A COMPREHENSIVE REPORT ON
THE TRAINING WORKSHOP
ON

"INTRODUCTION TO GLOBAL WATER AVAILABILITY ASSESSMENT (GWAVA) HYDROLOGICAL MODEL –II"

Held at

CENTRE FOR ECOLOGY AND HYDROLOGY (CEH)

Wallingford, United Kingdom

June 21- July 01, 2015

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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE, UTTARAKHAND, INDIA
July, 2015

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BACKGROUND

The accurate assessment of the available water resources is always a challenging task due to its significant variation in space and time. The variation becomes more vivid when assessments are carried out at the global, regional and local scales. Many global models have been developed worldwide, and many are still under development, to incorporate the complex hydrological processes. With upgradation of the knowledge about the hydrologic system and introduction of new techniques, models are being fine-tuned to replicate the climate behavior.

Centre for Ecology and Hydrology (CEH), Wallingford, United Kingdom (UK) earlier known as Institute of Hydrology, has developed GWAVA (Global Water Availability Assessment) model to assess the water availability at global and regional scale. In the GWAVA approach, the integration of water availability with water use provides quantitative information about plausible future states of a basin's water resources and unique insights into critical impacts of different combinations of climate, population and land use drivers. GWAVA also offers the opportunity to model water quality and assess the impacts of future scenarios on environmental flows. The generated information can inform management and policy decisions, mediate between competing demands to achieve equitable and sustainable water use, and enable adaptation to reduce vulnerability to future change.

National Institute of Hydrology (NIH), Roorkee is actively engaged in the field of hydrological modelling and research in India. The Institute has developed and tested several hydrological models in different basins and regions of India. In an effort to mutually exchange the experience gained between CEH, Wallingford and NIH, Roorkee, a collaborative approach envisaged. The recent visit to CEH, Wallingford is an outcome of the collaboration in which the visiting scientists have been nominated to attend the GWAVA Training Programme (Part II) during June 21 to July 01, 2015. The Part I: Introduction to GWAVA modelling has already been conducted at NIH Roorkee during 02-05 March, 2015 by Nathan Rickards and Egon Dumont of CEH.

TRAINING OBJECTIVES

The visit to CEH has been made with multiple objectives. Apart from learning about the application of GWAVA model to Narmada basin, field visits have also been made to CEH's experimental catchment at Plynlimon including the Severn and the Wye catchments located at South West Wales and wetland of Lambourn at Boxford, to explore and learn the techniques involved in carrying out the hydro-climatic measurements. However, the following specific activities were envisaged to be taken up during the visit as stated below:

i. To work on the input files to GWAVA model for the Narmada basin.
ii. To make an uncalibrated model run for the Narmada basin.
iii. To understand the approach and techniques for hydro-climatic measurements in UK.
iv. To understand the approach and techniques of environmental flow (e-flow) assessment in UK.

THE SCHEDULE

The training programme was scheduled for eight working days during 22nd June 2015 to 01st July 2015. During these eight days, three days have been kept aside for field visits to experimental set-up at CEH (Meteorological site on 23.06.2015), Boxford (wetland hydrology on 24.06.2015), and Plynlimon (29.06.2015 & 30.06.2014). An entire day has been kept aside on 25.06.2015 for presentations by Dr. Mike Acreman, Dr. Cedric from CEH on environmental flows and Dr. Julian R. Thompson and Ms. Mandy Green from Wetland Research Unit of University College of London (UCL) on hydrologic modelling using MIKE-SHE. A special session had also been kept aside for presentations by the visiting scientists on 24.06.2015. In between time slots have been kept to meet and discuss with other scientists working at CEH especially with Dr. Jenkins, Dr. Ryees, Dr. Ragab, Dr. Katia, Dr. Evans and Dr. Morrison.

NIH Timetable: 22nd June – 1st July

Day➔	MON 22nd	Tue 23rd	Wed 24th	Thu 25th	Fri 26th	Sat & Sun 27th & 28th	Mon 29th	Tue 30th	Wed 1st
AM	10 am Arrive Meet & Greet Glimpse of CEH sections & Divisions	10 am Met site	GWAVA	E-Flow Risk Assessment	GWAVA		Pick up from Oxford and heading to Coach Reservoirs & Plynlimon catchments in wales	Visit to Plynlimon catchments and return back to Walling ford	GWAVA Time line See Off
		GWAVA	NIH PPTs		NRFA PPT				
PM	GWAVA Revisit	GWAVA 3.00-3.30pm Ragab	Visit to Boxford Wetland	MIKE SHE UCL	GWAVA 2.00-2.30pm Jon Evans				Leave @ 5:00pm
Evening		Walling ford on Walk		Visit to Well (Maharaja's) & Dinner with the team			Meal in Plynlimon		

THE VENUE

Centre for Ecology & Hydrology (CEH) Wallingford site is located in the village of Crowmarsh Gifford, about 20-30 minutes' drive from the following motorway junctions: M4 J8/9, M4 J12 & M40 J6 (from London and the south-east); M4 J13 (from the west/south-west), and M40 J8 (from the midlands/north). CEH's headquarters is in Wallingford, in the Thames Valley to the west of London. The venue details is given below:

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Crowmarsh Gifford, Wallingford
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Centre for Ecology and Hydrology, Wallingford

ABOUT CEH AND ITS SCIENCE AREA

The Centre for Ecology & Hydrology (CEH) is a world-class research organisation focussing on land and freshwater ecosystems and their interaction with the atmosphere. CEH is a **Natural Environment Research Council (NERC)** Research Centre and integrated to the delivery of the NERC Strategy, The Business of the Environment, with over 425 researchers and students based at sites in England, Scotland and Wales.

