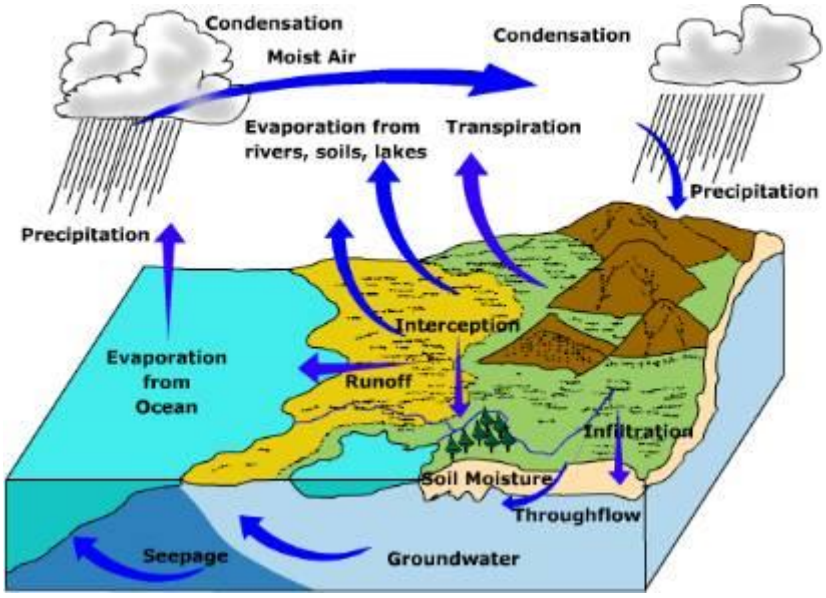
AGENDA AND AGENDA NOTES FOR THE 47th MEETING OF THE WORKING GROUP OF NIH

OCTOBER 23-24, 2018
AT 1100 HRS



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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 47th MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

ITEM NO. 47.1 Opening Remarks by the Chairman

ITEM NO. 47.2 Confirmation of the minutes of 46th meeting of the Working Group

The 46th meeting of the Working Group was held during 8-9 Feb., 2018. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/WG/NIH-10 dated 19 March 2018**. No comments were received on the circulated minutes. A copy of the minutes of the 46th Working Group is given in **Annexure A(Page#3).**

The Working Group may please confirm the minutes.

ITEM NO. 47.3 Action taken on the decisions/ recommendations of the previous Working Group meeting

During the 46th Working Group meeting, recommendations/ suggestions were made by the Working Group members and the actions taken shall be informed by the respective Divisions during the meeting.

ITEM NO. 47.4 Presentation and discussion on the status and progress of the work programme for the year 2018-19.

The approved Work Programme of the six Divisions of the Institute for the year 2018-19 has been given in the **Annexure B** in the following order**:**

The number of studies/projects handled by each Division under different categories are given below:

Division	**No. of Studies/Projects During the Year 2018-19**					
	New		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	1	-	1	3	**05**	**02**
Ground Water Hydrology	-	9	1	3	**13**	**01**
Hydrologic Investigation	-	3	-	3	**06**	**07**
Surface Water Hydrology	1	2	9	3	**15**	**10**
Water Resources System	1	3	3	11	**18**	**09**
Research Management & Outreach	2	2	2	3	**09**	**-**
Total					**66**	

During the present meeting, Division-wise progress and status of the work programme for the year 2018-19 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2018-19.

ITEM NO. 47.5: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 46th MEETING OF WORKING GROUP

MINUTES OF THE
46TH MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING 8-9 FEBRUARY 2018

The 46th meeting of the Working Group of NIH was held at NIH, Roorkee, during 8-9 February 2018 under the Chairmanship of Director, NIH. The list of the participants of the meeting is given in Annexure-I.

ITEM NO. 46.1: OPENING REMARKS BY THE CHAIRMAN

Dr. S K Jain, Director, NIH & Chairman, WG welcomed the Working Group members and the Scientists of the Institute. The Chairman informed the house about the expectation of the government that the research at NIH should lead to solution of practical problems. Also, he invited the WG members to closely interact with NIH scientists.

The Chairman then requested the Working Group members to give their general observations, suggestions and remarks on the scientific activities of the Institute. These are summarized below:

S N	Member	Suggestion(s)
1	Dr Pawan Labhsetwar	▪ Impact assessment of training courses is needed
2	Dr R D Deshpande	▪ Increase level of criticality in interpreting the data ▪ Strengthening of inter-divisional linkages by grouping of activities ▪ Work on pollution, remediation, rejuvenation ▪ Mapping of NIH scientists with WG members for specific studies ▪ Bring out review publications with help of WG members, etc.
3	Dr. Sadhna Malhotra	▪ Improve soft skills ▪ Training on presentation and project management skills needed
4	Dr S S Grewal	▪ Agenda write up should include brief results for ongoing studies
5	Dr U K Sinha	▪ Include GNIP data in IMD database. No Indian data after 1990.
6	Mrs Jancy Vijayan	▪ Prepare standard template for presentations
7	Dr Ramakar Jha	▪ Write up on studies (in PDF format) may be sent in advance to WG members so that they come prepared. ▪ NIH may work on urban water management, smart city
8	Dr A P Dimiri	▪ Align studies with BIMSTECH and SAARC countries, urban hydrology/ flooding
9	Sri Sudhindra M Sharma	▪ Focus on transfer of research results to community, other stakeholders
10	Dr Ashok K Das	▪ Share data from experimental catchment
11	Sri Punit K Mall	▪ Transfer solution of practical problems to practitioners
12	Dr C T Dhanya	▪ Create a data repository
13	Dr Shakeel Ahmed	▪ Place more emphasis on conceptualization

After taking the views of the members and their self-introduction, the Chairman asked the Member-Secretary to take up the agenda of the meeting.

ITEM No. 46.2: CONFIRMATION OF THE MINUTES OF 45th MEETING OF THE WORKING GROUP

The 45th meeting of the Working group was held during 11-12 May 2017. The minutes of the meeting were circulated to all the members and invitees vide letter No. RMOD/WG/NIH-10 dated 06 June 2017. No Comments were received. The members confirmed the Working Group minutes.

ITEM No. 46.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING

Dr V C Goyal gave a brief account of the actions taken on the recommendations/ decisions of the 45th working group meeting.

ITEM Nos. 46.4 & 46.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2017-18 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2018-19.

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2017-18 and work programme for the year 2018-19. Accordingly, the progress of various studies and sponsored projects was presented by all Scientific Divisions during the two day deliberations of the Working Group. The Division wise minutes of each study/project presented during the meeting are given next.

ENVIRONMENTAL HYDROLOGY DIVISION

Dr. C. K. Jain, Sc. 'G' and Head, EHD presented an overview, progress of studies and activities carried out by the division during 2017-18 and proposed Work Programme for 2018-19. He also gave an account of scientific personnel available at the division, sponsored and consultancy projects carried out, trainings courses organized and also future activities planned for the Division. The study-wise progress reported and suggestions / comments received on the various studies are as follows:

WORK PROGRAMME FOR 2017-18

S.No.	Study	Suggestions / Comments
Internal Studies (ongoing)		
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams **Study Team**: Pradeep Kumar (PI), C. K. Jain Duration: 2 Years (04/16-03/18) **Status**: In-progress	• The relationships developed need to be checked for their significance. • Limitations of the methodology adopted need to be incorporated in the report. • Chairman advised that the report should be completed by 15th March 2018 and sent to NEERI for comments.
Sponsored Projects (ongoing)		
2.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin **Study Team**: C. K. Jain (PI), Manohar Arora, M. K. Sharma, Pradeep Kumar, D. S. Malik (GKU) Duration: 5 Years (04/16-03/21) Sponsored by: DST under NMSHE Project Cost: 2.25 Crore Status: In-progress	No specific comments.
Sponsored Projects (New)		
3.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures **Study Team**: M. K. Sharma (PI), C. K. Jain, Surjeet Singh, Pradeep Kumar **Partner:** WRD, Raipur - A. K. Shukla, Ashok Verma, P. C. Das Duration: 3 Years (09/17-08/20) Sponsored by: NHP-PDS Project Cost: 25.4 Lakh Status: In-progress	Dr. Pawan Labhasetwar (NEERI) advised that impact on health should be studied and safe ground water sources should be identified based on aquifer characteristics.
4.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures **Study Team**: Rajesh Singh (PI), M. K. Sharma, Sumant Kumar, Pradeep Kumar **Partner:** Irrigation Department, Punjab Duration: 3 Years (09/17-08/20) Sponsored by: NHP-PDS Project Cost: 65.6 Lakh	Dr. Pawan Labhasetwar pointed out that there are more than 3000 carcinogenic contaminants and the problem should be studied holistically with proper data base. He further indicated that results should be reported carefully after consulting subject experts.

	Status: In-progress	
Consultancy Projects (ongoing)		
5.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines **Study Team**: C. K. Jain (PI), Sudhir Kumar, Y. R. S. Rao, S. D. Khobragade, Anupma Sharma, , M. K. Sharma, Pradeep Kumar **Duration**: 15 Months (04/16-06/17) Sponsored by: NTPC Project Cost: Rs. 54.96 Lakh **Status**: Draft Final Report submitted and comments awaited.	-
6.	Downstream Impacts of Water Withdrawal by TTPS from Brahmani River **Study Team**: Pradeep Kumar (PI), C. K. Jain, M. K. Sharma **Duration**: 6 Months (02/18-07/18) Sponsored by: NTPC Project Cost: Rs. 20.0 Lakh **Status**: In-progress.	-

WORK PROGRAMME FOR 2018-19

S.No.	Study	Study Team	Duration / Status
Internal Studies (Cont.)			
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows	Pradeep Kumar (PI) C. K. Jain	3 Years (04/16-03/20)
Sponsored Projects (Cont.)			
2.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI), NIH Manohar Arora, NIH M. K. Sharma, NIH Pradeep Kumar, NIH D. S. Malik, GKU	5 Years (04/16-03/21) Sponsored by: DST Project Cost: 2.25 Crore Status: In-progress
3.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) C. K. Jain Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur A. K. Shukla Ashok Verma P. C. Das	3 Years (09/17-08/19) Sponsored by: NHP-PDS Project Cost: 25.4 Lakh Status: In-progress
4.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) M. K. Sharma Sumant Kumar Pradeep Kumar **Partner:** Irrigation Department, Punjab	3 Years (09/17-08/20) Sponsored by: NHP-PDS Project Cost: 65.6 Lakh Status: In-progress
Consultancy Projects (ongoing)			
5.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines	C. K. Jain (PI) Sudhir Kumar Y. R. S. Rao	15 Months (04/16-06/17) Sponsored by: NTPC

		S. D. Khobragade Anupma Sharma M. K. Sharma Pradeep Kumar	Amount Rs. 54.kh Lacs Status: Final Draft Report submitted and comments awaited.
6.	Downstream Impacts of Water Withdrawal by TTPS from Brahmani River	Pradeep Kumar (PI) C. K. Jain M. K. Sharma	6 Months (02/18-07/18) Sponsored by NTPC Amount: 20 Lakh. Status: In-progress

***Note**: The study on Environmental Assessment of Village Ponds in Uttarakhand and Western UP has been dropped from EHD and merged with RMOD with Dr. Rajesh Singh, Sc. 'C' as one of the members of the study group.*

GROUND WATER HYDROLOGY DIVISION

Dr. N. C. Ghosh, Scientist 'G' & Head presented an overview, progress of studies and activities carried out by the division from May 2017 to January 2018. He gave an account of scientific personnel available at the division, sponsored and consultancy projects being done, conference and trainings organized, and also future activities planned by the Division. Dr. Ghosh informed that three in-house R&D studies and six sponsored studies were approved for the year 2017-18, out of which three in-house and two sponsored studies were completed and four sponsored studies will continue in the next year work program. In addition to continuing studies, seven new sponsored studies have been proposed for the year 2018-19.

Dr. Ghosh informed that during the year 2017-18, the division has (i) successfully organized 7th International Ground Water Conference (IGWC-2017) on "Groundwater Vision 2030 : Water Security, Challenges and Climate Change Adaptation", during 11-14 December, 2017 at ICAR-NASC complex, Pusa, New Delhi; (ii) has been awarded two DST-NERC-Indo-UK- Newton –Bhabha Fund Water Quality Research program projects: a) "Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin-FAR GANGA", and b) "Impact of Rainwater Harvesting on Groundwater Quality in India with Specific reference to Fluoride and Micro-pollutants".

The study-wise progress reported and suggestions emerged are given below.

1. Project Ref. Code: NIH/GWD/NIH/15-19: **Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply**

   Dr. N. C. Ghosh (PI) informed that currently four sites: Agra & Mathura in U. P. along Yamuna river, Berhara village in Arrah district in Bihar along the Ganga river, and Varaha River at Vishakapatnam are being pursued for developing RBF wells through respective state water supply department. Dr. Ghosh requested for one year extension of the project from April, 2018 and the Working Group approved it.

2. Project Ref. Code: NIH/GWD/NIH/14-17: **Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin**

   Dr. Anupma Sharma (PI) informed about the declining groundwater levels in different districts of the Yamuna-Hindon inter-basin and the increasing pollution in the Hindon river and its tributaries. The numerical model developed by using Visual Modflow was described. The water quality analysis of samples taken from Hindon river and groundwater taken from villages located within a zone of 500 m on either side of river was presented. The presence of trace metals above acceptable limits in groundwater samples corresponding to pre- and post-monsoon season along with location of villages and industries in the region was illustrated. WG suggested that the presence of trace metals should also be investigated for urban areas in the region including Delhi.

She informed that the study would be completed by March 31, 2018, and further analysis would be undertaken in a follow up study.

3. Project Ref. Code: NIH/GWD/NIH/16-20: **Ground water fluctuation and conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements**

Dr. Gopal Krishan (PI) presented the progress and the future work plans. He described the action taken on the comments made during the 45th WG meeting and suggestions given for inserting few specific objectives. To collate new evidence on recharge processes, groundwater quality, groundwater residence times, and connectivity of the layered aquifer systems and surface water, by repeated sampling of shallow and deep piezometers using a suite of environmental tracers were carried out.

4. Project Ref. Code: NIH/GWD/NMSHE/16-20: **Study of river - aquifer interactions and groundwater potential in the upper Ganga basin up to Dabrani**

Dr. Surjeet Singh (PI) described the soil and landuse maps developed, status of installation of piezometer, water sampling & analysis being carried out, future plans and results of water quality and isotopic analysis. He informed that site-wise analysis of water quality and isotopic results is in progress. Dr. Deshpande inquired whether the isotopic data are falling on the GMWL. PI informed that all the data points are lying along the GMWL.

5. Project Ref. Code: NIH/GWD/NIH/16-18: **Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR"**

Suman Gurjar (PI) presented the progress made in the study, which is completed. She informed that the model will be hosted on NIH website by February, 2018. WG suggested to mention limitations of the model in the web enabled system.

6. Project Ref. Code: NIH/GWD/NIH/16-17: ***Country-wide Capacity Building Program on*** **"Bank Filtration for Sustainable Drinking Water Supply"**

Dr. N. C. Ghosh (PI) informed that out of four training courses sponsored by the DST, three have been organized. The third course was organized at Shillong in collaboration with PHED, Shillong during 18th -22nd September, 2017. The fourth (last) training course is scheduled to be held during 5th -9th March at NIH, Roorkee.

7. Project Ref. Code: NIH/GWD/NIH/16-19: **Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water**

Dr. N. C. Ghosh (PI) informed that the land measuring 45 m x 45 m allotted by the Civil Administration along the Solani river in the Khanapur village is not suitable for installation of Bank Filtration well because of scientific, technical and tactical reasons, as the distance required for implementation of BF technology is not met and the given location does not meet the technical requirement. Hence, the progress of undertaking field experimental work is pending since May, 2017.

8. Project Ref. Code: NIH/GWD/DST/18-20: **Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin-FAR GANGA**

Dr. N. C. Ghosh (Indian Lead) presented the project funded under the Indo-UK - DST NERC-EPSRC Newton Bhabha Fund. He informed that the project is a 4 x 4 consortium partner from each country and the Indian partners are NIH (Indian Lead); IIT Kharagpur, IIT Roorkee; and Mahavir Cancer Sansthan, Patna and that of UK partners are University of

Manchester (UK Lead), British Geological Survey, Salford University; and Univ. of B irmingham. The project is of 3 years duration and cost is about 6.5 crore including UK budget.

Dr. Ghosh presented the objectives, aims, hypotheses to be tested, details about the work packages and responsibility in work packages by each partner.

9. Project Ref. Code: NIH/GWD/DST/18-20: **Impact of Rainwater Harvesting on Groundwater Quality in India with Specific reference to Fluoride and Micro-pollutants**

Dr. Anupma Sharma (India Lead PI) presented the study funded under the India-UK DST-NERC-EPSRC Water Quality Research Programme (Newton Bhabha fund). The study has recently commenced from Jan. 01, 2018. The names of institutes participating from UK and India along with the names of co-partners were informed. The research gaps, objectives of the study, and the work packages were also presented. The three different types of rainwater harvesting (RWH) structures that would be studied in detail in Rajasthan along with their locations were shown. WG suggested that another type of RWH structure, namely, the groundwater recharge shaft may also be investigated.

10. Project Ref. Code: NIH/GWD/PDS/18-21: **Ganges Aquifer Management in the context of Monsoon Runoff conservation for sustainable River Ecosystem Services- A Pilot study**

Dr. Surjeet Singh (PI) presented the background, statement of the problem, objectives, methodology and future plans of the study. Dr. M. L. Kansal, Professor, IITR suggested to modify the title of the study as "*Ganges Aquifer Management in the context of Monsoon Runoff conservation for sustainable River Ecosystem Services- A Pilot Study of Sot River Catchment*".

11. Project Ref. Code: NIH/GWD/PDS/18-20: **Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures**

Dr. Gopal Krishan (PI) presented the background, statement of the problem, objectives, methodology and future plans of the study. Director, NIH advised PI to discuss with Dr. C.T. Dhanya, IIT-Delhi about simulation work.

12. Project Ref. Code: NIH/GWD/PDS/18-20: **Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin**

Mr. Sumant Kumar (PI) informed that the study has been approved as purpose driven study (PDS) under the National Hydrology Projects (NHP). Dr. U. K. Sinha informed that BARC, Mumbai and CGWB, Patna had conducted many studies related to Arsenic in the study area (Bhojpur, Bihar) and reports are available. Chairman, WG suggested PI to contact Dr. Sinha to get his guidance and the relevant papers and report.

