Q1: What are the potential uses of previous UK-India joint research in the sector?
Q2. What would be the impact of using this new science?

} **1.30 hrs (45 mins /exercise)**

To help answer the first two questions discussion should be facilitated with the help of the below table as follows:

1) The group should first identify the key challenges in relation to the current methods used for freshwater monitoring for their particular sector and list these area along the top of the table (note: this information might be based on the presentations from Day two and other knowledge they have).
2) Based on the research discussed on day one and any additional scientific outputs that they may be aware of, participants are then asked to list the relevant outputs of joint India-UK research in the left hand column of the table.
3) With this information completed, participants should then discus where the science outputs could potentially be used to solve one or more of the issues and record their ideas in the relevant part of the table.

Table C-1: Example for Water Quality Monitoring sector exercise: material needed: flip charts & markers

The group needs to shortlist a minimum of six issues/ key challenges of WQM and how these are currently monitored and UK – India methods available to monitor. **The aim would be to have an inventory of all monitoring methods.**

Issue/ key challenges	**Need to improve point-source effluent monitoring from industry in large cities**	**Need to improve non-point source effluent monitoring from agriculture**	**More issues here…..**			

Outputs available						
Improved *in situ* water quality sensors	Sample collection & handheld devices (specific names) / probes for ammonia/heavy metals, etc : fixed at site / periodic site visits					
Improved water quality modelling		Ability to identify the impacts of changing agricultural practices using model X				
More outputs here…						

Similarly issues/ Key challenges can be deduced for all the sectors, some potential examples for different sectors are given below:

Agriculture and irrigation: Improving monitoring of water supply/ hectare; Need to improve monitoring of Water extraction/ Consumption monitoring (ground water vs. surface water: - consumption/ pumping /hectare OR per farmer); Remote monitoring of no of wells/ bores/ seasonality; Improving real-time monitoring of water metering; soil moisture; Need for modelling water demand based on crop type to identify over extraction / under supply/ water budgeting.., etc.

Aquatic / wetland biodiversity: Improved monitoring of flora (algae, diatoms, aquatic flora/ waterside species, etc.) / fauna (microbial/ migratory - native avian/ amphibian/mammals, etc.); Improved periodic monitoring of invasive species; ecosystem monitoring, inflow and drainage for lakes, food web, health of ecosystem, etc.

Urban water supply: Improved water supply monitoring (monitoring availability: drinking water / other purpose), Modelling for allocation – budgeting; Real time pipe leak and water supply network monitoring, Improved real-time/periodic water consumption and metering monitoring (industries/ hotels/ domestic/ other), Improved monitoring of water treatment and discharge from different sources and identifying effluent quality parameters by remote monitoring, Improved periodic monitoring of ground water use and extraction and emergence of new borewells.

Exercise 2

The aim of this exercise is to identify specific factors/ barriers associated with uptake of different scientific methods.

Reflecting on the discussions in Table 1, the group now needs to think upon the ease of uptake of joint India UK research outputs to solve issues/ key challenges discussed above. The ease of uptake can be classified as very difficult, moderate and easy and can depend on various factors like financial, ease of procurement, logistics, Staff training and capacity building needs, need of scientific support, lack /doubt wrt on ground validation and other practical aspects. The ease of uptake can be depicted by different colours in sticky notes provided and the associated factors can be noted on the respective sticky note and stuck in the relevant part of the table.

Sticky note codes: Green: Easy to uptake; Yellow: Moderate; Pink: Very difficult

An example is provided below

Issue/ key challenges / **Outputs available**	**Need to improve point-source effluent monitoring from industry in large cities**	**Need to improve non-point source effluent monitoring from agriculture**	**More issues here…..**			
Improved in situ water quality sensors	Sample collection & handheld devices (specific names) / probes for ammonia/heavy metals, etc.:					
Improved water quality modelling		Ability to identify the impacts of changing agricultural practices using model				

Pink sticky note (Improved in situ water quality sensors): Financial: Probes and *in situ* equipment can be expensive

Green sticky note (Improved in situ water quality sensors / point-source effluent monitoring): Logistically very convenient

Pink sticky note (Improved water quality modelling): Skilled personnel / Scientific support needed

Exercise 3

This exercise aims to identify the need for collaborative work between scientific organisations and the state government bodies and the best way to achieve the same. The following questions are thus expected to be discussed through this exercise.

Q3 What further collaboration between researchers and stakeholders is needed to enable the sector to make use of the science?
For example, Do the methods need adapting and/or testing in different locations/environments?
Q4. What is the best way to achieve the above needs (options for collaboration?)

1 hr

The groups can start here by selecting at least 4 key of the potential uses of India-UK research outputs identified in Table 1. Then, taking into consideration the challenges and opportunities identified in Table 2, the group should list the on-going or potential collaborative activities which would help the update of the science outputs. The group can use different colour sticky notes here to highlight activities that are already underway or are needed along with details of such activities and stick them to appropriate sections on the table.

Table C-2: Example for water quality monitoring: material needed: flip charts & red – green markers

Research needs of the hour	**Collaborative work**			**Benefits (rate on a scale of 1 – 5; 5 being the highest)**
	Institution	**Type**	**Activities**	
Site specific *In situ* equipment	University of Portsmouth - MPCB	Consultancy	Joint meetings/ consulting sessions	**4**
Real time UAV /RS monitoring	ISRO –State biodiversity board	Capacity building	Training sessions	**4**
Modelling (Specific model) for specific purpose	IITM - State water resources dept	Long term Project	Joint research activities	**4**
Urban water demand and water budgeting modelling with XX model	IIHS – state water supply board	Pilot Project	In house / visiting IIHS scientist	**5**

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