CEH also integrates UK-wide observation systems and curiosity driven research, from the smallest scale of genetic diversity to large-scale, whole- Earth systems. It work across disciplines and facilitate academic, public, private and voluntary sector partnerships. CEH's extensive, long-term monitoring, analysis and modelling deliver UK and global environmental data, providing early warnings of change and management solutions for our land and freshwaters. This ranges from evaluating the causes of change in biodiversity stock and function, forecasting floods, identifying and addressing the impacts of pollution and climate change, and safeguarding UK soils and carbon stocks. It also includes developing decision support tools for the sustainable intensification of agriculture and the management of ecosystem services and water resources.

The Centre for Ecology & Hydrology is one of four environmental research organisations wholly owned by NERC, along with the British Geological Survey, the British Antarctic Survey and the National Oceanography Centre. The single organisation CEH was established in 1994 from the combination of four existing NERC research centres. The Centre operates from four sites across the UK: Wallingford (headquarters), Edinburgh, Lancaster and Bangor. The current director is Prof. (Dr) Mark J. Bailey and his deputy is Prof. (Dr) Alan Jenkins. All the researches at CEH falls under one of these identified core science areas:

1. Biosphere-Atmosphere Interactions
2. Sustainable Land Management
3. Ecological Processes & Resilience
4. Environmental Informatics
5. Monitoring & Observation Systems
6. Natural Capital
7. Natural Hazards
8. Pollution & Environmental Risk
9. Soil
10. Water Resources

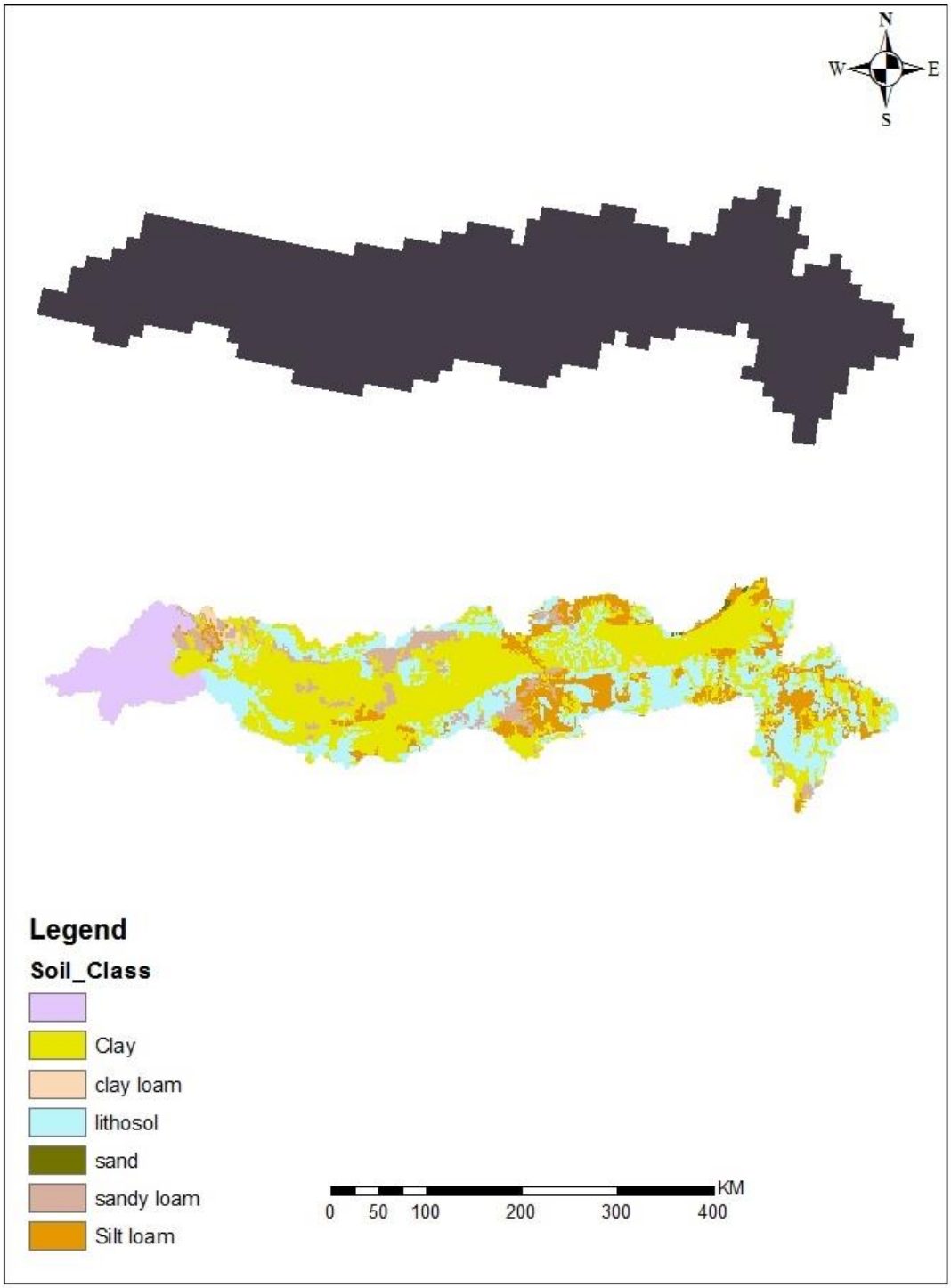
Each of the area is like a scientific division with a lead scientist to govern the research activities and within a science area there are small scientific groups of people who are engaged in a similar sort of activities.

DAY WISE SUMMARY OF ACTIVITIES

Day 1 (22.06.2015, Monday)

The first day started with formal greetings on arrival by the two training coordinators Nathan Rickards and Egon Dumont. The coordinators accompanied us to have a glimpse of their Institute and took us to the different Sections/Divisions. Finally, we were taken to the Training Room (IT Suite – SF 20). Initially, a revisit was made on the Part I training made at NIH Roorkee before working on the different components of Part II training. Then, we were briefly informed about the input files required to run GWAVA model and how to prepare them. Before attending the training, the requisite data had been procured and collected on the Narmada basin to initiate the work on GWAVA model application. The processing of the database pertaining to population, livestock,

land use/land cover, soil and climatic data up to the resolution of 0.125 degree could be completed at CEH, as agreed upon previously during the Part I training.