13. Project Ref. Code: NIH/GWD/PDS/18-20: **Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi**

This project shall be undertaken as a special project under the "Centre of Excellence for Hydrologic Modeling" after it is approved by the NHP cell of MoWR, RD & GR.

14. Project Ref. Code: NIH/GWD/NIH/18-19: Follow-up on **"Strategic Basin Planning for Ganga River Basin"**

Er. Suman Gurjar (PI) proposed the study "*Application for Conjunctive use management of Surface Water and Ground Water in Saryu Nahar Pariyojana, U.P.*" using integrated model developed by Deltares, Netherlands. Working Group recommended the study and suggested to explore the model in detail and its ease of implementation and usage. The knowledge gained in this study can be used in the "Center of Excellence for Hydrologic Modelling" at NIH.

Er. Suman Gurjar also gave a presentation on Internet of Things (IoT) and its applications in water resources, viz Smart water solution for irrigated agriculture using sensors and ICT tools, water distribution management, real time monitoring of water levels in reservoir, real-time, continuous and remote monitoring of water quality, etc. It was suggested that this type of research work can be taken up as PDS under NHP.

WORK PROGRAM FOR 2018-19

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/NIH/15-19	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.	N.C. Ghosh (Project Lead), B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff of SW Lab	21/2 year (11/15 – 4/18) **Status:** Continuing study. Extended upto 04/2019	Sponsored by MoWR, RD & GR under Plan Fund.
2. NIH/GWD/BGS/16-20	Ground water fluctuation andconductivity monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements	**From : NIH, Roorkee** Gopal Krishna, (PI), Surjeet Singh, C. P. Kumar, N.C Ghosh **From : BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator	03 Years (01/16-11/20) **Status:** Continuing study.	**Sponsored by** BGS, UK
3.NIH/GWD/NMSHE/16-20	Study of river - aquifer interactions and ground water potential at selected sites in the upper Ganga basin up to Dabrani.	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, Manohar Arora, Gopal Krishan,	1 year (01/16 – 12/20) **Status:** Continuing study	Sponsored by DST under NMSHE SP-8.
4. NIH/GWD/NIH/16-19	Grey Water to Blue Water –Natural Treatment Techniques for Trans-forming Wastewater into Sustainable Useable Water	N.C. Ghosh (Project Leader), Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Chaudhury, Sanjay Mittal, Ram Chandar	3 years (11/16-10/19) **Status:** Continuing study (progress in hold)	Sponsored by NWM, MoWR, RD & GR
5.NIH/GWD/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin-**FAR GANGA**	**NIH-Team:** N. C. Ghosh (Indian Lead) Surjeet Singh; Sumant Kumar; Gopal Krishan; Suman Gurjar **Other Indian partners:** IIT Rke; IIT Khg; & Mahavir Cancer Sansthan, Patna. **UK- Partners:** Prof. David Polya – UK lead; Univ. of Manchester; BGS; Salford University; Univ. of Birmingham.	**3 years** (01/18 – 12/20) **Status :** New Study.	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme.

6.NIH/GWD/DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific reference to Fluoride and Micro-pollutants.	**NIH-Team:** Anupma Sharma (Indian Lead); Sumant Kumar; Gopal Krishan; Suman Gurjar and M. K. Sharma **Other Indian partners:** IIT Ropar & IIT Jodhpur. **UK Partner:** Cranfield Univ. Alison Parker – UK Lead; Cranfield University Pablo Campo Moreno, School of Water, Energy and Environment; Cranfield University	**3 years** (01/18 – 12/20) **Status:** New Study.	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme.
7. NIH/GWHD/PDS/18-21	Ganges Aquifer Management in the context of Monsoon Runoff conservation for sustainable River Ecosystem Services-A Pilot study	Surjeet Singh, (PI), N.C Ghosh, Sudhir Kumar, C. P Kumar, Suman Gujar, Gopal Krishan	04 Years (02/18-02/21) **Status:** New Study	Sponsored by NHP under PDS
8. NIH/GWHD/PDS/18-20	Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures	NIH, Roorkee, India Gopal Krishan (PI), N. C. Ghosh, Surjeet Singh, C.P. Kumar. Haryana Irrigation Department Consultants IIT-Roorkee Brijesh Yadav (PI) Sehgal Foundation, Gurgaon Lalit Mohan Sharma	03 years (01/18 12/20) **Status :** New Study.	Sponsored by NHP under PDS
9. NIH/GWHD/PDS/18-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), N.C. Ghosh, Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary, Ram Chandar	03 years (01/18 12/20) **Status :** New Study	Sponsored by NHP under PDS
10.NIH/GWD/PDS/18-20	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi.	NIH Team: Dr. Anupma Sharma (Lead)	05 years (02/18-01/23) **Status:** New Study	Special Project under "Centre of Excellence"
11. NIH/GWD/NIH/18-19	Application for Conjunctive use management of Surface Water and Ground Water in Saryu Nahar Pariyojana, U.P.	Suman Gurjar (PI), Jyoti P. Patil (Co-PI), N.C. Ghosh, Sumant Kumar, Anupma Sharma, Surjeet Singh	1 year (04/18-03/19) **Status:** New Study	NIH Internal Study

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr Sudhir Kumar, Scientist-G and Head presented the brief details of various studies being carried out under the H. I. Division along with number of research papers published/accepted for publication/communicated and analytical work carried out at the Nuclear Hydrology Laboratory. He also informed about the proposed training course of the Division.

The progress of studies was presented by the respective P.I. of the study. The actions suggested by the working group for various studies are as follows:

INTERNAL STUDIES:

S.N.	Project	Duration	Status	Action(s) Suggested
1.	Interaction between groundwater and sea water along the northern part of east coast of India	2 years (01/15-12/16) Extended to 12/2017	Completed	No specific action suggested
2.	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	3 years (04/15-03/18)	Completed	No specific action suggested
3.	Isotopic Investigations in parts of Upper Yamuna River Basin	2 years (04/16 – 03/18)	Completed	No specific action suggested
4.	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	3 years (04/16 – 03/19)	Continuing Study	No specific action suggested

SPONSORED PROJECTS:

SN	Project	Duration	Funding	Status	Action(s) Suggested
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	5 Years (04/16-03/21)	NMSHE Project	Continuing Study	No specific action suggested
2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	3 Years (06/16 - 05/19)	Project with GBPIHE	Continuing Study	No specific action suggested
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	3 Years (06/16 - 05/19)	IAEA	Continuing Study	No specific action suggested

WORK PROGRAMME FOR 2018-2019

SN.	Project Title	Duration	Remarks
INTERNAL STUDIES:			
1.	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	3 years (04/16 – 03/19)	Continuing Study
SPONSORED PROJECTS:			
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	5 Years (04/16-03/21)	NMSHE Project

2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	3 Years (06/16 -05/19)	Project with GBPIHE
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	3 Years (06/16 -05/19)	IAEA under CRP
4.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	3 ½ year 18/1)– (21/6	PDS under NHP
5.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	3 ½ year (1/18 – 6/21)	PDS under NHP
6.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	3 Years 18/1)– (20/12	PDS under NHP

SURFACE WATER HYDROLOGY DIVISION

WORK PROGRAM FOR 2017-18

S.No. & Ref. Code	Title	Study Team	Duration
SPONSORED STUDIES			
1.NIH/SWHD/NIH/15-18	WaterRAIN-Him: Changes in water Resou and Adaptation options in Indian-Himal basins	Archana Sarkar Sanjay K Jain	Ongoing 3 years (1 Jan 2015 to 31 Mar. 2018) **Total Cost: 188000 SEK**
2.NIH/SWHD/NIH/14-18	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	Ongoing 3.5 years (Oct. 2014 to May 2018) **Total Cost: 12.6 Lac**
3.NIH/SWHD/NIH/16-20	Hydrological modeling in Alaknanda basin and assessment of climate change impact	A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakantha L.N. Thakural	Ongoing 5 years (Jan. 2016 to Dec. 2020) **Total Cost: 42.296 Lac**
INTERNAL STUDIES			
4.NIH/SWHD/NIH/14-18	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar N.K. Bhatnagar Vaibhav Garg Rakesh Kumar	Ongoing 3 years (April 2014 to Mar. 2018)
5.NIH/SWHD/NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Archana Sarkar Vaibhav Garg N.K. Bhatnagar	Ongoing 3 years (April 2015 to March 2018)

6.NIH/SWHD/NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani Sanjay K. Jain	Ongoing 3 years (April 2015 to March 2018)
7.NIH/SWHD/NIH/15-19	Study of Hydrological Changes in selected watersheds in view of climate change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay Kumar Jain Shard Kumar Jain	Ongoing 4 years (April 2015 to March 2019
8.NIH/SWHD/NIH/16-17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh	Completed 1 year (April 2016 to Sep. 2017)
9.NIH/SWHD/NIH/16-19	Application and development of analytical models on data collected at NIH under Saph-Pani Project "The study was discontinued by the Working Group"	Sushil K. Singh	Discontinued
10.NIH/SWHD/NIH/16-18	Snow cover variability in the Upper Yamuna Basin	Naresh Kumar Manohar Arora Rakesh Kumar	Ongoing 2 years (April 2016 to June 2018)
11.NIH/SWHD/NIH/17-19	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments	Sushil K. Singh	Ongoing 1 years (April 2017 to March 2019)
12.NIH/SWHD/NIH/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J. P. Patra Pankaj Mani	Ongoing 4 years (April 2017 to March 2021)
13.NIH/SWHD/NIH/17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P.Patra Rakesh Kumar Pankaj Mani Sanjay Kumar	Ongoing 3 years (April 2017 to March 2020)

WORK PROGRAM FOR 2018-19

NEW STUDIES (Sponsored)			
14.NIH/SWHD/NIH/17-19	Impact Assessment of Climate Change on Water Resources and Agriculture in Banas basin in Western India using Climate change Indicators(CII's)	Archana Sarkar Surjeet Singh T. Thomas	3 years (Sep. 2017 to Feb. 2019) Total Cost: 24200 Euros
15.NIH/SWHD/NIH/17-20	Water efficient irrigation by using SCADA system for medium irrigation project (MIP) Shahnehar	R.P. Panday J. P. Patra Rajesh Singh N.K. Bhatnagar	3 years (Dec 2017-Dec 2020) Total Cost:75 L NIH Componen 15 Lac

NEW STUDIES (Internal)			
16.NIH/SWHD/NIH/18-21	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario	Ashwini Ranade Archana Sarkar	3 years (April 2018 to March 2021)

S. No.	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/ Suggestions
	SPONSORED STUDIES	
1.	WaterRAIN-Him: Changes in water Resources and Adaptation options in Indian-Himalayan basins **(**Ongoing**)** In collaboration with SMHI, Sweden, SEI, Sweden and IIT Delhi, India which has been funded by Swedish Research Council (through SMHI, Sweden). Study Group:Archana Sarkar, Sanjay K Jain **DOS:** 1 Jan2015 **DOC:** 31 Mar. 2018	Dr Archana Sarkar informed that the main aim of this project is to assess the impacts on the water fluxes due to change in climate in the Indian-Himalayan basins, i.e. Ganges. She further presented results pertaining to climate change impacts under three scenarios and four time periods on precipitation, temperature, evapotranspiration, drought and runoff/discharge at Ganga river basin scale as well as regional scale of four selected regions within the Ganga basin. Dr Sarkar informed that two stakeholder workshops were also organized under the project at NIH in 2015 and 2017 and the final report of the project will be submitted to Swedish Research Council before Dec 2018.
2.	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India **(**Ongoing**)** Sponsoring Agency : Science and Engineering Research Board (SERB), DST, New Delhi. Study Group: Ashwini Ranade **DOS:** Oct. 2014 **DOC:** May 2018	Dr. Ashwini Ranade, PI of the project presented the current status of the project, the analysis carried out in last six months, and important results of the study.
3.	Hydrological modeling in Alaknanda basin and assessment of climate change impact (Ongoing) (PDS) Study Group: A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural **DOS:** Jan. 2016 **DOC:** Dec. 2020	Dr A.K. Lohani, Scientist G mentioned that the land use, DEM, River network, Snow cover area maps have been prepared. Furthermore, temporal meteorological data have been collected for the study basin. Flow data has been collected and analyzed for different gauging sites. VIC model has been setup for the study basin and the calibration and fine-tuning of the model parameters is in progress.
	INTERNAL STUDIES	
4.	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State **(**Ongoing**)**	Dr Archana Sarkar, Sc D & PI presented the background, objectives, methodology and results of the study. Results of trend analysis of historical rainfall series of number of rainfall events of various intensity (annual and monsoon) by parametric and non-parametric methods for ten rainfall

	Study Group: Archana Sarkar N.K. Bhatnagar Vaibhav Garg Rakesh Kumar **DOS:** April 2014 **DOC:** Mar. 2018	stations (grid centres) five each in Kumoan and Garhwal regions using IMD gridded rainfall data of 113 years (1901 to 2013) was explained. Further, results of rainfall from three sources (observed, TRMM and APHRODITE) were presented showing better accuracy of TRMM data in comparison to APHRODITE. Dr Dimri asked to mention the limitations of data in the final report. Dr Sarkar informed that the final report of the study will be submitted by the end of April 2018.
5.	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin (Ongoing) Study Group: Archana Sarkar Vaibhav Garg N.K. Bhatnagar **DOS:** April 2015 **DOC:** March 2018	Dr Archana Sarkar, Sc D & PI presented the background, objectives, methodology and results of the study. Degree day approach along with soft computing has been followed for hydrological modeling including snowmelt runoff modelling. Various scenarios (hypothetical) of precipitation and temperature were considered to study the impact of climate change on the hydrological regime of the study basin. Results showing various snow cover maps for four years using MODIS data as well as results of SRM, SNOWMOD & ANN models simulation were presented. Dr Sarkar further explained the results of the comparison of various models and impact of climate change using hypothetical results. Chairman of the working group, pointed out the importance of the study due to the proposed Pancheshwar dam in the study basin. Dr Kireet Kumar suggested for collaboration with NIH for working in the Sharda basin. Final report of the study will be submitted by the end of April 2018.
6.	Flood and Sediment studies in Himalayan basin using MIKE-11 Model (Ongoing) Study Group: A.K. Lohani Sanjay K. Jain **DOS:** April 2015 **DOC:** March 2018	Dr A.K. Lohani, Scientist G presented the progress and mentioned that an event of Assiganga cloudburst 2012 has been considered for the study. Various raster and vector maps of the study area have been prepared using the satellite data, DEM and google earth. Dr Lohani mentioned that cloudburst flood routing in Assiganga and Bhagirathi rivers have been carried out using MIKE-11 software. Results were superimposed on Google Earth for better display and interpretation. Historical sediment data (prior to the construction of Tehri Dam) of Bhagirathi river was also collected and study of temporal sediment variation and sediment-discharge correlation was carried out at the selected site. Dr. P.R. Ojasvi, inquired the sediment data shown is total sediment load or suspended sediment. Dr Lohani confirmed that the data is suspended sediment load. Report writing is in progress.
7.	Study of Hydrological Changes in selected watersheds in view of climate change in India **(**Ongoing**)** Study Group: L.N. Thakural D.S. Rathore Surjeet Singh Sanjay Kumar Jain Shard Kumar Jain **DOS:** April 2015 **DOC:** March 2019	PI of the study presented the objectives, methodology and the status of the ongoing study. The GIS database created by using Digital Elevation Model (DEM) and satellite imagery for flow accumulation, stream network, watershed boundary, Land use/Land cover thematic maps in addition to soil map for the four watersheds was presented. Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches for the Ramganga, Bina and Chaliyar river basins was also presented in the meeting. The outcomes/results of hydrological models (NAM and SWAT) calibrated and validated for the three river basins i.e. Ramganga, Bina and Chaliyar river basins were also presented. The study has

		been extended for a period of one year. Dr. Pawan Labhasetwar, NEERI suggested to interact with the stakeholder departments. Director NIH advised PI to visit the study area.
8.	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data (Completed) Study Group: Sushil K. Singh **DOS:** April 2016 **DOC:** Sep. 2017	Dr. S. K. Singh informed that the study model (Unified Extreme-Value, UEV-unified extreme value distribution) developed in a previous report unifying the three extreme-value distributions (EV-1, EV-2, and EV-3 or Gumbel, Frechet, and Weibull distributions, respectively), which better replaces the widely used GEV (generalized extreme-value distribution) has been applied illustratively on measured/published data on a few GD sites on Indian catchments particularly in different CWC-subzones. The two methods proposed in the report/ paper have been applied to estimate the parameters of the new model (UEV distribution). Concept of deterministic confidence limit with its quantification is proposed in the paper, which is easy to apply, and avoids the tedious process involved in currently used statistical hypothesis-testing with a probabilistic confidence interval, has been used to quantify the confidence limit of the UEV application in each case. Results show that the applications of the proposed UEV closely reproduce the observed data with good predictive reliability besides ease in application outperforming the prior methods.
9.	Application and development of analytical models on data collected at NIH under Saph-Pani Project Study Group: Sushil K. Singh	The Working Group decided to discontinue the study and accordingly the study has been dropped.
10.	Snow cover variability in the Upper Yamuna Basin **(**Ongoing**)** Study Group: Naresh Kumar Manohar Arora Rakesh Kumar **DOS:** April 2016 **DOC:** June 2018	Shri Naresh Kumar, Scientist B mentioned that MODIS Mod 10A2 snow data from National Snow and Ice Data Center (NSIDC) for a period 2000 to 2016 have been downloaded. All the 8-day MODIS snow data were imported from HDF-EOS format to IMAGINE Image format and transformed to the projection WGS1984-UTM44N (Universal Transverse Mercator). The data have been clipped to the extent of the study area. Data base preparation in ArcGIS (Basin map and drainage network) from DEM has been completed. Data analysis is in progress. As suggested by the working group a new objective, "Modelling of melt water at Paonta Sahib" has been added to the study.
11.	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments (Ongoing) **Study Group:** Sushil K. Singh **DOS:** April 2017 **DOC:** March 2019	Dr S K Singh informed that the development of the new model for runoff modeling is complete and the development of method/procedure for the estimation of its parameters is in progress. Testing of the model is in progress. The PI requested for extension of time up to March 2019 and the same was agreed by the Working Group.

12.	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f) (Ongoing) Study Group: Sanjay Kumar Rakesh Kumar J. P. Patra Pankaj Mani **DOS:** April 2017 **DOC:** March 2021	Dr. Sanjay Kumar explained the background, objectives and methodology. The study specifically focuses on developing design flood estimation methods for partially gauged or un-gauged regions based on the concept of regionalization using L moments approach. The study would also develop relationship between mean annual peak floods and physiographic characteristics of the basin and develop regional relationships for NASH and Clark IUH model parameters. Daily discharge data of 21 sites in the lower Godavari basin has been collected and at site frequency analysis based on L-moments approach is in progress. He also mentioned that various CWC reports, PMP atlases and other relevant literature have been collected for the study. It was informed that climate change impact on design flood estimation is one of the objectives of the study.
13.	Development of regional methods for design flood estimation in Uttarakhand **(**Ongoing**)** Study Group: J.P.Patra Rakesh Kumar Pankaj Mani Sanjay Kumar **DOS:** April 2017 **DOC:** March 2020	Mr. Jagadish Prasad Patra, presented the objectives, need for such study with brief methodology. Daily rainfall data of about 30 raingauge stations were collected from IMD along with gridded rainfall data from 1901 to 2013. The progress of at site flood frequency analysis using L-moments approach for annual maximum peak flood series data of CWC gauging sites were also presented. Further it was explained that the non-stationary aspect of data series will also be considered in frequency analysis for climate change aspects.
	NEW STUDIES (Sponsored)	
14.	Impact Assessment of Climate Change on Water Resources and Agriculture in Banas basin in Western India using Climate change Indicators (CII's) (New Study) In collaboration with SMHI, Sweden, SEI, Sweden and 12 other countries which has been funded by ECMWF (through SMHI, Sweden) Study Group: Archana Sarkar Surjeet Singh T. Thomas **DOS:** Sep. 2017 **DOC:** Feb. 2019	Dr Archana Sarkar, PI, presented the background and objectives of this international study Banas river basin located in the State of Rajasthan in western India has been selected for applying the products of GLORIOUS C3S Global Service. Bisalpur drinking water cum irrigation project is constructed across river Banas with an ultimate irrigation potential of 55224 hectare (irrigation during the months of October to March for the Rabi crop), besides providing 458.36 MCM of drinking water for Jaipur, Ajmer, Beawar, Kishangarh, Nasirabad and other enroute cities/town/villages. Therefore, it is important to assess the water availability of this reservoir using climate impact indicators for future years and suggest suitable adaptation options. Dr Sarkar further informed that Climate indicators namely, temperature (min & max), rainfall, solar radiation, soil moisture, water temperature and drought indicators will be used in the Banas basin to assess the future climate impacts on the water availability in the Bisalpur reservoir and crop yields in the command area.
15.	Water efficient irrigation by using SCADA system for medium irrigation project (MIP) Shahnehar **(**New Study**)** (PDS)	Dr. R.P. Pandey, Scientist G and PI reported that this is a PDS taken up in collaboration with the Department of Irrigation & Public Health Engg. (I&PHE) Himachal Pradesh. A field visit of the Shahnehar Project areas has been conducted by the NIH team in December 2017 for reconnaissance survey and to work out the modalities of the

	Study Group: R.P. Pandey J. P. Patra Rajesh Singh N.K. Bhatnagar **DOS:** Dec 2017 **DOC:** Dec 2020	project works. Primary objective of this study is to devise a suitable approach to improve irrigation water use efficiency in Shah Nehar Project (SNP) and automation of the irrigation water supply system based on real time crop water demands. The proposed methodology and the work component includes development of a system of water supply database of quantum of water used to each beneficiary so the charges can be levied accordingly. The deliverables of the study will be estimates of water availability at headwork's and irrigation water requirements for various crops at different growth stages & time period; quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application method; identification of components of irrigation system needing intervention to enhance water use efficiency; and experimental assessment of SCADA based approach in the enhancement of water use efficiency.
NEW STUDIES (Internal)		
16.	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario (New Study) Study Group: Ashwini Ranade Archana Sarkar **DOS:** April 2018 **DOC:** March 2021	Dr. Ashwini Ranade, PI has proposed a new internal study and presented the objectives, dataset and methodology. The study mainly aims to understand the effect of global temperature change on the long-term rainfall fluctuations major and minor river basins. The study also highlights the meteorological conditions associated with large-sale extreme rain events in different parts of the country.

WATER RESOURCES SYSTEMS DIVISION

Dr. Sanjay K Jain, Sc. G and Head (WRS Div.), presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. He also informed about the progress of ongoing National Hydrology project (NHP) and its different components mainly the PDS and training programmes. Following are the comments received from working group on the various studies.

PI: Dr. M. K. Goel, Scientist "G"

1. ***Study title: NIH_Basin – A WINDOWS based model for water resources assessment in a river basin (Ongoing)***

Dr. M. K. Goel (MKG) informed that envisaged objectives of the study included modifications in the modeling methodology and development of WINDOWS interface (named as NIH_Basin – NIH_Basin-Simulation) of the model. He informed that no more modifications are planned for the time being and the FORTRAN code of the model is nearing finalization. After this, the data entry forms for WINDOWS interface would be developed.

Some of the members desired that simulation of sediment movement should also be a part of the model. MKG clarified that initially it is planned to complete the water balance aspect and later on modules for sediment analysis, water quality analysis, etc. will be added. Regarding the simulation of snowmelt runoff, MKG clarified that results of existing snowmelt model (WinSRM or SNOWMOD etc.) runoff series can be considered as an input to the river basin simulation at a desired node. Some members expressed that assumption of uniformity of conditions in a grid (of size, say 1 km) may not truly represent the actual field conditions. Director, NIH clarified that model is planned to serve as a

hydrological tool for supporting management and policy decisions at basin scale and since the river basins cover large areas, some compromise with regard to the grid size has to be made. MKG clarified that grid-size is a variable and depending on the size of study basin, the smaller or larger grid-size can be selected.

2. Study title: National Mission for Sustaining the Himalayan Ecosystem (NMSHE) (Ongoing)

MKG made a general presentation of the NMSHE project on the first day of the Working Group meeting. He informed about the concepts of NMSHE Task Force and the objectives of 11 sub-projects which are under progress at NIH under NMSHE.

The progress of six sub-projects under NMSHE being carried out in the WRS division was presented by MKG.

Sub-project – 1: Development of a project website and hydrological database in Upper Ganga Basin (PI-Dr. M. K. Goel, Sc-G)

Dr. Ojasvi suggested that springs are an important source of water for Himalayan population and geo-tagging of springs in the study area may also be carried out. MKG informed that one Scientist from WHRC, Jammu had made a presentation on this aspect in the Niti Ayog and he is carrying out a PDS under NHP for the Ravi basin. It is also planned to carry out such activity for the study area in the present case. Some members expressed that for spring-related data, Wadia Institute and some State departments such as Jal Nigam of Uttarakhand State and NGOs may be contacted.

Sub-project – 2: Real-time snow cover information system for Upper Ganga basin (PI-Mr. D. S. Rathore, Sc-F)

Members suggested to refer to the SAC website for snow cover information.

Sub-project – 3: Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region (PI-Dr. Sanjay K. Jain, Sc-G)

No specific comments were received from members.

Sub-project – 4: Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios (PI-Dr. Renoj J. Thayyen, Sc-D)

Results of a new method of cloud cover removal is discussed and showed the snow cover duration changes during 2000 -2016 period for different elevation zones of the basin. RJT highlighted the significant decline in snow cover duration observed in 4000-4500 m elevation band. New finding of increasing uncertainty of discharge during May/June and September months since year 2000 as compared to previous decade (1989-1999) have been discussed. RJT also informed that an AWS has been installed in Harsil under this project. No specific suggestions received for this project

Sub-project – 5: Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin (PI-Dr. Sharad K. Jain, Sc-G)

The results of calculation of diffusion coefficient for the AWS site at Henval was discussed by RJT. Issues related to dominant katabatic winds in controlling the temperature was discussed. Members were informed about the successful installation of AWS at 1800 m a.s.l. on the mountain ridge under this project.

No specific suggestions received for this project

Sub-project – 11: Water Census and Hotspot analysis in selected villages in Upper Ganga basin (PI-Dr. P. K. Mishra, Sc-C)

Results of the recent survey of 27 villages were presented by MKG. In the absence of Dr. P. K. Mishra, PI, RJT explained that most of the surveyed village experience water problems during some time of the year. RJT highlighted that the recurrence of extreme events in the 1000-2000 elevation zone which also populated heavily making this elevation zone as hazard hotspot. Refinement of hazard hotspot mapping is possible with geotagging of the extreme events of past 7 years.

No specific suggestions received for this project

PI: Dr. Renoj J Thayyen (RJT), Scientist "D"
RJT presented three studies.

1. ***Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh (Ongoing)***

RJT presented the background of the project and summarized how ground ice melt and permafrost processes to be found important for the catchment. One year data retrieved from 22 ground temperature sensors were shown. It is also showed that extending zero curtain period from low to higher elevation sites. RJT also showed result of ground temperature profile modelling suggesting significant permafrost in the region.
No specific suggestions received for this project.

2. ***Runoff modeling of Shyok River, Karakorum Range (Ongoing)***

RJT informed that the project is being executed in association with Border Roads Organisation (BRO) at Km 150 of Durbuk—DBO axis. The project was initiated in January 2015 and only discharge data have been collected so far and no meteorological data is available from the region. This leads to difficulty in modelling runoff from the basin. RJT discussed the snow cover depletion in the upper Shyok basin during 2016 period.
Considering the practical difficulty in installation of instruments and accessibility without any support from BRO, continuation of the study is difficult, RJT suggested discontinuation of this study.
No specific suggestions received for this project.

3. ***Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range (Ongoing)***

RJT presented the results of this SERB sponsored project and informed the members that the project is in second phase. The project is aimed at generating a long-term glacier mass balance data series from Ladakh region representing the cold-arid system of the Himalaya. The present project is focussing on studying the surface energy mass balance of Phuche and Khardung glaciers. RJT informed that the Phuche glacier experienced positive mass balance during 2016-17 ended on 30 September. Whereas Khardung glacier consistently experience negative mass balance. RJT informed that two weather stations were installed over the glacier for detailed SEB studies and a 10 m thermal profiler also installed on each glacier. RJT also showed result of energy balance data at 5600 m a.s.l. for the past two years.
No specific suggestions received for this project.

4. ***Dynamics of Himalayan Ecosystem and its Impact under changing climate scenario (Ongoing)***

RJT informed that this project is funded by MoEF under National Mission on Himalayan Studies (NMHS). This project is undertaken in collaboration with Jawaharlal Nehru University and other 4 institutions. He informed about the procurement of 50 temperature/ humidity sensors and 10 rain gauges under this project. He discussed about the five proposed profiles across the Uttarakhand and updated that installation of three profiles have been already completed. RJT also presented the results of lapse rate analysis of Sutlej and Upper Ganga basin and discussed the monsoon lowering of SELR, unique and consistent temperature lapse rates equaling SALR values of the glacier regimes of both the study basin.
No specific suggestions received for this project.

PI: D. S. Rathore (DSR), Scientist "F"

1. Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra (Ongoing)

The progress of the project was presented by Mr D.S. Rathore. It was informed that the study is near completion. DSS applications, namely drought categorization, reservoir operation, water quality modelling and conjunctive use modelling were presented. Basin wide drought categorization was done utilizing monthly rainfall data. Standardized Precipitation Index (SPI) of four- month scale was used in the application. Reservoir operation for Khadakwasla complex was investigated for historic and reduced inflow scenarios. For 20% reduced flow scenario, reduction in yield varied from 15- 24% at different dependability. BOD and DO were simulated for Mula, Mutha and Bhima (up to Daund) for historic and reduced inflows and increased STP capacity. In NMRBC command, releases were apportioned in to sub commands based on crop area. Scenario of lower release in the tail sub command was simulated. Return flow to river and aquifer was 10% each. Mrs Vijayan enquired about the impact of reduced flow scenario in case of conjunctive use. It was informed that the scenario is yet to be modelled. Dr Dimri inquired whether soil moisture indices were estimated. It was informed that the index was not estimated.

2. Design and development of DSS (H) platform for Neeranchal National Watershed Project (Ongoing)

The progress of the project was presented by Mr D.S. Rathore. It was informed that the DSS is to under development for State Level Nodal Agency (SLNA) of nine peninsular states in India. For each state, two districts and six watersheds in each district were identified. The features and architecture of the DSS were presented. The DSS is web based system which acts as repository of data, performs data analysis and provide decision support to users at watershed and district level. User management system is implemented through a content management system, Drupal. DSS allows visualization of data in map, table and graph form. Tools for computing potential evapotranspiration, water quality index, water poverty index are implemented for test/ sample data. Data for Chhattisgarh state are being entered in DSS. Dr S M Sharma informed that hydrogeological maps have been prepared by NRSC and are available in image format at Bhuvan portal and can be utilized in the project. Mr Rathore stated that the data were downloaded from internet and will be utilized in the study.

3. Investigating water stress using hydro-meteorological and remote sensing data (New Study, PDS)

The objectives of the study were presented by Mr D.S. Rathore. The objectives of the study are characterizing water stress using hydro-meteorological and remotely sensed data and vadoze zone modeling, studying impact of drought mitigation measures, field level soil moisture investigation, forecasting and regionalizing drought indices and devising reservoir operation policies.

PI: Shri M. K. Nema (MKN), Scientist "C"

1. Hydrological Processes and Characterization of Lesser Himalayan Catchments (Ongoing)

The progress of the study was presented by MKN. It was informed that almost all proposed instrumentation like 03 No. of AWSs; 10 no. of SRGs, two gauging sites, one AWLR; Eddy covariance tower, one COSMOS sensor; two Pan Evaporometer etc. have been installed in the experimental catchment and data is being received at NIH, Roorkee. Soil monitoring station has also been established at project site. Some of the preliminary data analysis of rainfall, air temperature, humidity, wind speed and direction, solar radiation and various soil parameters were also shown and discussed during the presentation.
No specific comments were received from the members.

2. Modelling of Narmada basin using GWAVA Model
MKN presented the progress of the study. It was informed that the study is almost completed and going to be finalized by March-2018. It was also informed that a workshop is also planned in March,

2018 at Bhopal. Various results were shown and discussed during the presentation. With reference to the future climatic scenarios, Dr AP Dimri suggested to use RCM model outputs along with GCM models. He has given his consent to provide the RCM outputs. It was suggested Chairman that the study on use of climate change scenarios may be taken up as a separate study.

PI: D. Chalisgaonkar (DC), Scientist "F"

1. Development of Ganga Information Portal

Mrs Deepa presented the progress of the study. She informed that the major objective for developing such a portal are to collect scientific and technical information about river Ganga from varied sources, organize it in standardized format and provide a thin client scalable web enabled information system. The purpose is to provide easier, faster access, sharing of consistent and authentic information through a centralized repository in public domain, user-friendly and personalized way for several key areas related to public interest and to operate, update and maintain the e-portal on 24X7 basis. A sample session was also presented.

Working group noted the progress of the study.

2. Development of windows based software for hydrological data processing and Unit Hydrograph Analysis

Mrs Deepa presented the study and informed that flood estimation is one of the most important components of water resources project planning, design and operation. In NIH, a number of software/ computer program have been developed for these analyses. However, they were written in FORTRAN/Pascal/Basics languages which did not provide user-friendly environment to the users. In view of this, it is proposed to develop a WINDOWS based software to carry out hydrological data processing and unit hydrograph analysis for the estimation of flood for gauged as well as ungauged catchments of small and medium size.

Chairman suggested including design flood estimation in the software.

PI: Dr. M. Arora (MA), Scientist "D"

1. Modeling of Gangotri Glacier melt runoff and simulation of stream flow variation under different climate scenarios

Dr. Arora presented the progress of the study. He informed that the data collected for the ablation period of 2017 have been analyzed. The results for the study period 2014-2017 were presented before the experts. The HBV model was used to simulate the melt runoff and the results obtained by SNOWMOD and HBV was explained to the experts. The total volume of water from the glacier was very much in comparison to the previous year values. It was also informed to the members that climate scenarios are being developed and the model performance will be tested with this.

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Dr V C Goyal, Sc. G and Head, presented an overview of the Division. He informed about the progress under Neeranchal National Watershed Project (NNWP). Thereafter, scientists of the Division presented their respective studies. Following are the comments/suggestions received from the working group members:

	Title of Project/Study, Study Team	**Status and Recommendations/Suggestions**
1.	Development of IWRM Plan for Ibrahim-Masahi village (Haridwar district) **Team:** Omkar Singh, V.C. Goyal, Subhash Kichlu and Rajesh Agarwal DOS: April 2013, DOC: September 2017 (Completed)	The results of the study were presented by Shri Omkar Singh (PI). PI also presented the IWRM plan for Ibrahimpur Masahi village. The study has been completed and the NTS will be commissioned by March 2018.
2.	Development of IWRM Plan for Jhansi, Lalitpur and Chhatarpur districts (MoWR-funded Bundelkhand-4 district project) **Team:** V. C. Goyal and Jyoti P Patil **Co-investigators from MPCST, Bhopal:** Sandeep goyal and Rajesh Saxena **Co-investigators from UP-RSAC, Lucknow:** Rajiva Mohan and Sudhakar Shukla DOS: Apr 2016, DOC: Mar 2018	The results and present status of study were presented by Dr. V C. Goyal (PI). The PI presented the three components of IWRM Plan prepared for the identified watersheds in Jhansi, Lalitpur and Chhatarpur districts. The PI also mentioned that the IWRM Plans are proposed to be handed over to the respective DMs in March 2018.
3.	Study on effect of climate change on sediment yield to Pong reservoir. **Team:** A. R. Senthil kumar, J. V. Tyagi, S. D. Khobragade and Manohar Arora DOS: Apr 2015, DOC: March 2018	The results and present status of the study were presented by Dr A. R. Senthil kumar (PI). The PI reported that the discharge and sediment yield at Nadaun Brdige (Pong reservoir) was simulated using SWAT. A six month extension was requested by the PI to carry out the downscaling of the climate scenarios from GCM models and simulate the future sediment yield using downscaled data. The working group approved the six-month extension up to September 2018.
4.	Effect of climate change on evaporation at point scale **Team:** Digambar Singh**,** A. R. Senthil kumar and Manohar Arora DOS: Apr 2014, DOC: October 2017 (Re-scheduled)	The results and present status of the study were presented by Sh. Digambar Singh (PI). The PI requested for an extension of six months to complete the downscaling of rainfall and temperature from GCM models and CORDEX and the computation of future evaporation and evapotrnsporation for the downscaled scenarios. The working group aprroved the six-month extension up to June 2018.
5.	Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of water management plan. **Team:** Digambar Singh**,** Omkar Singh, Subhash Kichlu and N R Allaka DOS: Apr 2018, DOC: March 2020	The proposed objectives, methodology and expected outcome were presented by Sh. Digambar Singh (PI). The PI mentionend that the proposed components of the study would include water quality analysis and bathymetric survey of some identified ponds in Jhansi, Lalitpur, Tikamgarh and Chhatarpur districts.