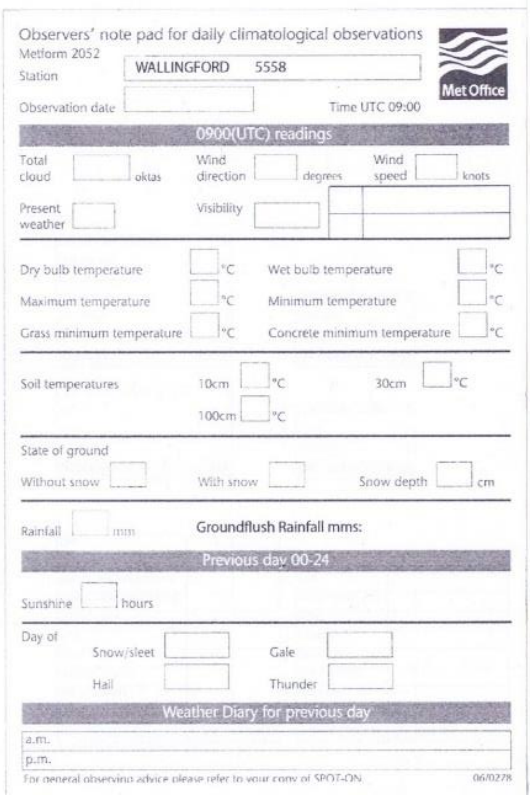


Narmada basin grids and soil map as per GWAVA model requirement

Tawa dam near Itarsi in Hoshangabad district, Madhya Pradesh.

Day 2 (23.06.2015, Tuesday)

We reached CEH office at 9:00 am and started working on processing the input files which takes considerable time. At 10:00 am we were accompanied by our Training Coordinators to the CEH Meteorological site located within their campus. Dr. Katie Muchan led the team to the observatory site and showed the various meteorological instruments and explained the approach and techniques laid down to record data.



Observers' note pad for daily climatological observations

Metform 2052

Station WALLINGFORD 5558

Met Office

Observation date Time UTC 09:00

0900(UTC) readings

Total cloud oktas | Wind direction degrees | Wind speed knots

Present weather | Visibility

Dry bulb temperature °C | Wet bulb temperature °C

Maximum temperature °C | Minimum temperature °C

Grass minimum temperature °C | Concrete minimum temperature °C

Soil temperatures 10cm °C | 30cm °C | 100cm °C

State of ground

Without snow | With snow | Snow depth cm

Rainfall mm | Groundflush Rainfall mms:

Previous day 00-24

Sunshine hours

Day of

Snow/sleet | Gale

Hail | Thunder

Weather Diary for previous day

a.m.

p.m.

For general observing advice please refer to your copy of SPOT-ON 06/0278

Scanned copy of the data proforma

Automatic Weather Station and Tipping Bucket type rain gauge installations

The automatic weather station and the various observations being recorded were shown. It was interesting to note that, the rainfall measurements were being carried out at three different elevations and their impact was being studied. Also apart from the tipping bucket type rain gauges, the weighing type rain gauges which are quite innovative and costly have also been installed in the observatory at various elevations and data is being monitored and the differences in the rainfall catch between these two types of rain gauges were being studied. Also it was informed that most of the rain gauges in UK will soon be replaced by the weighing type rain gauges which record the rainfall more accurately.

Meteorological site showing the Weighing type rain gauge at CEH, Wallingford

A separate time slot had been kept to meet Dr. Ragab Ragab, Head, Water, Soils and Landscape and Vice President, ICID.CIID. He appraised us with his present research activities and his research association with ICRISAT, Hyderabad on the collaborative project "Water4Crops" which addresses the European Commission's Framework Programme 7 (FP7) Topic 'Biotechnological Wastewater Treatments and Reuse in Agronomical Systems' and is being executed as twin projects "Water4Crops-EU" and "Water4Crops-India".

Day 3 (24.06.2015, Wednesday)

The third day of the training was scheduled with presentation by the three visiting Scientists from 10 a.m. and a field visit to Boxford at 12:30 p.m.

Presentation theme:

i. Water related problems of India by P. K. Mishra
ii. Current Research activities at NIH by M. K. Nema
iii. Hydrological Case studies from Central India by T. Thomas

Presentations by the NIH scientists at CEH, Wallingford

A short presentation on the water related problems in India was delivered by P K Mishra, wherein he highlighted briefly the various hydrological problems being faced in various parts of India. He also explained about the role of Regional Centres and various Divisions in NIH. Subsequently the presentation was continued by Manish Nema, who highlighted the capabilities available at the Institute to tackle the various problems. He also informed about the various modes of taking up hydrological studies including sponsored project mode, consultancy mode and in-house studies. This was followed by another presentation by T. Thomas about the various hydrological case studies being carried out in Central India. He explained briefly about the Narmada basin and the

climate change studies being carried out in the basin along with the modelling studies. He also showcased the drought management study and development of a Decision Support System (DSS) being implemented in the Bundelkhand region in Central India. The presentation sessions were quite interactive and appreciated by the august gathering present over there.

Visit to Natural Wetland Monitoring Sites at Boxford

CEH is working on the wetland hydrology along the Lambourn stream a tributary of River Kennet, which is a major southern tributary of River Thames. Andrew, one of the Ph.D scholars at CEH alongwith Nathan Rickards, led the team to this wetland site at Boxford and showed the network of gauging sites, piezometers and other instrumentations. He also explained about the studies being carried out in the catchment and the research work on the surface water-ground water interaction. He explained in detail about the peat soils and the geology comprising of limestone in some areas which are predominantly discharging water to the streams. It was interesting to observe the water quality was excellent as the river was virgin with no human interventions. The water quality was also being monitored apart from the discharge, weather and groundwater levels in the natural wetland catchment.