6.	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system **Team:** Omkar Singh, V C Goyal, Digambar Singh, Subhash Kichlu, and N R Allaka **Co-investigators from Centre for Ecology & Hydrology, Edinburgh, United Kingdom:** Prof. Laurence Carvalho, Er. Mike Clark DOS: Apr 2018, DOC: March 2020	The proposed objectives, methodology and expected outcome were presented by Sh. Omkar Singh (PI). The PI mentioned that the proposed study is the extenstion of the earlier study entitled "Water conservation and management in Ibrahimpur Masahi village of Haridwar district (Uttarakhand)", and the impact of Constructed Wetland (CW) on the water quality of the pond would be studied in collaboration with CEH, UK.
7.	Vulnerability assessment of identified watersheds in Neeranchal Project States **Team:** Dr Jyoti P Patil and nodal scientists from Regional centres (Bhopal, Patna, Kakinada, Belgaum) DOS: July 2017, DOC: June 2019 (**NNWP**)	The results and present status of the study were presented by Ms. Meeta Gupta, JRF. Ms Meeta informed that the required data for calculating the vulnerability index is being collected from secondary sources like census (population/livestock), state department web sites, statistical handbooks etc.
8.	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact **Team:** A R Senthil kumar, J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora and Digambar Singh DOS: July 2016, DOC: June 2021 (**NMSHE**)	The results and present status of the study were presented by Dr. A. R. Senthil kumar (PI). The PI mentioned that the discharge and sediment yield at Tehri dam was simulated using SWAT.
9.	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts **Team:** V C Goyal, Omkar Singh, Digambar Singh and Subhash Kichlu **Project Team:** N .G. Shrivastava, Nihal Singh, Kalzang, Sandeep Yadav and Subhash Vyas DOS: July 2017, DOC: June 2020	The present status of the study was presented by Dr. V. C. Goyal (PI). The PI mentioned that the DPRs for 12 ponds have been prepared and waiting for the release of funds from MoWR,RD&GR. Sh. Sudhindra Mohan Sharma inquired about the location of floating wetland in the pond. Dr. N. G. Srivastava clarified that the floating wetland will be installed in the settling chamber. Mrs Jancy Vijayan inquired about the control of nutrient load in the pond. Dr. N. G. Srivastava clarified that the nutrient load will be controlled by integrated approach through floating wetland and microbial inoculum.
10.	Development of water allocation plan for a Neeranchal watershed in Chhattisgarh **Team:** A. R. Senthil kumar, Jyoti P Patil, T R Nayak and Rajesh Agarwal DOS: Apr 2018, DOC: March 2020 (**New study**)	The proposed objectives, methodology and expected outcome were presented by Dr. A. R. Senthil kumar (PI). The PI mentioned that the water availabilty at district level would be computed by a suitable hydrologic model. The water allocation plan would be developed using WEAP model.
11.	Development of Innovation Centre for Eco-prudent Wastewater Solutions (IC-EcoWS) **Partner Institutions:** National Institute of Hydrology, Roorkee Indian Institute of Technology Bombay (IITB) Department of Civil Engineering, MNIT Jaipur Institute of Rural Management Anand.	Dr. V. C. Goyal (PI) mentioned that the study would commence once the approval is received from DST.

WORK PROGRAMME FOR 2018-19

SN	Title of Project/Study	Funding	Study Team	Duration	Status
			Internal Study		
1	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar (PI) J V Tyagi, S D Khobragade	Apr 2015-Sep 2018	Ongoing
2	Effect of climate change on evaporation at point scale	NIH	Digamber Singh (PI) A R Senthil Kumar, Manohar Arora	Jun 2014-Jun 2018	Ongoing
3	Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of water management plan	NIH	Digamber Singh (PI) Omkar Singh, Subhash Kichlu, N R Allaka	Apr 2018-Mar 2020	New Study (Follow up of Bundelkhand 4-district project)
4	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH,CEH (UK) & IITR	**NIH**: Omkar Singh (PI) V C Goyal, Digamber Singh, Subhash Kichlu, NR Allaka **IITR**: Himanshu Joshi **CEH**: Laurence Carvalho, Mike Clarke	Apr 2018-Mar 2020	New Study (Follow up of earlier study)
			Sponsored Projects		
1	Vulnerability assessment of identified watersheds in Neeranchal Project States	NNWP	Jyoti P Patil (PI) + RCs	Jul 2017-Jun 2019	Ongoing
2	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	NMSHE	A R Senthil kumar (PI) J. V. Tyagi, M. K. Goel S. D. Khobragade P. C. Nayak, Manohar Arora	Mar 2016-Mar 2021	Ongoing
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts	MoWR-funded project	V C Goyal (PI) Omkar Singh, Digamber Singh, Rajesh Singh, Subhash Kichlu, Rakesh Goel	Apr 2017-Mar 2020	Ongoing
4	Development of water allocation plan for a Neeranchal watershed in Chhattisgarh	NNWP	A R Senthil kumar (PI) T R Nayak, Jyoti P Patil Rajesh Agarwal	Apr 2018-Mar 2020	New Study
5	Development of Innovation centre for EcoPrudent Wastewater Solutions	DST	V C Goyal (PI), Jyoti P Patil, Amrendra Bhushan + from NIT Jaipur, IIT Bombay and IRMA Anand	5 Years	New Study (subject to approval)

Dr. V C Goyal thanked the members for their valuable contributions during deliberations in the Working Group meeting.

The meeting ended with vote of thanks to the Chair.

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ANNEXURE-I

List of Working Group Members who attended the 46th WG meeting

1.	Dr. S.K. Jain, Director, NIH	Chairman
2.	Sh. Ankit Dudeja, CWC, New delhi	Member
3.	Dr. Ashok K. Das, IMD, New Delhi	Member
4.	Smt. Jancy Vijayan, NWDA, New Delhi	Member
5.	Dr. P R Ojasvi, ICAR-IISWC, Dehradun	Member
6.	Dr. S K Bartarya, WADIA, Dehradun	Member
7.	Er. Kireet Kumar, GBPIHED, Almora	Member
8.	Dr. U K Sinha, BARC, Mumbai	Member
9.	Dr. R D Deshpande, PRL, Ahmedabad	Member
10.	Dr. Pawan Labhasetwar, NEERI, Nagpur	Member
11.	Dr. S P Aggarwal, IIRS, Dehradun	Member
12.	Dr. Shakeel Ahmed, CSIR-NGRI, Hyderabad	Member
13.	Dr. Varun Joshi, GGSIP, New Delhi	Member
14.	Prof. K K Singh, Kurukshetra	Member
15.	Prof. A K Saraf, IIT, Roorkee	Member
16.	Prof. M L Kansal, IIT, Roorkee	Member
17.	Dr. S S Grewal, Chandigarh	Member
18.	Dr. C T Danya, IIT, Delhi	Member
19.	Dr. Kaushal K. Garg, ICRISAT, Hyderabad	Member
20.	Prof. Ramakar Jha, NIT, Patna	Member
21.	Prof. A P Dimri, JNU, New Delhi	Member
22.	Dr. Sadhana Malhotra, Mindspace, Dehradun	Member
23.	Sh. Sudhindra Mohan Sharma, Indore	Member
24.	Sh. Punit Kumar Mall, IRI, Roorkee	Member
25.	Dr. N C Ghosh, Sc.G & Head GWH Division, NIH	Member
26.	Dr. Rakesh Kumar, Sc. G & Head SWH Division, NIH	Member
27.	Dr. C K Jain, Sc.G & Head EH Division, NIH	Member
28.	Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH	Member
29.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
30.	Dr. V C Goyal, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from National Institute of Hydrology

	EH Division		**SWH Division**
1	Dr. M.K. Sharma, Sc.D	16	Dr. J.V. Tyagi, Sc.G
2	Dr. Rajesh Singh, Sc.C	17	Dr. A.K. Lohani, Sc.G
3	Dr. Pradeep Kumar, Sc.C	18	Dr. R.P. Pandey, Sc.G
	GWH Division	19	Dr. S.K. Singh, Sc.F
4	Er. C.P. Kumar, Sc.G	20	Dr. Sanjay Kumar, Sc.E
5	Dr. Anupama Sharma, Sc.E	21	Dr. Archana Sarkar, Sc.D
6	Dr. Surjeet Singh, Sc.E	22	Dr. L.N. Thakural, Sc.C
7	Er. Sumant Kumar, Sc.C	23	Sh. J.P. Patra, Sc.C
8	Mrs. Suman Gurjar, Sc.C	24	Dr. Ashwini A. Ranade, Sc.C
9	Dr. Gopal Krishan, Sc.C	25	Sh. Naresh Saini, Sc.B
	HI Division	26	Sh. N.K. Bhatnagar, Sc.B
10	Dr.Suhas Khobragade, Sc.F		**WRS Division**
11	Dr. M.S. Rao, Sc.E	27	Dr. M.K. Goel, Sc.G
12	Sh. S.K. Verma, Sc.D	28	Smt. Deepa Chalisgaonkar, Sc. F
	RMO Division	29	Er. D.S. Rathore, Sc.F
13	Er. Omkar Singh, Sc.F	30	Dr. Renoj J. Thayyen, Sc.D
14	Dr. A R Senthil Kumar, Sc.E	31	Dr. Manohar Arora, Sc.D
15	Sh. Digamber Singh, Sc.C	32	Sh. Manish Nema, Sc.C

ANNEXURE – B

Division-wise Work Programme

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. C K Jain	Scientist G & Head
2	Dr. M K Sharma	Scientist D
3	Dr. Rajesh Singh	Scientist C
4	Dr. Pradeep Kumar	Scientist C
5	Ms. Swapnali Barman	Scientist C
6	Smt. Babita Sharma	RA
7	Smt. Bina Prasad	RA

Work Programme 2018-19

S.No.	Study	Study Team	Duration / Status
	Internal Studies (Ongoing)		
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows	Pradeep Kumar (PI) C. K. Jain	3 Years (04/16-03/19) Status: In-progress
	Internal Studies (New Proposed)		
2.	Impact of Climate Change on Runoff and Sediment Yield for a Major Tributary of River Brahmaputra	Swapnali Barman (PI) J. V. Tyagi Surya Singh R.K. Bhattacharya (IITG)	3 Years (10/18-09/21)
	Sponsored Projects (Ongoing)		
3.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI) Manohar Arora M. K. Sharma Pradeep Kumar D. S. Malik (GKU)	5 Years (04/16-03/21) Sponsored by: DST Project Cost: 2.25 Crore Status: In-progress
4.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) C. K. Jain Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur A. K. Shukla Ashok Verma P. C. Das	3 Years (09/17-08/20) Sponsored by NHP-PDS Project Cost: 25.4 Lakh Status: In-progress
5.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) M. K. Sharma Sumant Kumar Pradeep Kumar	3 Years (09/17-08/20) Sponsored by NHP-PDS Project Cost: 65.6 Lakh Status: In-progress
	Consultancy Projects (Ongoing)		
6.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines	C. K. Jain (PI) Sudhir Kumar Y. R. S. Rao Anupma Sharma S. D. Khobragade M. K. Sharma Pradeep Kumar	15 Months (04/16-06/17) Sponsored by: NTPC Amount Rs. 54.96 Lakh Status: Completed.
7.	Downstream Impacts of Water Withdrawal by TTPS from Brahmani River	Pradeep Kumar (PI) C. K. Jain M. K. Sharma	6 Months (05/18-10/18) Sponsored by NTPC Amount: 20 Lakh Status: In-progress

Study – 1 (Internal Study)

Sustainable Development Goals **:** SDG Target 6.6: Protect and Restore Water-related Ecosystems

1. Title of the Study: Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows

2. Study Group:

Project Investigator Dr. Pradeep Kumar, Sc. 'C'
Project Co-investigator Dr. C. K. Jain, Sc. 'G'
Scientific/Technical Staff Nil

3. Type of Study: Internal

4. Nature of Study: Applied Work

5. Date of start: April 2016

6. Scheduled date of completion: March 2019

7. Duration of the Study: 3 Years

8. Study Objectives:

i) To compile the data/information on biotic parameters (abundance of aquatic species) and influencing abiotic parameters (water depth & velocity and water quality parameters: water temperature, pH, DO, BOD, turbidity etc.)
ii) To identify the significant relationships between biotic and abiotic parameter and among the biotic parameters at selected locations
iii) To establish the habitat suitability curves for aquatic species and habitat parameters
iv) To assess environmental flows at the selected stretches in Western Himalayan Region

9. Statement of the Problem:

A large number of water resources projects (mostly hydropower schemes) in the western Himalaya are in different stages of development. These projects are altering the flow regime either due to storage or diversion of water. The river reach is deprived of its natural flows due to water diversion at control structure. There may be critical reaches in the river where altered flows are not able to sustain the ecosystem services existing prior to implementation of these types of projects. The developmental planning process in eco-sensitive and fragile Himalayan mountainous region should ensure that the biodiversity and ecological integrity of the aquatic and terrestrial ecosystems are protected and conserved. In this view, the environmental flow assessment has become imperative for the Himalayan rivers. However, due to lack of knowledge base on the biotic and abiotic interactions, the assessment of environmental flows in India has been mostly limited to hydrological and hydraulic methods. In this connection, the present study has been envisaged for developing the habitat suitability curves (relationships between abiotic and biotic parameters) for the aquatic species of the western Himalayan streams.

10. Approved Action Plan / Methodology:

Work Element	Duration of total project work											
	1st year				2nd year				3rd year			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Identification of data/ information on baseline biotic and abiotic parameters of western Himalayan streams and site selection	■	■										
Compilation of biotic and abiotic data/information			■	■								
Identification of relationships between biotic and abiotic parameters					■	■	■					
Development of habitat suitability curves								■	■	■	■	
Assessment of environmental flows											■	■
Synthesis and report writing												■

11. Objectives and achievement during last one year:

Objectives	Achievements
To compile the data/information on biotic parameters (abundance of aquatic species) and influencing abiotic parameters (water depth & velocity and water quality parameters: water temperature, pH, DO, BOD, turbidity etc.)	The data related with biotic (density of phytoplanktons, zooplanktons, macroinvertebrates, fish) and abiotic parameters (water temperature, pH, DO, turbidity, Nitrates, Phosphatesetc.) of western Himalayan streams have been collected through different agencies. The baseline data of biotic and abiotic parameters have been compiled for 48 western Himalayan streams. Out of these 48 streams, three tributaries of Satluj river (Gambhar, Gamrola and Seer), three tributaries of Beas river (Sainj, Tirthan and Suketi) and two tributaries of Ravi river (Panjpula and Chaner) have been selected due to availability of detailed information.
To identify the significant relationships between biotic and abiotic parameter and among the biotic parameters at selected locations	The graphs between biotic and abiotic parameters and also among biotic parameters have been prepared. Different mathematical relationships are being tried to find out the significant relationships.
To establish the habitat suitability curves for aquatic species and habitat parameters	Habitat suitability curves between abiotic and biotic parameters have been developed for the significant relationships.

12. Recommendation / Suggestion: Nil

Recommendation / Suggestion	Action Taken
• The relationships developed need to be checked for their significance. • Limitations of the methodology adopted need to be incorporated in the report. • The final report should be sent to the Working Group member from NEERI for review.	• Habitat suitability curves are being modified as per the suggestions. • Limitations will be incorporated in the report. • Final report will be sent to NEERI after modification.

13. Analysis and Results:

The data related with biotic (density of phytoplanktons, zooplanktons, macro invertebrates, fish) and abiotic parameters (water temperature, pH, DO, turbidity, Nitrates, Phosphates etc.) of western Himalayan streams have been collected through the existing literature. The average annual baseline data of biotic and abiotic parameters have been compiled for 48 western Himalayan streams. Out of these 48 streams, three tributaries of Satluj river (Gambhar, Gamrola and Seer), three tributaries of Beas river (Sainj, Tirthan and Suketi) and two tributaries of Ravi river (Panjpula and Chaner), average monthly data of biotic and abiotic parameters was also available. Hence, the analysis has been carried out in two parts: (i) using average annual data of 48 streams and (ii) using average monthly data of 8 streams. The correlogram between biotic and abiotic parameters and also among biotic parameters have been prepared and significant relationships have been identified. Different mathematical relationships (linear, polynomial, logarithmic, exponential etc.) have been tried to establish the relationships between abiotic and biotic parameters. Thus obtained relationships are not having very good coefficient of determination and therefore not properly representing the physical significance among these parameters. Hence, it is being attempted to test other statistical models for developing the habitat suitability curves. Further, these developed habitat suitability curves will be used to assess environmental flows at selected locations in western Himalayan region through habitat simulation modeling.

14. End Users / Beneficiaries of the study: Water Resources Development Agencies

15. Deliverables: Technical Report & Research Papers

16. Major items of equipment procured: None

17. Lab facilities used during the study: None

18. Data procured or generated during the study:

Baseline information on the biotic and abiotic parameters of 48 western Himalayan streams (tributaries of Ravi, Beas, Satluj, Yamuna, Alaknanda and Bhairathi) has been procured from various sources.

19. Study Benefits / Impacts:

Measurable indicators	Achievements

20. Involvement of end users/beneficiaries: Nil

21. Specific linkage with Institution and /or end users/beneficiaries: Nil

22. Shortcoming/Difficulties: No

23. Future Plan:

Work Element	3rd year (2018-19)			
	I	II	III	IV
Development of habitat suitability curves (to be modified as per suggestions of working group)	■	■	■	
Assessment of environmental flows for eight selected tributaries of Satluj, Beas and Ravi through habitat simulation modeling using the developed habitat suitability curves			■	■
Synthesis and report writing				■

Study - 2 (Internal Study – New Proposed)

Sustainable Development Goals **:** SDG Target 6.6: Protect and Restore Water-related Ecosystems

1. Title of the Project: Impact of Climate Change on Runoff and Sediment Yield for a Major Tributary of River Brahmaputra

2. Study Group

Project Investigator Dr. Swapnali Barman, Sc. 'C'
Co-Investigator Dr. J. V. Tyagi, Sc. 'G' Dr. Surya Singh, Research Scientist
Collaborating Agency Prof. R.K. Bhattacharya, IIT Guwahati

3. Objectives

i) Impact of climate change on future runoff and sediment yield
ii) Sediment yield modeling using SWAT and its comparison with ANN based model

4. Statement of the Problem

Climate change affects hydrology mainly through changes in precipitation, temperature and evaporation and it subsequently influences the temporal-spatial distributions of runoff and sediment, as well as the patterns of runoff and sediment transport. The highly dynamic Brahmaputra river in South Asia carries one of the world's highest sediment yields. The Brahmaputra flows through a seismically active region, which has the effect of causing it to carry one of the highest sediment loads in the world. During its course, the river Brahmaputra is joined by important tributaries from the Himalayan ranges of Arunachhal Pradesh and Bhutan in the north viz., Subansiri, Ranganadi, Jia-Bharali,Dhansiri, Barnadi, Pagladiaand Manas and from the Khasi Hills, the Garo Hills, the Mikir Hills and the Patkai Hills in the south by the Buri Dehing, Disang, Dikhow, Jhaji and Kopoili. The contribution of discharge and sediment from the north bank tributaries are more compared to those from the south bank tributaries. Hence it is important to study the tributaries which in turn effect the total sediment yield of the Brahmaputra River. For the present study the one of the tributary (Dhansiri/ Pagladia/Manas) will be chosen to study its impact on sediment yield to the Brahmaputra.

As the basin is highly influenced by the monsoon rainfall, the climate change that results in variation in intensity of the monsoon, will affect both high and low flows leading to increased flooding and variability of available water both in space and time in the basin. Climate models are the primary tools to evaluate the projected future response of the atmosphere-land-ocean system to changing atmospheric composition. Downscaling that transform information from climate models at coarse resolutions to a fine spatial resolution is necessary, as the underlying processes described by the environmental impact models are very sensitive to the nuances of local climate, and the drivers of local climate variations, such as topography, are not captured at coarse scales.

Runoff calculation of a river is essential owing to its effect on flood and erosion at the downstream. The actual physical processes that convert rainfall to runoff are both complex and highly variable. However, through the use of simplifying assumptions and empirical data, there are several mathematical models and equations that can simulate these processes and predict resultant runoff volumes and rates with acceptable accuracy. Being one of the major tributaries of the Brahmaputra, the river has major contribution towards discharge at its confluence with Brahmaputra. As such a rainfall-runoff model is proposed to study the impact of change in rainfall on the runoff of the river.

5. Methodology

The multiple non-linear regression based statistical downscaling technique and downscaling by ANN model will be applied to downscale the rainfall over the catchment area. The best downscaling technique will then be used to predict rainfall. A rainfall-runoff model will be developed to predict the future runoff of the river. Sediment yield modelling using SWAT and ANN model will be used to study the sediment yield contribution of the river to Brahmaputra.

6. Research Outcome from the Project

i) Climate change impact on future rainfall over the catchment
ii) Impact of change in rainfall on future runoff of the basin
iii) Contribution of sediment yield of the tributary to the river Brahmaputra

7. Work Schedule

a. Probable date of commencement of the project : Oct. 2018
b. Duration of the project : 3 Years
c. Stages of work & milestone

S.No.	Activities	1st Year				2nd Year				3rd Year			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
1	Downloading of GCM data and their downscaling												
2	Rainfall prediction and its analysis over the basin												
3	Downloading of satellite data and preparation of LULC maps												
5	Runoff and sediment analysis using ANN model												
6	Sediment yield modelling using SWAT												
7	Report writing												

Study - 3 (Sponsored Project)

Sustainable Development Goals : SDG Target 6.6: Protect and Restore Water-related Ecosystems

1. Title of the Study: Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin

2. Study Group:

Project Investigator/Co-Project Investigator Dr. C. K. Jain, Sc. 'G' Dr. Manohar Arora, Sc. 'D'
Co-Investigator Dr. M. K. Sharma, Sc. 'D' . Pradeep Kumar, Sc. 'C'
Scientific/Technical Staff Sri. Rakesh Goyal, Tech. Gr. I
Collaborating Agency Prof. D. S. Malik, Professor, GKU, Haridwar

3. Type of Study: Sponsored Project by DST, New Delhi, Budget: Rs 2.24 Crore

4. Nature of Study: Applied Research

5. Date of start: April 2016

6. Scheduled date of completion: March 2021

7. Duration of the Study: 5 Years

8. Study Objectives:

i) To study ecology, biodiversity and water quality of Upper Ganga Basin
ii) To study in-stream reactions and sediment dynamics of Upper Ganga Basin
iii) To assess environmental flows in critical stretches of River Ganga

9. Approved Action Plan/Methodology:

i) Water quality assessment through comprehensive field and laboratory investigations.
ii) Monitoring point and non-point source pollution
iii) Adsorption characteristics through laboratory scale model studies.
iv) Kinetics and thermodynamics of adsorption process through experiment approaches.
v) Monitoring temporal abundance of different aquatic species at selected locations
vi) Monitoring aquatic habitat parameters (depth, velocity, slope, gradient, substrate, pH, conductance, water temperature, DO, BOD, COD, TDS, salinity, etc.) at selected locations
vii) Assessment of aquatic biodiversity: Phytoplankton, zooplankton, benthos and piscine fauna (distribution, species richness and abundance as per their habitat)
viii) Impact assessment of environmental flows in relation to productivity of River Ganga
ix) Estimating environmental flows in critical reaches

10. Timeline:

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Recruitment of Project Staff										
Equipment/software procurement										
Literature survey										
Field investigations										
Sample collection and analysis										
Adsorption characteristics										
Habitat characteristics										
Aquatic biodiversity										
Environmental flow estimations										
Report preparation										

11. Progress:

i) Water quality monitoring from fifteen identified sites is being carried out on monthly basis from September 2016. The analysis of hydro-chemical data indicated that water quality is satisfactory for bathing purpose except COD and TSS.

ii) High values of COD indicate anthropogenic pollution. TSS is high at all the locations and decreases from higher elevation to lower elevation because sediments gets deposited due to geomorphology of the river.

iii) Sediment samples from 15 sites have been collected and characterized for size distribution, pH, conductance and organic matter to study of in-stream reactions and sediment dynamics.

iv) Adsorption characteristics of sediments, kinetic and thermodynamic studies are hampering due to non-availability of facilities for trace element analysis. Attempts are being made to procure the equipment ICP-MS for trace element analysis.

v) Eight sampling zones are being monitored for temporal abundance of different aquatic species (Phytoplanktons, Zooplanktons, Macro-Benthos) on monthly basis. The analysis of collected data indicated that most common biotic species in the Upper Ganga Basin are phytoplanktons, zooplanktons, macro-benthos and fishes.

vi) Phytoplanktons are decreasing towards lower elevations while zooplanktons and macro-benthos are increasing at lower elevations.

vii) Monitoring aquatic habitat parameters (depth, velocity, slope, gradient, substrate, pH, EC, TDS, temperature, DO, BOD, COD, etc.) at eight selected zones on monthly basis for development of habitat suitability curves.

viii) Review of Environmental Flow Requirement (EFR) methodologies has been completed. Brief details of various hydro power projects under different stages of development in Upper Ganga Basin have been compiled for deciding the critical reaches for estimation of environmental flow requirement.

ix) Discharge data has been obtained from CWC and environmental flows recommendations will be based on the integration of hydrological, hydraulic and biological response data.

12. Research Outcome from the Project:

The present investigation will help in understanding the basic hydrology and associated water quality, ecology and biodiversity in Upper Ganga Basin for sustainable development of natural resources so that ecosystem stability is maintained. As a number of water resource projects are

coming up in the Ganga Basin, the values of environmental flows in the critical reaches of the river will help in environmental clearance of the water resources projects.

Study - 4 (Sponsored Project)

Sustainable Development Goals : SDG Target 6.6: Protect and Restore Water-related Ecosystems

1. Title of the Study: Groundwater Quality Assessment with special reference to Sulphate contamination in Bemetara District of Chhattisgarh State and ameliorative measures

2. Study Group:

NIH	WRD, Raipur
Project Investigator: Dr. M. K. Sharma, Sc. 'D'	**Project Investigator:** Mr. A. K. Shukla, Sr. Geohydrologist
Co-Investigator Dr. C. K. Jain, Sc. 'G' Dr. Surjeet Singh, Sc. 'E' Dr. Pradeep Kumar, Sc. 'C'	**Co-Investigator** Mr. Ashok Verma, Asstt. Geohydrologist Mr. P. C. Das, Asstt. Geohydrologist

3. Type of Study: Sponsored project by NHP (PDS), Budget: Rs 25,39,600/-

4. Nature of Study: Applied Research

5. Date of start: September 2017

6. Scheduled date of completion: August 2020

7. Duration of the Study: 3 Years

8. Study Objectives:

i) Groundwater quality monitoring in pre- and post monsoon seasons.
ii) To map degraded ground water quality zones and possible sources of pollution and identify specific parameters not conforming to drinking & irrigation water quality standards.
iii) To investigate the important geochemical processes responsible for the groundwater contamination.
iv) Modelling flow and transport of sulphate contamination using MODFLOW & MT3D
v) To suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking & irrigation purpose by investigating the hydro-geology of the area.
vi) Dissemination of knowledge and findings to field engineers/scientists and common people through preparation of manual, leaflets, booklets and by organizing workshops/training courses.

9. Statement of the Problem:

Groundwater is one of the vital resources, which meets the requirements of daily livelihood especially in rural areas of India. Growing demand of water in various sectors viz; agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the groundwater resource, continuously declining groundwater levels, sea water ingress in coastal areas, and groundwater pollution in different parts of the country. Geo-environmental conditions have a marked influence on the groundwater quality. Hydrogeochemical studies relevant to the water quality explain the relationship of water chemistry to aquifer lithology. Such relationship would help not only to explain the origin and distribution of dissolved constituents but also to elucidate the factors

controlling the groundwater chemistry. In the District Bemetara, Chhattisgarh, the Precambrian sedimentary province includes Chhattisgarh Super group of rocks of upper proterozoic age of marine origin. It mainly consists of arenaceous-argillaceous-calcareous rocks and dominated by Limestone, dolomite and calcareous shale. The weathered, cavernous and fractured part of the formation constitutes the aquifers in the area. The groundwater of Bemetara district is affected by sulphate contamination reported by Public Health Engineering Department, Durg. Berla block of the district has also the possibility of such type of sulphate contamination in ground water. Therefore, Bemetara district is selected for purpose driven study for sulphate contamination in ground water. The high concentration of sulphate in ground water is due to the dissolution of gypsum veins present within maniyari shale formation. Higher concentration of sulphate in ground water causes gastrointestinal irritation. A cost effective, economic viable and environmental friendly measure will be suggested for remediation of groundwater with special reference to sulphate contamination considering hydrogeology of the area.

10. Approved Action Plan/Methodology:

i) Literature survey on assessment of groundwater quality and issues in the region.
ii) Analysis of groundwater resources in the Bemetara district.
iii) Collection of existing meteorological and groundwater quality data of various locations of the Bemtara district and analysis.
iv) Collection of groundwater levels and lithological data from State Groundwater Department.
v) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.
vi) Collection of groundwater samples from selected sources in pre- and post-monsoon seasons at identified locations.
vii) Analysis on flow and movement of groundwater.
viii) Analysis for physico-chemical parameters: pH, EC, TDS, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4,) and Toxic (Heavy) Metals: As, Cd, Cr, Pb, Cu, Ni, Fe, Zn, Mn in the collected water samples.
ix) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose.
x) Ionic relationships will be developed and water types will be identified. Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking & irrigation water quality standards.
xi) Suitability of ground water for irrigation purpose will be assessed on the basis of total soluble salts, SAR and RSC. Classification of water will be made using Piper trilinear diagram, Chadha's diagram, U.S. Salinity Laboratory Classification.
xii) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.
xiii) MODFLOW & MT3D will used for modelling flow and transport of sulphate, the model will be calibrated using data collected along space & time for a period of one year.
xiv) Suggesting ameliorative measures to control / restore the groundwater quality for sustainable use by various users investigating site-specific measures considering contaminant transport, hydrogeology and system dynamics (flow-movement of groundwater, hydrogeology, managed aquifer recharge, withdrawal patterns, etc.).

11. Timeline:

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
2017-18	-	-	Literature Survey	Field visit and Data Collection, Interim Report
2018-19	Field visit, Sampling, Data Collection and processing of the data	Sample Analysis and processing of the data	Field visit, Sampling, Data Collection & Analysis and processing of the data	Analysis and processing of the data, Interim Report
2019-20	Field visit, Experiment, Data Collection & Analysis and processing of the data	Analysis & Processing of the data	Modelling flow and transport of sulphate using MODFLOW & MT3D	Analysis & Processing of the data, Interim Report
2020-21	Analysis & Processing of the data	Writing of Report	Writing of Report	-

12. Objectives and achievement during last six months:

Objectives	**Achievements**
Field visit, Sampling, Data Collection and processing of the data	A field visit was made during 14-18 May, 2018 for pre-monsoon sampling and collected data
Sample Analysis and processing of the data	• Hydro-chemical analysis completed & Metal analysis is in progress. • Processed hydro-chemical data and ground water level data.

13. Recommendation / Suggestion:

Recommendation / Suggestion	**Action Taken**

14. Analysis and Results:

i) Carried out the extensive literature survey related to assessment of groundwater quality.
ii) WRD also suggested to focus on Maniyari shell formation region which will cover 9 blocks existing in five districts viz; Bemetara, Kawardha, Bilaspur, Mungeli and Baloda Bazar (Bhatapara).
iii) Processed ground water level data of observational wells of WRD existing in study area from 2000 to 2017.
iv) Prepared drainage, geomorphology, lithology, landuse, soil and well location map of study area in GIS platform.
v) Prepared spatial distribution map of water quality parameters to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking water quality standards.
vi) Processed hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.

15. End Users / Beneficiaries of the Study: Policy makers and planners of Government of Chhattisgarh.

16. Deliverables: Technical report and research papers

17. Major items of equipment procured:

18. Lab facilities used during the study: Water Quality Laboratory (NIH)

19. Data procured or generated during the study: Hydro-chemical data

20. Study Benefits / Impacts:

For any scheme of water supply in an area, it is mandatory to have the status of water quality of the water resources being used for supply. An extensive survey of groundwater quality monitoring of district Bemetara will provide the knowledge about degraded ground water quality zones and possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards, which will help the policy makers and society. Further, present PDS will suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking and irrigation purpose by investigating the hydro-geology of the area.

21. Involvement of end users/beneficiaries: Water Resources Department (WRD), Government of Chhattisgarh, Raipur

22. Specific linkage with Institution and /or end users / beneficiaries: CGWB, Raipur and WRD, Raipur

23. Shortcoming/Difficulties: No

24. Future Plan:

- Field visit and Collection of ground water samples in post-monsoon season (November 2018) and their analysis.
- Processing of ground water data and water quality data.
- Collection of ground water data, aquifer parameter data and historical ground water quality from CGWB

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Study - 5 (Sponsored Project)

Sustainable Development Goals : SDG Target 6.6: Protect and Restore Water-related Ecosystems

1. Title of the Study: Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures

2. Study Group:

Project Investigator Dr. Rajesh Singh,Sc. 'C'
Co-Investigator Dr. Mukesh K. Sharma, Sc. 'D' Er. Sumant Kumar, Sc. 'C' Dr. Pradeep Kumar, Sc. 'C'
Scientific/Technical Staff Sh. Rakesh Goyal, Tech. Gr. I Km. Meenakshi Rawat, JRF

3. Type of Study: Sponsored project under NHP, Budget: Rs. 65.6 lacs

4. Nature of Study: Applied Research

5. Date of start: October 2017

6. Scheduled date of completion: September 2020

7. Duration of the Study: 3 Years

8. Study Objectives:

i) Spatial and temporal variation of water quality parameters and carcinogenic contaminants.
ii) Quantification of mutagenic potential (carcinogenicity) of water samples.
iii) Source identification of major contaminants in the study area and impact assessment on human health.
iv) Suggestions for possible remedial measures to reduce the impact of contaminants.
v) Dissemination of knowledge and findings to field engineers/scientists and common people through the preparation of manual, leaflets, booklets and by organizing workshops/training.

9. Statement of the Problem:

Punjab has been the subject of much skepticism in the last decade. It has previously been called the "grain bowl of the country", but has recently adopted a new nickname, "the cancer bowl of the country". The pride of holding the title "a state with maximum per capita income" came with the price of cancer due to unrestricted use of chemicals (pesticides, fertilizers, metals, polycyclic aromatic hydrocarbons, pharmaceutically active hydrocarbons, etc.) in the agricultural fields and industries. A train which connects the affected region with the nearby Bikaner city, which contains a cancer hospital, has been nicknamed Cancer Express. Thakur et al. (2015) analyzed trace metals, pesticides, and other relevant parameters in some major drains, water samples (surface as well as groundwater), fodder, vegetable, and blood samples, and concluded that these samples contained harmful contaminants in excess of desired levels. Intake of these contaminants through the water as well as food is leading to deleterious health effects such as gastrointestinal disorders, reproductive toxicity, neurotoxicity, renal toxicity, and carcinogenic manifestations (WHO, 2011). Another study conducted

by Thakur et al. (2008) observed a higher prevalence of cancer cases and cancer-related deaths in the area. A year-long study entitled "An epidemiological study of cancer cases reported from villages of Talwandi Sabo block, district Bathinda, Punjab", conducted by School of Public Health (SPH) at the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, compared cancer incidents in the villages producing cotton with those producing rice and wheat, and found high cancer rates in the villages where pesticide usage was high. A recent hospital-based study for Punjab shows that out of the 1328 cancer cases in the state, 1230 cases were from the seven districts of Southern Punjab comprising Muktsar, Firozpur, Bathinda, Faridkot, Fazilka, Moga& Mansa districts (Aggarwal et al., 2015). Considering the high cancer numbers and poor water quality described above, a comprehensive study of groundwater contaminants, especially carcinogens, is urgently required for the state of Punjab. The objectives of this study is to analyze the water quality of the area with an emphasis on carcinogenic chemicals, identifying their sources, and suggesting appropriate remedial measures.