Lambourn Wetland site at Boxford

Experimental setup along the river Lambourn

Day 4 (25.06.2015, Thursday)

The entire day had been slotted for various presentations particularly by Dr. Mike Acreman and Dr. Cedric Laize to share the approach and techniques of environmental flow assessment (e-flow) with us. A lecture on "e-flow releases for GEP" was delivered by Mike Acreman, wherein he explained about the concept of e-flows, its estimation based on various downstream requirements, managing e-flows and adaptive management techniques.

Centre for Ecology & Hydrology
Visit of staff from National Institute of Hydrology, Roorkee

Environmental flows training - draft programme

Main conference room – next to reception

Thursday 25 June

`	-	10:30	reading of literature on eflows (provided by Cedric Laize)
10:30	-	11:30	introduction to eflows – Mike Acreman
11:30	-	12:30	application to risk assessment in Europe – Cedric Laize
12:30	-	13:30	lunch
13:30	-	15:00	application of MIKE-SHE/MIKE II – Mandy Green (UCL) eflows assessment in the Mekong – Julian Thompson (UCL)
15:00	-	15:30	tea
15:30	-	17:00	reading literature on eflows

Friday 26 June

11:00	-	11:45	discussion of eflow applications to India

This was followed by a lecture by Dr. Cedric Laize on "Ecological Impacts of Drought" which focused on the habitat-discharge modelling exercise using PHABSIM. He also explained about the computation of life scores and various hydro-ecological models for computing EFR. He also delivered a lecture on "Abstraction and Climate Change in Europe", which focused on the risk to ecology due to climate change and the main drivers responsible for this. The WaterGAP model was used along with two GCM and two monthly abstraction scenarios. The other scenarios considered used nine variables and 16 indicators. Monthly flow regime indicators (MFR) were employed and ecological risk to flow abstraction (ERFA) was assessed.

It was also considered to explore the use of MIKE-SHE for hydrologic modelling in the Narmada Basin for a comparison of GWAVA and MIKE-SHE. In this regard, a presentation was made by Dr. Julian R. Thompson and Ms. Mandy Green from Wetland Research Unit of University College of London (UCL) on application of MIKE SHE/ MIKE 11 in the Mekong river basin. The study was quite interesting and in the light of the proposed hydrological modelling in Narmada basin using MIKE-SHE in a collaborative mode.

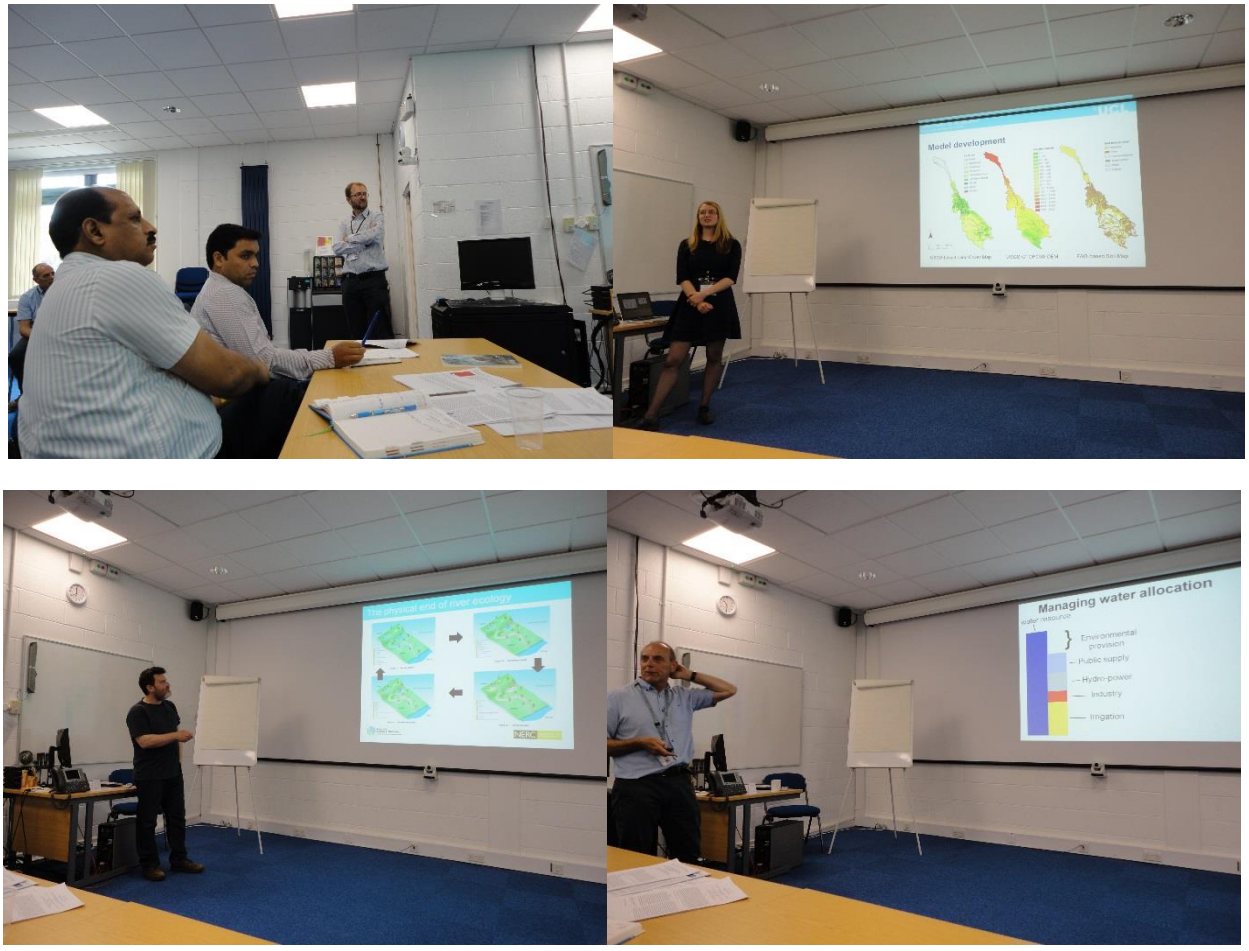
We were provided with few literature on e-flows. Finally, discussion were made on the e-flows assessment in the context of India.

Day 5 (26.06.2015, Friday)

During previous four days, we had a good exposure to GWAVA database preparation, meteorological instrumentation, e-flow assessment and field visit to Boxford. On fifth day we focused on completing the database preparation on population, livestock, land use and land cover, soil map and climatic data. Apart from this we were informed about the UK meteorological status and salient features of the gauging sites and UK's national programme on river flow data National River Flow Archive (NRFA) by Dr. Katie Muchan.

Day 6 & Day 7 (27.06.2015, Saturday & 28.06.2015, Sunday)

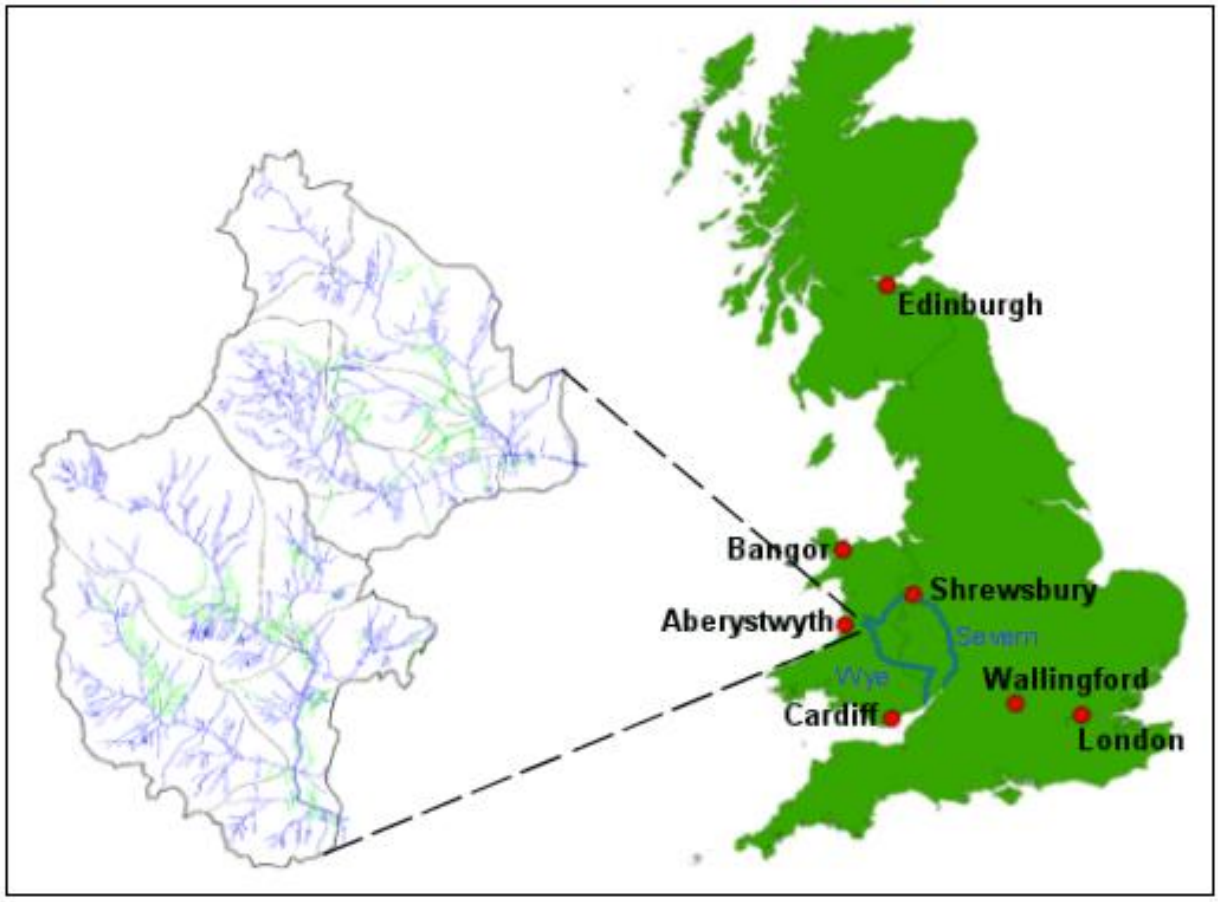
Being weekend CEH office was closed.



Presentations by Dr Thompson, Ms Mandy, Dr Cedric and Dr Acreman

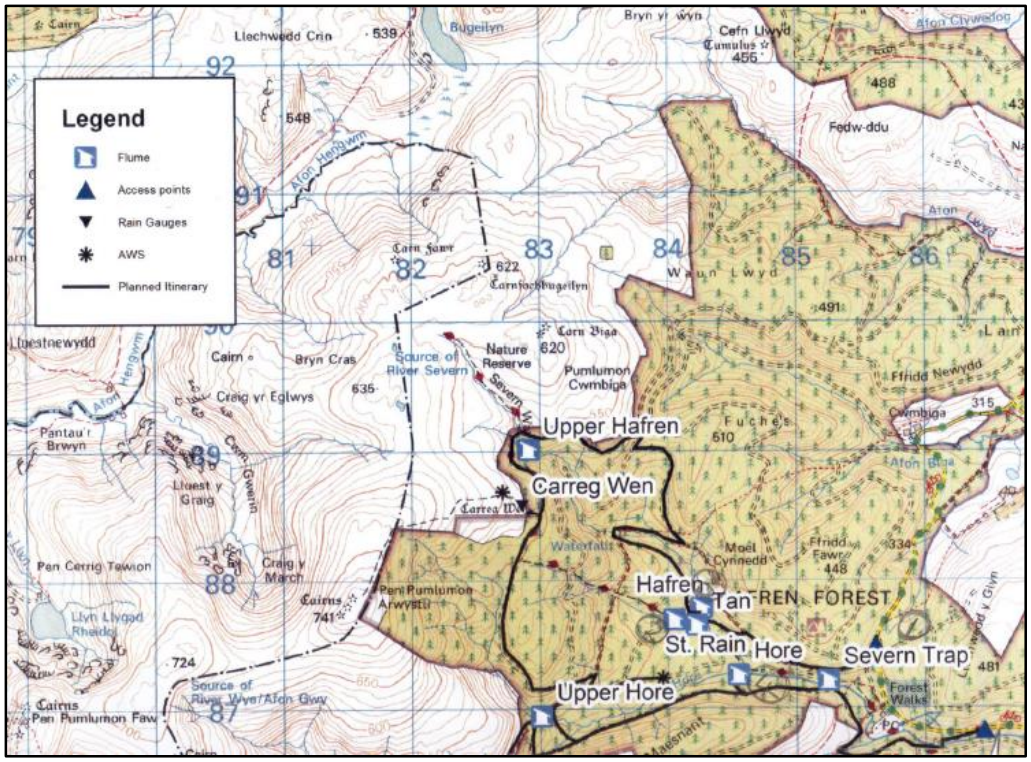
Day 8 & 9 (29.06.2015, Monday & 30.06.2015, Tuesday)