10. Approved Action Plan/Methodology:

i) Upgradation of literature and data collection
ii) Delineation of villages and finalization of sampling locations
iii) Sampling & analysis of water samples
iv) Statistical analysis of the contaminant data and cancer incidences
v) Mutagenicity of water resources
vi) Contaminant remediation

11. Timeline:

S. No.	Activities	YEAR 1				YEAR 2				YEAR 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Hiring of manpower & training												
2	Purchase of equipment & consumables												
3	Upgrading literature and data collection												
4	Delineation of villages and finalization of sampling location												
5	Collection and analysis of samples												
6	Statistical analysis of data and carcinogenicity test												
7	Contaminant remediation												
13	Training & capacity building												
14	Scientific publications												
15	Final technical report												

12. Objectives and achievement during last twelve months:

Objectives	Achievements
Hiring of manpower & training	• Hired

Purchase of equipment & consumables	• Multiparameter analyzer & laptop purchased. • Purchase of syringe pump and geochemistry software under process by procurement section. • Purchase for trace metals, pesticides, and PAHs standards and extraction chemicals has been initiated.
Upgrading literature and data collection	• Data related to cancer cases has been collected from government agencies and conversion of the same from Punjabi to English is in progress. The work has been completed for two districts and three are remaining. • The data related to type of cancer cases has been collected for Bathinda district and for remaining districts, will be collected by December. • A review paper related to cancer contaminants in water resources is under progress. Moreover, a review on carcinogenic chemicals has been presented in the STIWM – 2018 conference.
Delineation of villages and finalization of sampling location	• The sampling locations for Bathinda district has been finalized. • The sampling locations for other districts will be finalized once the data is translated.
Collection and analysis of samples	• Drinking water samples were collected from Bathinda district and analysis of organoleptic, major cations & anions, and trace metals completed. • Analysis of pesticides and PAHs will be initiated, once the chemicals are purchased.
Statistical analysis of data and Carcinogenicity test	• Health hazard quotient due to trace metals was computed for Bathinda district.

13. Recommendation / Suggestion:

Recommendation / Suggestion	**Action Taken**
Dr. Pawan Labhasetwar pointed out that there are more than 3000 carcinogenic contaminants and the problem should be studied holistically with proper data base. He further indicated that results should be reported carefully after consulting subject experts.	It was informed to the experts that there are only 120 identified carcinogens, 82 probable carcinogens, and 302 possible carcinogens in the environment. During the project, the probable trace metal, pesticides, and PAHs will be analyzed. Moreover, to understand the holistic effect of other contaminants Ames test will be conducted. The conclusions will be discussed with the cancer expert before finalization. In this regard, Director, Advanced Cancer Institute, Bathinda has been contacted.

14. Analysis and Results: Nil

The villages for sample collection were delineated based on the number of cancer cases. Accordingly, drinking water samples were collected from 19 villages of Bathinda district and were analyzed for physical parameters, major anions and cations, and trace metals. All the analyzed organoleptic parameters except turbidity and TDS were well within the limits prescribed by BIS for drinking water. The turbidity was higher than the desirable limit for 57.8% of the samples, but was within the permissible limit for drinking water. The TDS content of 84.2% samples exceeded the desirable limit for drinking water, however only 10.5% exceed the permissible limit. In the study area, Ca, Mg and NH4 content in the analyzed drinking water samples exceeded the desirable limit

for 5.3%, 63.1%, and 31.6% samples respectively. Similarly, Cl, SO4, and F content exceeded the desirable limit for drinking water in 10.5%, 47.4%, and 5.3% samples respectively. Also, the total hardness and total alkalinity exceeded the desirable limit in 84.2% and 52.6% samples, respectively.

Based on Hazards Quotients (HQ) computed through trace metal concenration, sample from Mandi Kalan was highly hazardous to human health, and samples from Mehma Sarja, Bambiha, Hanuman Chowk, Jai Singh Wala, Bhai Rupa, Dayalpur Mirza, Nasibpura, Central University of Punjab temporary campus, and Nathana were moderately hazardous, and rest were low in health hazard.

15. End Users / Beneficiaries of the Study: Policy makers and planners of State/Central Government Organizations

16. Deliverables: Technical report and research papers, First-hand information on water quality of the area related to carcinogenicity

17. Major items of equipment procured: i) Multiparameter Ion Analyzer ii) Syringe Pump iii) Geochemistry Software

18. Lab facilities used during the study: Water Quality Laboratory (NIH) / Isotope Lab (NIH) / IIC (IITR)

19. Data procured or generated during the study: Water quality data of the area

20. Study Benefits / Impacts:

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the first-hand information on the water quality of the area related to carcinogenicity. This will also lead in preparing a protocol for monitoring the carcinogenicity of water and will be helpful for the monitoring agencies. The project will also suggest the remedial measure for providing safe water to the habitation, which can be implemented by concerned state government agencies.

21. Involvement of end users/beneficiaries: Water Resources & Environment Directorate, Punjab and Local people

22. Specific linkage with Institution and /or end users / beneficiaries: Yes

23. Shortcoming/Difficulties: NA

24. Future Plan:

i) Delineation of villages and finalization of sampling location
ii) Collection and analysis of samples
iii) Statistical analysis of data and carcinogenicity test

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. N C Ghosh	Scientist G & Head
2	Er. C.P. Kumar	Scientist G
3	Dr. Anupma Sharma	Scientist E
4	Dr. Surjeet Singh	Scientist E
5	Er. Sumant Kumar	Scientist C
6	Mrs. Suman Gurjar	Scientist C
7	Dr. Gopal Krishan	Scientist C
8	Mrs. Anju Choudhary	SRA
9	Sri Sanjay Mittal	SRA
10	Sri S.L. Srivastava	SRA
11	Sri Ram Chandra	RA

APPROVED WORK PROGRAMME FOR 2018-19

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/ NIH/15-18	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply	N.C. Ghosh (Lead), C.P. Kumar, B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Choudhury, Sanjay Mittal, Ram Chandar	2-1/2 year (11/15 – 4/18) Extended by one year. **Status: In progress**.	Sponsored by MoWR, RD & GR under Plan Fund.
2. NIH/GWD/ BGS/16-20	Ground water fluctuation and conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements	**From : NIH, Roorkee** Gopal Krishna, (PI) Surjeet Singh, C. P. Kumar, N.C Ghosh **From : BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald	03 Years (01/16-11/20) **Status: In progress**.	**Sponsored by** BGS, UK
3.NIH/GW D/NMSHE/ 16-20	Study of river - aquifer interactions and groundwater potential at selected sites in the upper Ganga basin up to Dabrani.	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan,	5 year (01/16 – 12/20) **Status: In progress.**	Sponsored by DST under NMSHE SP-8.
4. NIH/GWD/ NIH/16-19	Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water	N.C. Ghosh (Lead), Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Chaudhury, Sanjay Mittal, Ram Chandar, etc.	3 years (11/16-10/19) **Status: In hold. Partners:** IIT Bombay UJS, D. dun	Sponsored by NWM, MoWR, RD & GR
5.NIH/GW D/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin- **FAR GANGA**	**NIH-Team:** N. C. Ghosh (India Lead) Surjeet Singh; Sumant Kumar; Gopal Krishan; Suman Gurjar from NIH **Other India partners:** IIT Roorkee; IIT Kharagpur; & Mahavir Cancer Sansthan, Patna. **UK- Partners:** Univ. of Manchester; BGS; Salford University; Univ. of Birmingham.	**3 years** (01/18 – 12/20) **Status : In progress.**	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme.
6.NIH/GW D/DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific reference to Fluoride and Micro-pollutants.	**NIH-Team:** Anupma Sharma (Indian Lead); Sumant Kumar; Gopal Krishan; Suman Gurjar and M. K. Sharma **Other Indian partners:** IIT Ropar & IIT Jodhpur. **UK Partner:** Cranfield University, School of Water, Energy and Environment; Cranfield University	**3 years** (01/18 – 12/20) **Status : In progress.**	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme.
7.	Ganges Aquifer Management in	Surjeet Singh, (PI), N.C	04 Years	Sponsored by

NIH/GWHD/PDS/18-22	the context of Monsoon Runoff conservation for sustainable River Ecosystem Services- A Pilot study	Ghosh, Sudhir Kumar, C. P Kumar, Suman Gurjar, Gopal Krishan **Implementing Agency:** GW Deptt., Govt. of UP	(03/18-02/22) **Status:** **In progress.**	NHP under PDS
8. NIH/GWHD/PDS/18-20	Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures	**NIH, Roorkee, India** Gopal Krishan (PI), N. C. Ghosh, Surjeet Singh, C.P. Kumar **IIT-Roorkee** M.L. Kansal, Brijesh Yadav (PI) **Sehgal Foundation, Gurgaon** Lalit Mohan Sharma	03 years (01/18-12/20) **Status : In progress.**	Sponsored by NHP under PDS
9. NIH/GWHD/PDS/18-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), N.C. Ghosh, Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary, Ram Chander **Partner Organization** MWRD, Bihar **Collaborator** Brijesh Yadav, IIT Roorkee N.S Maurya, NIT Patna	03 years 01/18-12/20 **Status : In progress.**	Sponsored by NHP under PDS
10.NIH/GWD/PDS/18-20	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi.	**NIH Team:** Anupma Sharma (PI) N.C Ghosh, Sanjay K. Jain, Archana Sarkar, M.K. Sharma, L.N. Thakural, Sumant Kumar, Suman Gurjar **Partner Organization:** Sanjeev Bansal (C.E, IWRD Haryana), Amod Kumar (Tech. Coord., GWD U.P), S.E. YBO, CWC New Delhi	04 years 04/18-03/22 **Status : In progress.**	Special Project under "Centre of Excellence"
11. NIH/GWD/NIH/18-19	Application for Conjunctive use management of SW & GW in Saryu Nahar Pariyojna, U.P. using "Strategic basin Planning model for Ganga River Basin"	Suman Gurjar (PI), Jyoti Patil (Co-PI), N.C. Ghosh, Anupma Sharma, Sumant Kumar, Surjeet Singh	1 Year (04/18 – 03/19) **Status: In progress**	Internal Funding.
Other R & D Projects				
12.	DSS planning & Management in selected states	Anupma Sharma + Team		NHP
13.	Development of Groundwater Model for Integrated Hydrologic Model	Anupma Sharma, Surjeet Singh, Suman Gurjar, Sumant Kumar		CEHM, NHP
Consultancy Projects				
1. CS-145/2018-	Impact of Metro Railroads Viaduct on Groundwater	Gopal Krishan (PI)	03 Months (06/18-08/18)	Sponsored by: DMRC

18/GWH	Recharge in NCT Delhi		**Status: Completed.**	
2.CS-126/2017-18/GWH	Water Availability and Water Budgeting Study of Kalsi Micro-Watershed, Uttarakhand	Surjeet Singh (PI)	08 Months (10/17-05/18) **Status: Completed.**	Sponsored by WMD, Dehradun
3.CS-146/2018-18/GWH	Investigation of Physical Groundwater Table and Ascertaining its Fluctuation and Trend in Stretch from Chainage 59+600 m to 67+300 m in Rewari to Dadri of CTP-14 Package of Western Dedicated Freight Corridor Project	N.C. Ghosh (PI)	06 Months (05/18-10/18) **Status:** In progress	L & T India, Ltd.
4.	Water Availability Study based on Hydrological Investigations and Modeling of Upper Hindon Basin	Anupma Sharma (PI)	02 Months (10/18-11/18) **Status:** In progress	Irrigation Dept., Saharanpur

The detailed of the studies is given in Annexure-I.

Outreach activities during 2018-2019

1. Scientists published/accepted **3** papers in international/national journals & Conferences.
2. Scientists delivered **12** lectures in different training courses and Workshops.
3. Scientists guided/guiding **5** M.Tech/Ph.D students for their thesis work.
4. One scientist attended 3 weeks International training on GW Modeling at IHE Delft, The Netherlands.

1. PROJECT REFERENCE CODE: NIH/GWD/NIH/15-18

Title of the Project: Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.

Project duration : 30 months (November, 2015 – April, 2018), extended by one year up to March, 2019.

Type of study : Sponsored by MoWR, RD & GR, GoI. Under NIH's Plan Fund.

Nature of study : Demonstration and applied research

Objectives:

(i) Baseline investigations and development of pilot demonstration sites for riverbank filtration (RBF) in different hydrogeological settings;
(ii) Performance and limitations analysis of RBF schemes;
(iii) Effectiveness of RBF technique in different river-aquifer settings and river flow conditions;
(iv) Analysis of RBF under variable pollutants loads and flood situations;
(v) Development of technical elements for flood-proof water abstraction schemes; and
(vi) Scope of extending the technique in attaining drinking water security.

Methodology

Six pilot demonstration schemes in 5 states, viz. One in Uttarakhand (Laksar along Solani river), two in Uttar Pradesh (Mathura and Agra along Yamuna river); one in Jharkhand (Sahebganj along Ganga river); one in Bihar (Bhojpur area along Ganga river), and one in Andhra Pradesh (Visakhapatnam area) were planned to develop. Respective State Jal Sansthan/PHED/Jal Nigam is the collaborating partner for the schemes. HTWD, Germany is the associated partner as scientific and technical adviser.

The roles of State Jal Sansthan/PHED/Jal Nigam are towards extending administrative and logistic supports in the field including identification of sites and providing required land for the scheme and electricity facilities for installation of tube wells and O & M of the pumps.

Deliverables

Schemes demonstrating effectiveness of 'Riverbank Filtration' technique for sustainable drinking water supply in different hydrogeological settings, river hydraulic and groundwater conditions will come out as deliverable and these schemes after thorough investigations will be handed over to the respective state 'Jal Sansthan' to use them as the guiding scheme towards attaining drinking water security.

Progress

(i) Laksar Site, Uttarakhand:

The RBF site explored and installed the tube well at Kuan Khera village in Laksar UK in year 2016 was abandoned because of water quality problem of geogenic origin and due to its damage and flexibility of shifting of banks by erosion.

(ii) ***Mathura and Agra Sites***

Phase-I that deals with exploratory drilling, development and installation of bank filtrate production tube wells both at Mathura near Gokul barrage *and Agra* near Agra Water Works has been completed (Borelog stratigraphic profiles of both the sites are in Figure 1) through U.P. Jal Nigam, Agra as deposit work. The Phase-II that will deal with installation of submersible pumps, construction of pumping plants for the tube wells, pump house, stand post, etc. for both the sites as completed in Phase 1, is in progress. The estimated cost for Phase-II for both the sites is Rs. 34.72 lakh including all taxes and the works are being carried out through U.P. Jal Nigam, Agra Division as deposit work. The agreement has been signed and 1st inclement is under release.

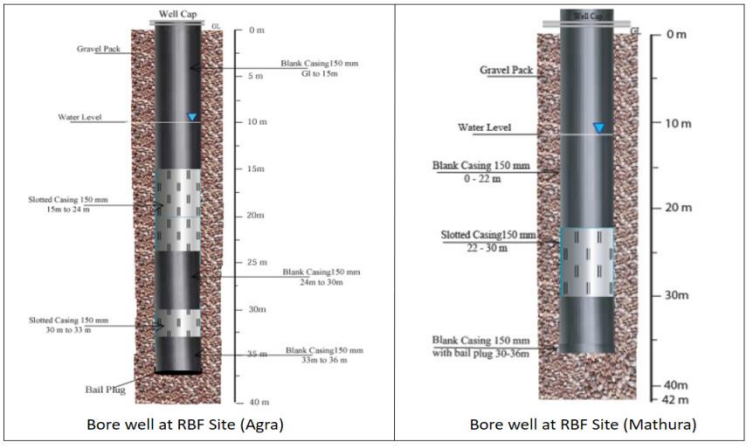


Figure 1: Borelog stratigraphic profiles of Agra and Mathura RBF site.

Arrah site in Bihar

Based on a number of field visits in potential locations of Arrah district and after discussing with local people, the site within the premises of a temple in the Berhara village (Figure 2) has been finally selected for exploratory drilling & development of RBF scheme. The villagers and the temple authority have agreed to provide land and installation of RBF well. Resistivity survey of the location has been carried out. First installment against the budget estimate of the PHED, Bihar to take up the work has been released. The exploratory drilling and installation of tube well are yet to take place.

PFigure 2 : RBF site in the temple premise of Behara village, Ara district.

(iii) **Vishakapattanam, A.P.**

A site along Varaha River at **Vishakapatnam** has been selected in consultation with A.P. RWS & S, Govt. of Andhra Pradesh (Figure 3a). For exploratory drilling and installation of RBF tube well through A.P. RWS & S, Govt. of Andhra Pradesh as deposit work, the 1st installment of Rs. 2.0 lakh against budget estimate of Rs. 3.25 lakh has been released. Geophysical survey has been carried out (Figure 3 b). The exploratory drilling and installation of RBF well are likely to start.

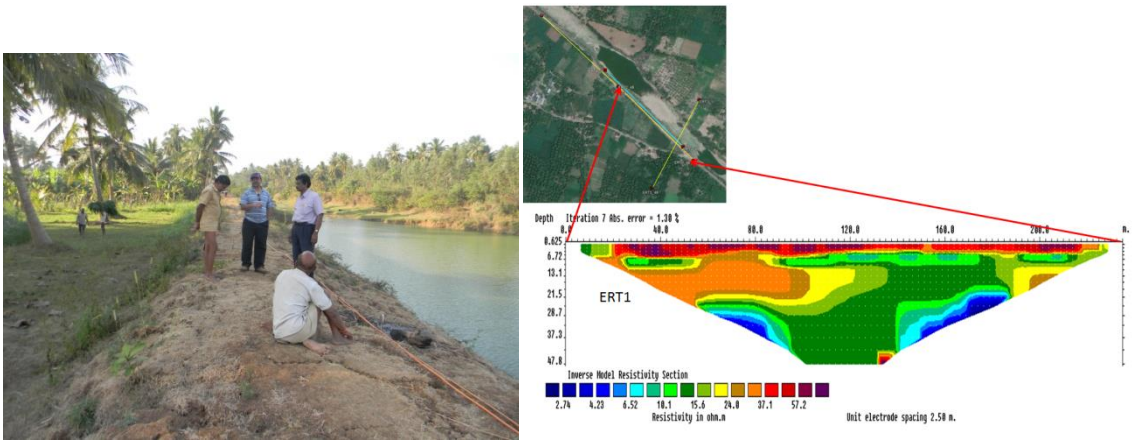


Figure 3: Selected RBF site along Varaha River at Vishakapatnam (a) field survey in progress, and (b) results of geophysical survey. .

(iv) Sahebganj, Jharkhand

The RBF in Sahebganj (Jharkhand) has not yet been decided.

2. PROJECT REFERENCE CODE: NIH/GWD/BGS/16-20

Title of the study	**:**	**Groundwater fluctuations and Conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements**
Type of study	**:**	**Sponsored,** BGS, UK.
Date of start (DOS)	**:**	December 2017
Scheduled date of completion	**:**	November 2020
Location	**:**	Bist- Doab Punjab

Study objectives:

1. To characterize multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers.
2. To collate new evidence on recharge processes, groundwater quality, groundwater residence times, and connectivity of the layered aquifer systems and surface water by repeated sampling of shallow and deep piezometers using a suite of environmental tracers.
3. To prepare a status report on groundwater issues in Punjab.