We started for CEH's Experimental setup known as 'Plynlimon catchments' at two major basins viz. Severn river and Wye River in the western Wales part of UK at 12:00 pm on 29.06.2015. The team wass led by Dr. Harry Dixon, senior hydrologist and Rickards Nathan, our training coordinator. The visit was scheduled for two days. The catchments, which cover a combined area of 19.25 km^2, are located on the east flanks of Plynlimon, which is approximately 20 km inland of Aberystwyth on the mid-Wales coast.

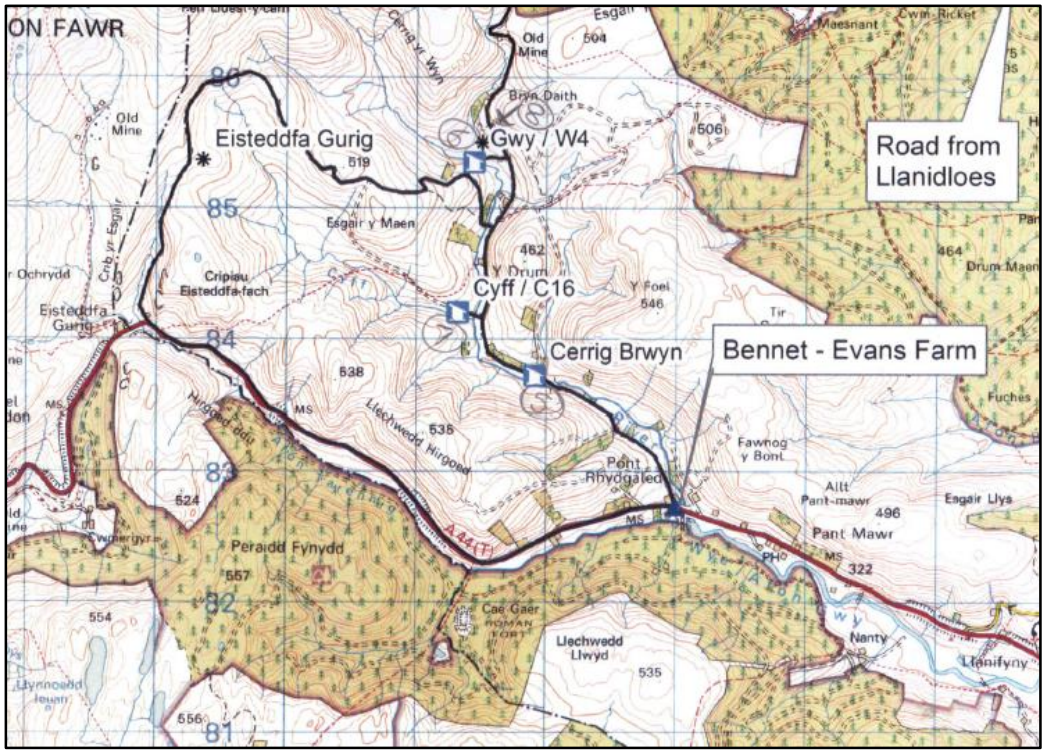


Location of Plynlimon catchments

In the Plynlimon catchments, CEH has been conducting long-term measurements of weather, stream flow and chemical fluxes. This information is used to look for time trends, understand the processes operating, and investigate the impacts of land use on water resources, floods, drought flows, stream sediment and dissolved chemicals and acidification. Also the water balance of the two catchments with completely different types of land use is being studied comprehensively.



Severn catchment (Forested)



Wye catchment (Open land)

On the visit to Plynlimon catchments, we saw Caban Coch Reservoir and Craig Coch Reservoir constructed during 1893 to 1904 which provides the water supplies to Birmingham, local towns and villages. Also the team visited two more dams. All these four dams form a series of reservoirs in the same catchment, regulated in accordance with the water requirements at Birmingham and other downstream regions.

Caban Coch Reservoir

Craig Coch Reservoir

Experimental set-up at the Plynlimon catchments (30.06.2015)

We started early on Tuesday to visit the gauging sites and other instrumentations maintained by CEH. The team was led by Mr Dave Moris, field manager who is carrying out the observations and sampling. First, we visited the lowest outlet point of the Severn River. The gauging approach is through a trapezoidal flume with provision of stilling basin for water level recording as shown below.

<u>Gauging site 1</u> (gentle slope)

<u>Gauging site 2</u> (Flume situated at large river bed slope)

<u>Gauging site 3</u> (Flume situated upstream of river Severn)

<u>Gauging site 3</u> (Data logger with sensor & Provision of safety measure)

<u>Gauging site 4</u> (AWS at the ridge of Wye catchment)

<u>Gauging site 5</u>

COSMOS-UK site

The **National Soil Moisture Network** (COsmic-ray Soil Moisture Observing System, COSMOS-UK) is establishing the first UK large area soil moisture network. The network delivers exciting new data showing how soil moisture varies across the country with soil type, climate and vegetation. COSMOS-UK stations also measure the weather and other environmental variables. COSMOS-UK has great potential to transform hydro-meteorological modelling by providing real-time data for assimilation and model validation. Leveraging the new technology of **cosmic-ray soil moisture sensing** makes our measurements representative of areas up to 700 m in diameter, which averages the inevitable small-scale variability in soils and vegetation. COSMOS-

COsmic-ray Soil Moisture Observing System UK (COSMOS-UK)

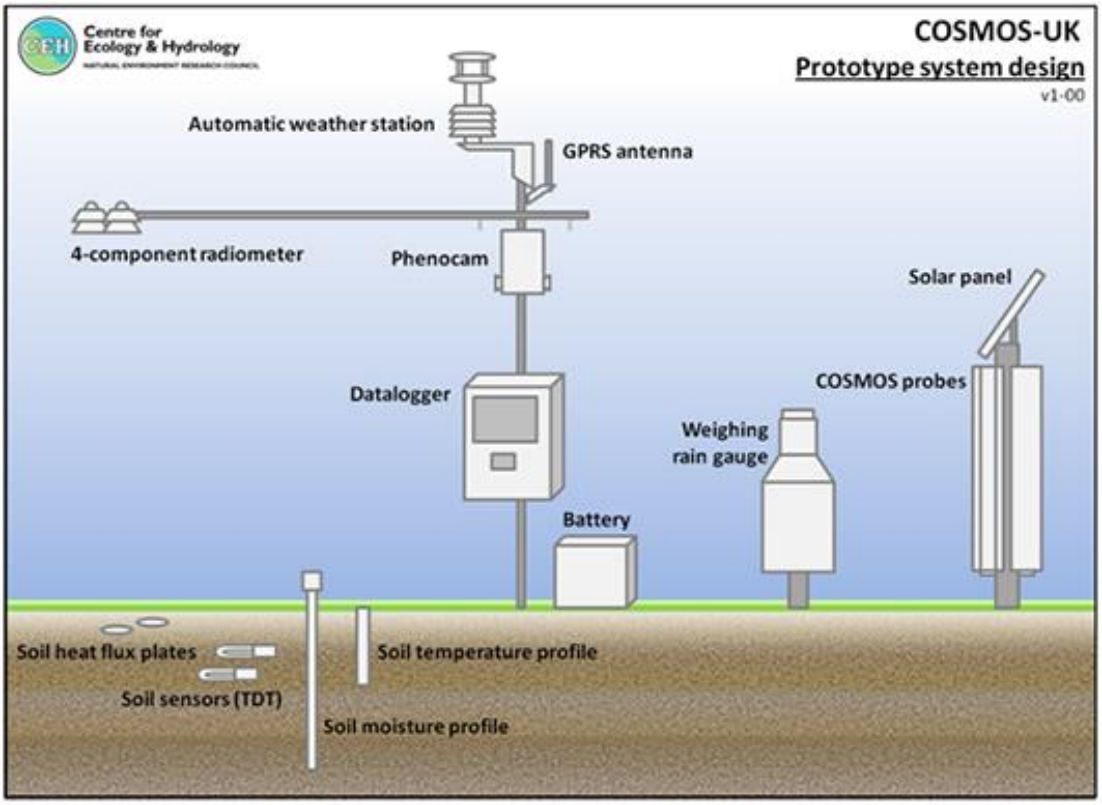
Soil moisture is a vital component of the natural environment. How much moisture is in the soil can be critical for flood forecasting; it can influence our weather; it controls soil chemistry, microbial activity and greenhouse gas exchange; and it is an important farming resource.

A new UK investment by the Natural Environment Research Council (NERC) is enabling the Centre for Ecology & Hydrology (CEH) to set up the **CO**smic-ray **S**oil **M**oisture **O**bserving **S**ystem UK (COSMOS-UK), a new network that will **deliver real-time weather monitoring and field scale measurements of soil moisture** across the United Kingdom.

COSMOS-UK Station at Chimney Meadows site.
Photo: Dr Helen Ward

UK is in the process of establishing two sites India apart from 25 sites at UK.

Principles and Components



COSMOS probes

The cosmic ray soil moisture probe provides spatially integrated soil water content representative of near-surface conditions across a large area (of approximately a 350 m radius and to a depth of about 0.5 m, although the sampling volume changes with soil moisture). The sensor actually detects fast neutrons, which have been generated from cosmic rays. At the earth's surface, fast neutrons are absorbed by water (or the hydrogen atoms within water molecules), so fewer neutrons detected implies a higher water content. In this way the neutron count can be related to soil moisture and other stores of water, such as that contained within plants.

The measurement principle is very similar to the **neutron probe developed at CEH Wallingford**, with the advantage that the COSMOS system relies on naturally occurring neutrons, rather than an artificial source. The COSMOS probes are also non-invasive and are installed above ground.

To convert the measured neutron count to soil moisture, data must be corrected to account for variations in atmospheric pressure, humidity and the intensity of cosmic rays. Then the corrected neutron count is converted to soil moisture by means of field calibration.

Soil sensors

Each station has two point sensors measuring soil temperature, soil electrical conductivity and soil permittivity using the time domain transmissometry technique. The soil moisture (volumetric water content) is calculated from the permittivity. This technique infers soil properties based on the time taken for an electromagnetic wave to travel through the soil. These sensors are installed in the soil at a depth of 0.10 m.

Soil moisture profile

A profile probe with three sensors provides soil moisture and soil electrical conductivity at depths of 0.15, 0.40 and 0.65 m. The probe sits within a specially-designed access tube and is sensitive over a radius of around 0.10 m, although the region of highest sensor sensitivity is closest to the access tube. Each sensor utilises the TDR (time domain reflectometry) technique.