Statement of the problem:

Higher rate of withdrawals are observed in the state of Punjab where the annual rate of groundwater level decline is increasing by about 80% and projected to fall by about 21 meter in 2/3rd area of central Punjab during next 2 decades. The large drop in groundwater levels can be due to several reasons like high withdrawals, low-recharge, low-transmissivity, poor conditions of surface water recharge source conditions etc. In addition to declining water level, the quality of groundwater is also a concern in Punjab. Considering these facts, National Institute of Hydrology, Roorkee, is carrying out a research project jointly with BGS, UK duly approved by Ministry of Water Resources, RD and GR to get a high frequency water level and conductivity data long with the analysis of water samples for a suite of tracers.

In the present study, Bist-Doab area was selected based on previous studies which cover Nawanshahr (new name SBS Nagar), Jalandhar and Kapurthala districts. It was found that groundwater fluctuation in the shallow aquifer and deep aquifer show different trends. Characterizing and understanding the reasons for this local heterogeneity is fundamental to develop effective water management plans. This requires higher resolution field-based observations. In Bist-Doab, occurrence of groundwater forms the multi-layered aquifer system. For getting aquifer specific measurements for shorter screened intervals of conductivity and water level will provide some conclusive results for proper water resource management of this important region of the Punjab state.

Whether Study is a New Study/Extension of Previous Studies: Extension of previous studies

Methodology:

In this study, groundwater level and conductivity data are monitored and high resolution field based observations are collected. For this the loggers for conductivity have been installed in 4 shallow piezometers of PWRED, Chandigarh at Saroya (Kandi region), Bhogpur, Kapurthala and Sultanpur Lodhi and water loggers are installed in the Saroya, Bhogpur and Sultanpur Lodhi in the month of May, 2018 and data will be downloaded in post monsoon season (Fig. 1).

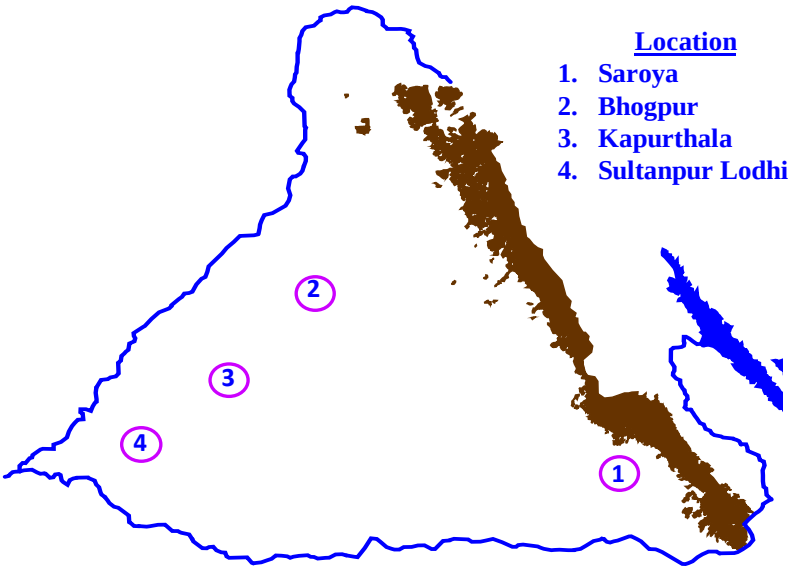


Fig. 1. Study area, Bist Doab, Punjab

These loggers are installed considering the physiography, geomorphology and hydro-geological conditions of the area.
The results for conductivity data showed that there were some irregular trends. e.g. In Saroya, the conductivity fluctuations were about 40 µS/cm while at Kapurthala the fluctuations were within 10 µS/cm. The data for water level will be collected after monsoons to get the fluctuations in water level for pre-monsoon and post monsoon in 2018.

Action plan:

Year	**Dec. 2017 to Nov., 2020** (Annexure 1)	**Remark**
Dec. 2017 to Nov. 2020	Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects in Punjab Monitoring of water level and conductivity fluctuations in Bist-Doab, Punjab Water sampling and analysis for isotopes Prepare a status report on groundwater issues in Punjab Presentation of work progress in a workshop/review meeting under the project	Report preparation as per Annexure 1

Study Benefits /Impact:

An overview report on groundwater status in Punjab

- Suggesting some water resources management plans
- Research publication in high impact journals.
- Upload of results on Websites.

Specific linkages with Institutions: BGS, UK

ACTIVITY SCHEDULE FOR THE GROUNDWATER FLUCTUATIONS AND CONDUCTIVITY MONITORING IN PUNJAB (QUARTER WISE FROM DEC. 2017 TO NOV. 2020)

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Downloading data	♦		♦		♦		♦		♦			♦
Sample collection and analysis			♦			♦			♦			

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Collection of data from various agencies (NIH)	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
First Draft (NIH-BGS)				♦								
Second Draft Report/Technical publication(NIH-BGS)								♦				
Final Report/Publication(NIH-BGS)											♦	♦

Progress

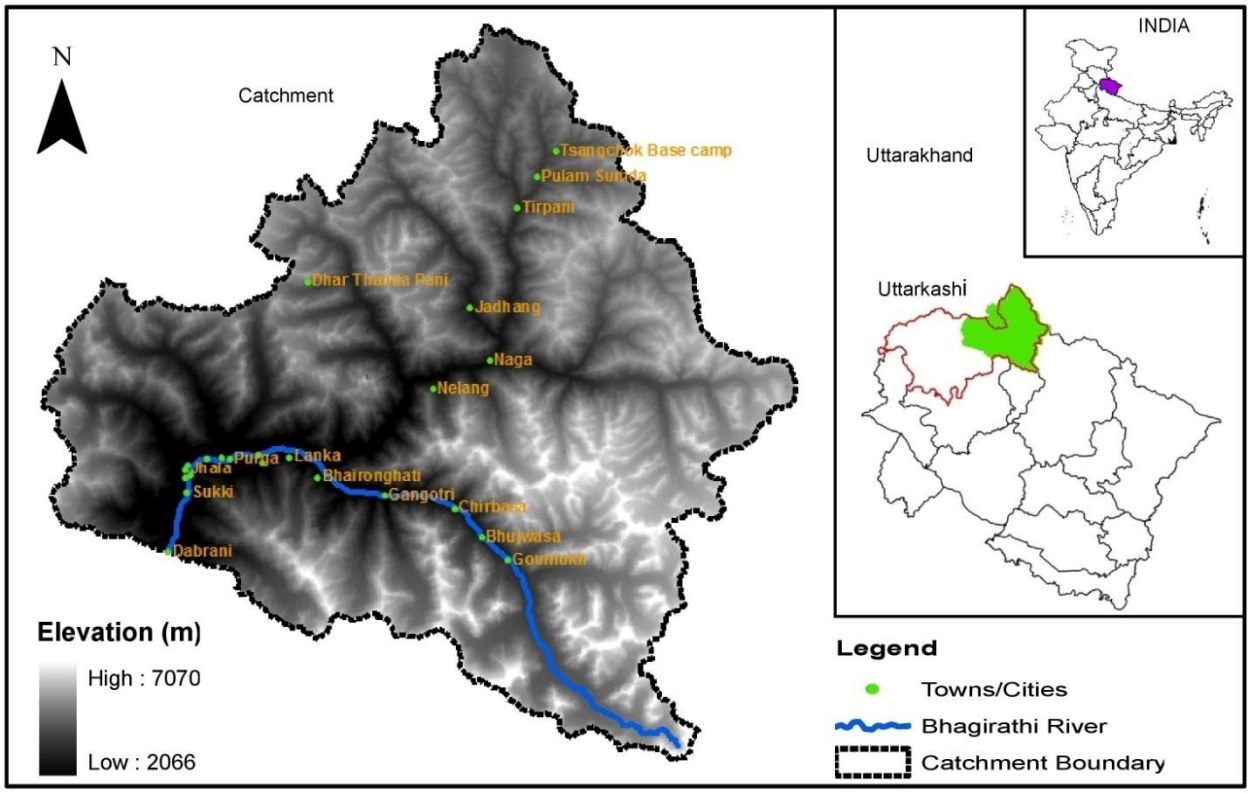
- The water loggers have been installed in the Pz of state department at Saroya, Bhogpur and Sultanpur Lodhi
- The water samples were collected from piezometers

Future plan

- Downloading data from SEC and water level loggers
- Collection of samples from piezometers
- The hydro-meteorological data will be collected from state departments
- Data analysis work will be carried out with respect to various parameters like rainfall, land use etc. to observe the seasonal and spatial variation
- There were battery issues with the old loggers, new loggers will be provided by BGS soon.
- 3 more water loggers will be installed at Tanda, Nakodar and Kapurthala

3. PROJECT REFERENCE CODE: NIH/GWD/NMSHE/16-20

Title of the study	**:**	**Study of river - aquifer interactions and ground water Potential at selected sites in the upper Ganga basin up to Dabrani**
Type of study	**:**	Sponsored by DST under NMSHE SP-8
Date of start (DOS)	**:**	January, 2016
Scheduled date of completion:		December, 2020
Location	**:**	Bhagirathi Basin up to Dabrani (Uttarkashi)



Study objectives:

1. Understanding of river-aquifer interaction and dynamics processes in Himalayan environment,
2. Groundwater potential assessment and availability prospects resulting from snow and glacier melt recharge.

Approved Action Plan:

- Collection/procurement of available long-term hydro-meteorological and hydro-geological data for the study area.
- Preparation of various thematic layers (sub-basins, geology, soils, wells, snow cover, drainage, monitoring network, water use, etc.).
- Selection of suitable sites for piezometer development.
- Development of piezometers for monitoring of groundwater.
- Developments of lithologs & aquifer characterization.
- Collection of water samples & monitoring of groundwater levels.
- Analysis on the stream-aquifer interactions and dynamics processes.
- Estimation of groundwater recharge & water potential.

Time-line and Justification for time over runs:

Piezometer development work awarded to the Uttarakhand Jal Sansthan (UJS), Uttarkashi.

Objectives vis-à-vis Achievements:

Part of Objectives	Achievements
Literature review	Completed till date.
Database preparation	DEM, drainage, sub-basins, 3D map, slope map, sampling location, geology, landuse, soil.
Selection of sites for piezometer development	- Sites were selected. - Map for selected sites also prepared.
Data collection	Geological map, litho logs of five locations, water quality, isotopic data from water sampling, rainfall and meteorological data from IMD and CWC.
Piezometer development	Under progress.

Recommendations/ Suggestions in previous meetings of Working Group/ TAC/ GB

Nil.

Analysis of Results:

The study is envisaged on the stream/river and groundwater flow interactions and dynamics including potential assessment emerging from snow and glacier melt recharge to answer the question of groundwater development prospects in the hilly areas as well as base flow regimes of the mountainous streams. In order to carry out the study, the existing basin information, geological and geo-hydrological investigations and development of piezometers for groundwater data acquisition are necessary. The study area, lies in the Uttarkashi district of Uttarakhand state, comprises an area of 3,487.06 sq.km. The Bhagirathi is the main river of the study area. The elevation of the basin varies from 2,066 to 7,070 m above mean sea level. Under the study, various thematic maps viz., digital elevation model, demarcation of basin boundary up to Dabrani, study area map, elevation zone map, 3D map, geological map, drainage map and stream ordering, sub-basin map, slope map, aspect map, digitization of ground surface contours at 10 m interval (SOI at 1:50,000), sampling location map, piezometer sites map, soli map, landuse, etc. have been prepared. Geological traversing from Dabrani to Gangotri was also done. Borelog data of five locations were collected and analyzed. The soil map of the basin area has been prepared and given below.

Water sampling from the Bhagirathi river, precipitation and groundwater is being continuously done at 10 daily frequency at ten locations for the isotopic and water chemistry analysis for studying the stream-aquifer interactions. These water samples were being collected from springs, river, stream, hand-pumps and rainwater on event-basis for the isotopic and water chemistry analysis. Preliminary interpretations indicate that isotopic values for most of the river and ground water samples rest close to the Local Meteoric Water Line shown above, which indicate mixing of surface and ground water. MoU between NIH and UJS (Uttarakhand Jal Sansthan) was signed for the piezometer development at seven locations in the study area on 19.09.2018. Work order is issued along with 40% payment. Piezometer development work is in progress.

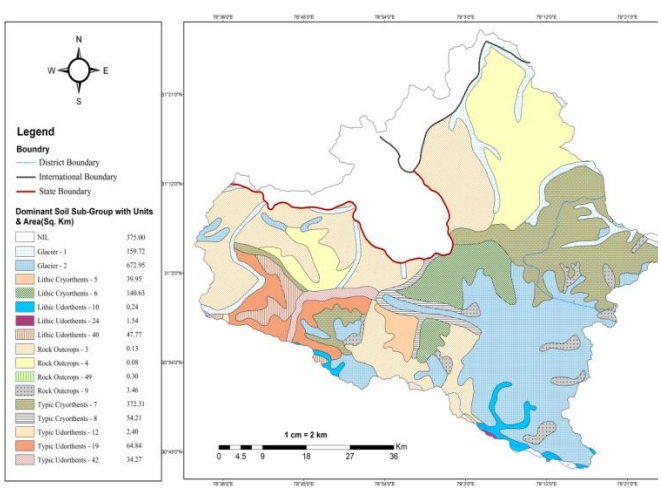


Figure 1: Soil group for the study area prepared from the NBSSLUP map

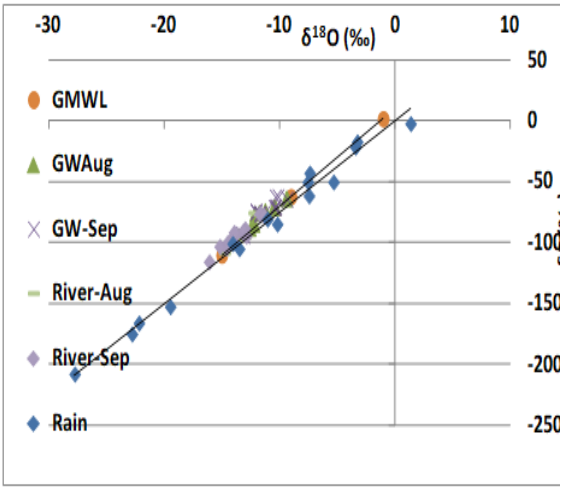


Figure 2: Local Meteoric Water Line for the monsoon season

Adopters of the Results of the Study and their Feedback: Study yet to be completed.

List of Deliverables:

- Reports; Research papers; Training Workshops.

Major Item of Equipment Procured: GPS, pH Meter, EC Meter and Water Level Indicators.

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research.
- Nuclear Hydrology Laboratory.
- Water Quality Laboratory

Data Procured/ Generated during the Study:

- Geological map; Water quality data; Isotopic data; Surface contours; Landuse; Soils.

Study Benefits /Impact:

- Process understanding of groundwater recharge due to glacier and snow melt recharge.
- Understanding dynamics and behavior of soil-snow interface in the snowmelt Himalayan region.

Specific linkages with Institutions: DST, UJS.

Major Items of equipment needed: GPS, Portable WL Indicator, pH and EC meter.

Future Plan:

- Development of piezometers.
- Generation of borelogs.
- Aquifer characterization.
- Monitoring of groundwater levels.
- Collection and testing of soil samples from various locations of the basin.
- Collection and testing of water samples from surface and ground water for quality and isotopic analysis (groundwater, spring, rainfall and river samples).

4. PROJECT REFERENCE CODE: NIH/GWD/NIH/16-19

Title of the Project: *Grey Water to Blue Water* – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water.

Type of study: Sponsored by: MoWR, RD & GR, GoI under National Water Mission.

Nature of study: Demonstration and applied research

Duration: November 2016 - October 2019

Objectives:

The objectives are to develop a cost effective and non-hazardous wastewaters treatment technique for re-use and recycling of treated water to attain urban and peri-urban water supply security.

Methodology:

- Pilot field experimentation,
- Sampling campaign at regular intervals and analysis of samples at laboratory,
- Field experimental setup establishment,
- Rigorous analysis of hydrological, hydrogeological, borelogs and water chemistry data using advanced tools and techniques,
- Space-time analysis of data and developing thematic maps in Arc-GIS framework,
- Groundwater flow and contaminant transport modeling,
- Risk assessment using conventional techniques, and
- Application of non-conventional source of energy.

Deliverables:

(i) Document on design criteria of natural treatment techniques for varying input and output conditions, hydrogeological setups and river flow conditions,
(ii) 'Hand book' on performance of 'Natural Treatment Techniques' for treatment and re-use of wastewaters,
(iii) Scientific publications,
(iv) Training and dissemination.

Progress

No progress since last "Working Group" meeting held during 8-9 February, 2018 because of land problem. The land allotted by the Civil Administration, measuring 45 m x 45 m for installation of the scheme is on the regular submerged area and very near to the Solani river. The area is neither suitable and nor feasible for installation of the scheme. Setting up of the experimental scheme, even with all local hurdles, on the allotted land would simply be wastage of money without any productive scientific outputs.

5. PROJECT REFERENCE CODE: NIH/GWD/DST/18-20

Title of the Project : Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin-**FAR GANGA**

Type of Study : Sponsored by Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund

Nature of study : Applied Research

Duration : 3 (three) Years : 01/2018-12/2020

India Project Partners : NIH (India Lead); IIT Kharagpur, IIT Roorkee; and Mahavir Cancer Sansthan, Patna.

UK Project Partner: University of Manchester (UK Lead), British Geological Survey, Salford University; and Univ. of Birmingham.

Research challenges:

(i) Role of anthropogenic activities in increasing arsenic groundwater hazard and health risks;
(ii) WQ challenges associated with surface derived labile organic matter ingresses in shallow groundwater systems and contribution to greater mobilization of groundwater arsenic,
(iii) Bio-geochemical magnification due to other 'competing ions and contaminants' and mobilization processes and so on…

Aims:

- Investigate the vulnerability of representative shallow sedimentary aquifer systems in the Ganges River Basin to secular increases in arsenic
- Predict future secular changes in groundwater arsenic
- Communicate with key stakeholders to inform them of future hazards and risks and how groundwater management practices and strategic selection of water remediation technologies and approaches might accordingly be modified.