Soil heat flux plates

Two heat flux plates per station provide the soil heat flux at a depth of 0.03 m. These plates have a self-calibrating feature to maximise measurement accuracy; the *in situ* calibration is performed once a day.

Soil temperature profile

The near-surface soil temperature is measured at five depths (0.02, 0.05, 0.10, 0.20 and 0.50 m) using a profile of thermocouples. The soil temperature gradient is used to estimate the surface soil heat flux.

Four-component radiometer

A four-component radiometer measures the individual radiation components using upward and downward facing pyranometers (for the shortwave components) and pyrgeometers (for the longwave components). The net radiation is calculated as the sum of the incoming minus the outgoing components and usually constitutes the main source term in the surface energy balance.

Automatic weather station

The automatic weather station provides fundamental meteorological variables. Wind speed and wind direction are given by a 2-D sonic anemometer; air temperature and relative humidity are measured by a probe situated within a radiation shield; and barometric pressure is also measured.

Weighing rain gauge

A weighing precipitation gauge gives precipitation amount and intensity readings. Both solid and liquid precipitation are measured as they contribute to the weight of the collecting bucket. Onboard processing algorithms account for spurious changes due to temperature or wind speed.

Phenocam

A phenological camera with almost 360° field of view provides visual information about the land cover (e.g. when crops are harvested, greenness of vegetation), cloud cover, snow cover and atmospheric visibility.

Day 10 (01.07.2015, Wednesday)

In the last day of the UK visit, both the coordinators tried to run the GWAVA model based on the database prepared so far, but some more modifications in the data input files were required. We met Dr Evans and Dr Morrisson and discussed him with the COSMOS-UK project. The colleagues from of Mike's section, finally, saw us off with thanks and presented us souvenirs.

Future agreed milestones and target dates for the envisaged work

A) Make an uncalibrated model run (*finished before Sept 2015*)

1. Checking PET in climate data
2. Correcting PET using measured pan evaporation
3. Make input on irrigated crops

a. Area of each irrigated crop in each cell
b. Planting date of each irrigated crop in each cell

4. Sub-catchment code (different code for cells upstream of different calibration gauges)
5. Soil (almost finished)
6. Land cover (almost finished)
7. Estimate and map reservoir parameters
8. Livestock
9. Ratio of surface water demand to total water demand
10. Give spatially constant parameters in initialization file

B) Model Calibration (*finished before Nov. 2015*)

11. Assign Muskingum parameters and possibly proportional loss parameters
12. Format gauged discharge data
13. Automatic calibration

C) Scenario Generation (*finished before end 2015*)

14. Estimate and map reservoir parameters of planned dams

D) Write ups

15. Writing first article about the effect of planned dams on water scarcity and e-flows

LESSON LEARNED FOR THE UPCOMING NIH EXPERIMENTAL SETUP AT HENVAL

Based on the field visit to the CEH's experimental catchments at Plynlimon and at Boxford, instrumentations and discussion with the scientists involved the following lessons has been drawn for the upcoming experimental hydrology project of NIH at Henval near to Chamba

- Plynlimon catchment are not only known for their length of data but also for the breadth of measurements in the world. The variety of data and monitoring is a worth thing to have it in our proposed experimental catchments.
- Research from just two small catchments (area less than $20km^2$) has been reported in more than 500 publications.
- Combination of scales : Comprising of catchment measurements and internal process studies
- Adaptability to take on new research: Initially focused on hydrology 1970-80s than hydrochemistry overtook from 90s. Our stations should also have these kind of adaptability.
- Stakeholder involvement from the outset. We must involve the local stakeholder.
- Use of several technology in parallel manual readings backup, helped to reduce the data loss / gaps.
- Sometimes aspiration exceeds capabilities : attempts to automatically snow monitoring and fitting soil moisture distribution to local topography failed
- Many of Plynlimon records are freely available to the researchers and more is being accessible via the internet
- Initially hesitation for the overlap with the work of other institute, the recent trend to encourage Inter-disciplinary research is a welcome development
- Major challenges for a long term strategic monitoring is a secure stable, long term funding.
- The Overriding lesson is to try to stay relevant to current problems and needs

POSSIBLE AREA OF FUTURE COLLABORATIONS:

During the visit we have meet many people at CEH with different specialization and different interest. Most of them were interested to get collaborated with NIH as there potential research partner in India. Based on those meetings the following research areas has been identified in which there is possibilities of future collaborations with CEH.

1. Hydro-Ecology
    - E-Flows
    - ERFA
    - River Ecology
2. Atmosphere-Hydrosphere-Biosphere Interaction
    - Studying the exchange of gases and aerosols between the Earth's surface and the atmosphere
    - CO_2 & H_2O flux exchange
    - Soil-Carbon Flux
    - Surface-atmosphere heat exchange and interaction
3. COSMOS Station
    - Soil motoring setup in NIH projects
4. Water Quality
    - Bio-chemical analysis of water sample
    - Quality modelling
5. Long-term monitoring and data collection
    - Experimental Hydrology at NIH
    - Setting up more experimental stations with world class standard

ACKNOWLEDGEMENT

We are grateful to the training coordinators Nathan Rickards, and Egon Dumont for meticulously chalked out the training schedule, and the excellent hospitality and support rendered during the training programme and our stay at UK. The team duly acknowledge Professor Alan Jenkins, Science Director, Professor Mike Acreman, and Dr. Gwyn Rees from CEH for providing the necessary logistic and financial support which was most vital for the said visit.

The team also duly acknowledge Er. RD Singh, Director, NIH and Dr Sharad K Jain, Head WRSD, for providing the technical and moral guidance for the making our visit a fruitful and grand success. We express our sincere gratitude to all others who helped us directly or indirectly by providing valuable inputs and timely help, which was vital for the successful completion of the training program.

We are optimistic about the changes this training programme will bring in our profession and hope that it will act as a booster dose for carrying out motivated professional activities with more enthusiasm and vigor in the times to come.

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