Objectives:

- Produce a national risk assessment of shallow groundwater arsenic from carefully selected tectonic, geological, geo-morphological and climatic variables;

- Produce recommendations for the remediation/ mitigation of human exposure and health risks arising from current and future arsenic prone groundwaters, with a particular focus on managed aquifer recharge (MAR), based on the data and models generated in this project, together with strong and effective participatory approaches with key stakeholders/end-users and by networking with other relevant research and water resource management institutions and projects.

Progress

One inception workshop with India partners at Patna during 11th & 12th May, 2018 and one review meeting with both India and UK partners during 19-23 July, 2018 at Varanasi to discuss about tasks, to finalize field sites for experimental works, and to outline the strategy to carry forward the works were held. Joint field visit in arsenic effected area in Bihar and demonstration on sampling protocol in Varanasi took place.

From NIH's side, two field visits for collecting water samples from Bijnor and Moradabad district took place to finalize the location of field experimentation sites. The samples have been analyzed in the IIC of IIT Roorkee. The results of analysis shall be presented in the working group meeting.

6. PROJECT REFERENCE CODE: NIH/GWD/DST/18-20

Title of the study : **Impact of rainwater harvesting on groundwater quality in India with specific reference to fluoride and micropollutants**

India Lead: NIH Roorkee
PI: Dr Anupma Sharma, Sc. E, GWH Division
Co-Investigators
Dr M K Sharma, Sc. D, EHD Division
Mr Sumant Kumar, Sc. C, GWH Division
Ms Suman Gurjar, Sc. C, GWH Division
Dr Gopal Krishan, Sc. C, GWH Division

Indian Co-Partners (i) IIT Ropar (ii) IIT Jodhpur
IIT Ropar PI: Dr Deepak Kashyap, Dept. of Civil Engg.
IIT Jodhpur PI: Dr Rakesh Kumar Sharma, Dept. of Chemistry

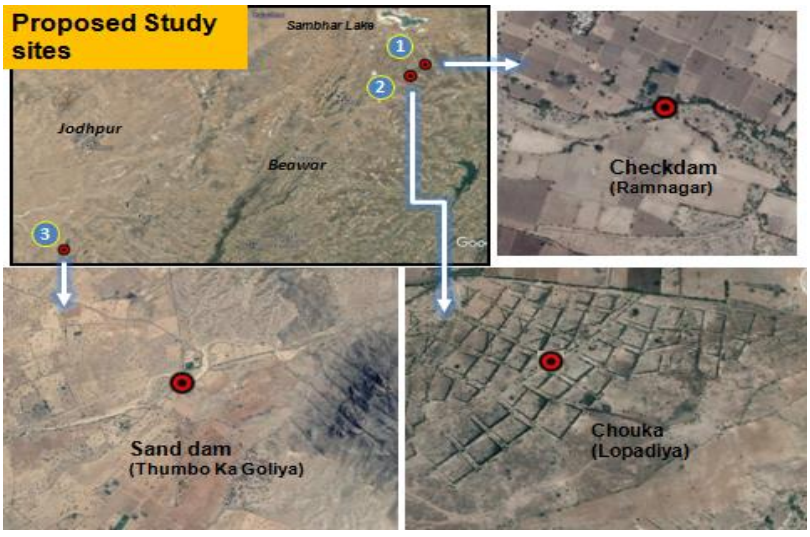
UK Partner: Cranfield University
PI: Dr Alison Parker, School of Water, Energy and Environment
Co-Investigator: Dr Pablo Campo Moreno, School of Water, Energy and Environment

Project Partners: Wells for India and Excellent Development, UK based NGOs together with their Indian offices and local NGO partners in Rajasthan.

Type of study (sponsored/consultancy/referred/internal):
Sponsored Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund**:** Rs. 255.884 lakh (total)
NIH Budget: Rs. 105.688 lakh (incl. overhead)

Nature of study: Study components include technology development, technology dissemination, technology adaptation, capacity building

Location Map



Project Aim & Objectives
To assess the impact of rainwater used for MAR on groundwater quality and specifically understand how DOM present in rainwater affects fluoride and other pollutant levels, thereby improving MAR structure design and management practices. Specific objectives:

1. Evaluate water level and quality at three selected MAR sites in Rajasthan;
2. Assess the proportion of recharged groundwater attributable to MAR systems at selected sites;

3. Investigate the consequences of recharging aquifers with rainwater on the fate and transport of pollutants into aquifers, and understand the role of rainwater DOM levels in remediating fluoride and other groundwater contaminants;
4. Develop analytical protocols to facilitate the detection of micropollutants in water bodies;
5. Understand the interactions of local users with the MAR structure and also their role in water management.

Work Packages
WP1: Field Surveys & Investigations
WP2: Laboratory Experiments & Analysis
WP3: Simulation of Pollutant Transport
WP4: Research Impact and Knowledge Dissemination

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Data collection	Historical groundwater level data from State and Central Ground Water Depts., crop cultivation, relevant reports and maps, meteorological data, data collection during field visits.
Field experiments and Laboratory investigations	– Three field visits May, June (Laporiya), July (Bhadrajun) – DTWL measurements in Laporiya watershed and Bhadrajun – Collection of soil (disturbed/undisturbed) and water samples – Field experiments for saturated hydraulic conductivity and infiltration – Socio-economic survey conducted in Bhadrajun – Laboratory experiments for grain size analysis, ICW and soil moisture retention curves – Drilling of boreholes to be initiated with support from State Dept
Database preparation	DEM, land use, soil texture, drainage, groundwater levels, water quality
Data analysis and Website development	Analysis of water level and water quality data, satellite data, land use; analysis of soil samples and data for infiltration rates and saturated hydraulic conductivity. Website for project activities developed
Organization of Indo-UK Consortium Meeting and Workshop	October 14-16, 2018, Jaipur Participation: NIH, IIT Ropar, IIT Jodhpur, Ground Water Dept. Rajasthan, Water Harvest (NGO), Jal Bhagirathi Foundation (NGO)

Deliverables & Beneficiaries: The project primarily addresses the Newton-Bhabha priority area "public health and well-being". Beneficiaries will include fluoride affected communities in Rajasthan. Deliverables include research papers, reports, software, manuals, brochures, flyers, users' interaction workshops.

7. PROJECT REFERENCE CODE: NIH/GWD/PDS/18-22

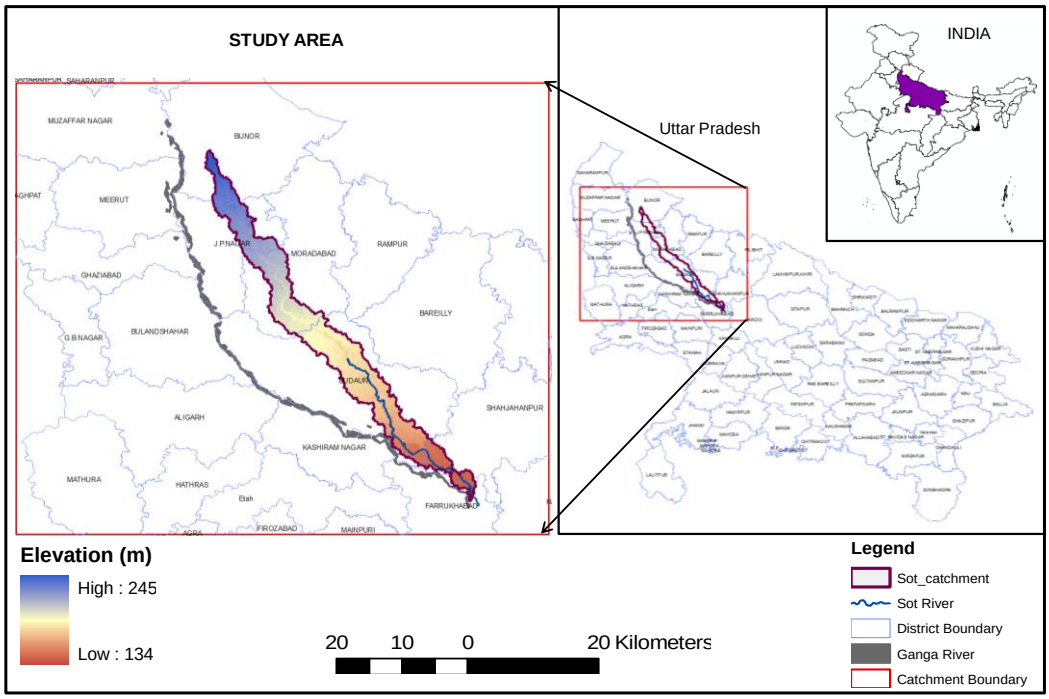
Title of the study : **Ganges Aquifer Management in the context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services– A Pilot Study**

Type of study : Sponsored by NHP under PDS

Date of start (DOS) : March, 2018

Scheduled date of completion: February, 2022 (Four Years)

Location : Sot River Catchment



Study objectives:

- Hydro-geological characterization of the area.
- Analysis of meteorological and hydrological variables *vis-a-vis* cessation of river flows during lean season.
- Estimation of surface water and groundwater availability.
- Analysis of stream-aquifer interaction.
- Aquifer management measures for enhancing river flow during lean season.

Statement of the problem:

Declining groundwater levels, diminishing river flows, turning perennial rivers into ephemeral rivers, impact of climate change are posing extreme scarcity of water availability in many tributaries of the Ganga River. Such phenomena are not only affecting the water resources but also the livelihood of farmers and the river ecosystem.

The study area comprises of the catchment of *Sot River*, a tributary of the Ganga River. The river flows in between the Ganga and the Ramganga River. Though both these rivers have good water potential, the Sot river catchment faces acute water problem and many hydrological problems, including extra-deep groundwater levels, recurrent droughts, soil erosion and desertification in some of the areas. The catchment area falls in districts of JP Nagar, Moradabad, Budaun, Shahjahanpur and Farrukhabad. The region suffers from extended droughts, depleted water resources, declining

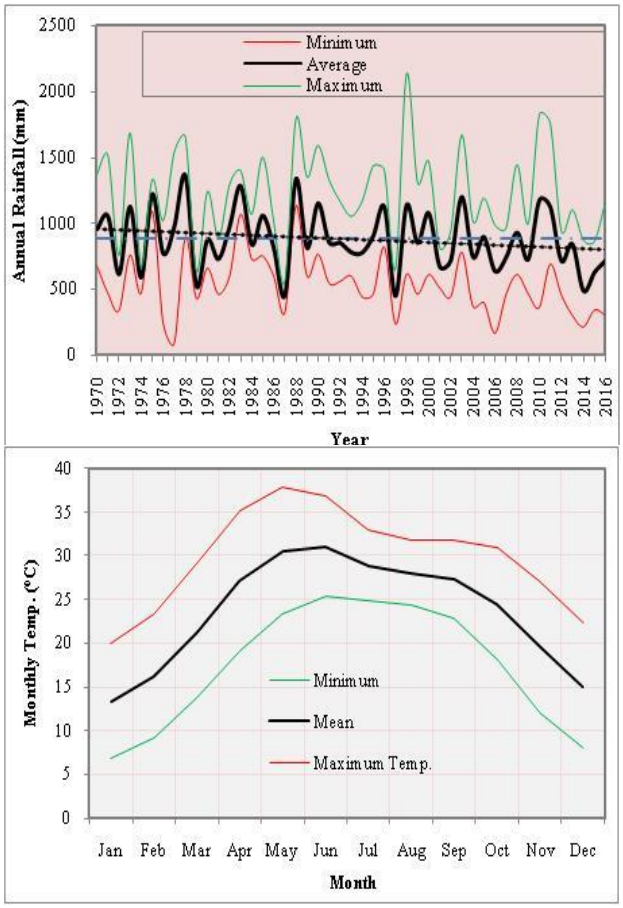
groundwater levels, and uncontrolled developmental activities. These factors coupled with the threat of the impending climate change may lead to an aggravation of the crop losses and desertification process in the area. The Sot river, earlier used to be perennial, has now become seasonal river. Under this background, it was felt necessary to investigate the river-aquifer interactions and dynamics to identify causes of drying of river and suggest measures for rejuvenation.

Methodology:

- Aquifers will be delineated using litholog/ borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks Software.
- Time series analysis will be carried out by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river flows during the lean seasons of various years.
- Parametric and non-parametric trend analysis using Mann-Kendall and Sen-Slope Estimator, and change detection using Pettitt technique will be carried out on the hydro-meteorological variables to find the declining trends in river flows, groundwater levels and rainfall during both monsoon and non-monsoon seasons in various years.
- Surface water availability shall be estimated from river flow data using flow-duration curve and groundwater availability using GEC-2015 methodology.
- Vulnerability analysis shall be carried out using SAHP/DRASTIC approach.
- Catchment water balance shall be carried out using mass balance approach.
- Integrated surface and ground water modeling shall be used for river-aquifer interactions and future scenarios for river flows during lean seasons.
- Isotopic analysis shall also be carried out to verify the reaches of recharge/discharge zones to/from the river.
- A management plan will be developed for the enhancement of water resources both surface and underground.

Analysis of Results:

The study is envisaged on the river and groundwater flow interactions and dynamics to answer the questions on drying of Sot river. To carry out the study, existing catchment information, literature survey, meteorological, hydrological and geo-hydrological investigations, and groundwater data acquisition are essential. Review of literature related to the study has been completed. Location map of the study area is prepared which indicates that the study area lies in the Uttar Pradesh state of India and covers an area of 3027 sq.km. The elevation of the catchment varies from 138 to 245 m above mean sea level. Under the study, catchment boundary has been delineated and various thematic maps have been prepared which include digital elevation model, study area map, 3D map, drainage map, soil map, stream ordering, grid maps, etc. The spatial variation of groundwater levels in the Sot catchment is analyzed for the period 2008 to 2017. IMD gridded rainfall and temperature data have been analyzed from 1970 to 2016 and 2015, respectively for temporal and spatial variation on weekly, monthly and annual basis. Non-parametric trend analysis has also carried-out. Variation of rainfall and temperature in the Sot catchment is shown below:



Adopters of the Results of the Study and their Feedback: CGWB; Agric. Deptt., GWD and IWRD, Govt. of U.P.

List of Deliverables:

- Reports; Research papers; Training Workshops.

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research.

Data Procured/ Generated during the Study:

- DEM, Meteorological data, Soil information, GW Levels, Landuse.

Study Benefits /Impact:

- Increased surface and ground water availability - Regional water security.
- Farmers' Access to Irrigation.
- Social and cultural activities.
- Improvement in water quality by continuous flushing and dilution of domestic and industrial wastewaters.
- Economic benefits through livelihood upliftment.
- Climate resilience.

Equipments to be Procured: Aquameter, EC and pH meter.

Future Plan:

- Aquifer characterization.
- Determination of soil texture, infiltration and conductivity tests.
- Analysis on variation of river flows.
- Collection and testing of water samples from surface and ground water for quality and isotopic analysis (groundwater, rainfall and river samples).

8. PROJECT REFERENCE CODE: NIH/GWD/PDS/18-20

Title of the study **: Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures**

Type of study **:** Applied Research

Date of start (DOS) **:** January**,** 2018

Scheduled date of completion **:** December, 2020

Location **:** Mewat district, Haryana

Study objectives:

1. Assessment of lowering of water table (depletion in groundwater level) in the salinity impacted area using the historical data.
2. Detailed qualitative analysis of the area and the aquifer depth impacted by higher salinity levels, and preparation of maps.
3. To monitor influx of saline groundwater into fresh water zone
4. To assess the impact of groundwater salinity on socio-economic aspects
5. To develop and demonstrate management and resilience building measures

Statement of the problem:

Groundwater salinity is a widespread problem in many productive agricultural areas in India including many districts in Haryana. Aquifer salinization gradually affects the agro-economy, livelihoods and drinking water supply in local and regional scale due to lowering of groundwater levels. Salinity is the main factor limiting the continued use of groundwater in surface water scarce area, and future reliance on groundwater is further diminished as groundwater levels decline, creating increases in salinity and in exploitation costs. A systematic groundwater development and management fulfilling the technical needs of supply-side and demand-side components can arrest the aggravation of salinity and provide sustainable solution to problem.

In this study, a comprehensive analysis on hydrological and hydrogeological features together with chemistry and isotopic characteristics of groundwater for evaluating the causes of aquifer salinity including its aggravation and effect on agro-economy, drinking water supply and livelihoods considering the problem of Mewat district in Haryana as the pilot would be carried out. A few demonstrative schemes as resilience building measures towards arresting the aggravation of salinity and increase of managed aquifer recharge together with their impact assessment on overall groundwater resources would also be undertaken. Development of a model to predict changes in groundwater salinity as a result of aquifer recharge and extraction is another focus of the study.

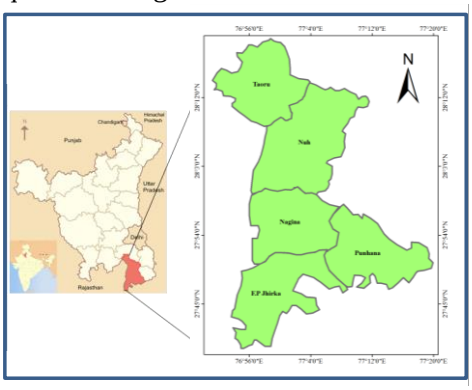


Fig. 1. Map of Mewat district

Methodology:

This work will be accomplished in five phases as detailed below:
In Phase 1, socio-economic based survey will be carried out to find out the impact of salinity on the socio-economic condition of the people on the basis of list of indicators given in the table below. The findings of the study will help initiate the development activities as coping strategies for the survival of humankind in the presence of salinity in the district of Mewat.
In Phase, a hydrogeological framework of the aquifer system in Mewat district based on all existing lithologic, stratigraphic and hydrologic information will be developed.
Phase 3 will include a hydro-chemical characterization (on the basis of anions, cations physico-chemical characteristics etc.) and quantification of salinity
Phase 4 will target the areas surrounding the drinking water wells that showed presence of salinity in Phase 2 using existing and new tube wells.
Phase 5 will include suggestion and development of resilience building measures. Some proposed measures will be construction of hydraulic barrier, solid barriers (clay); high pressure recharge.

Progress

- *Project staff (2JRF and 1 Project Assistant) has been recruited in March, 2017*
- *Procurement of field instruments (EC probe and water level recorders) is in progress*
- *Experimental model has been fabricated*
- *Field visits were conducted in Pre-monsoon and monsoon seasons, water samples were collected and are being analyzed for ions and isotopes (Fig. 2)*
- *An experimental model has been set up and work is in progress*

On the basis of the sampling and measurement of EC from 23 wells in pre-monsoon season, salinity was assessed in 2 blocks – Nagina and Firozepur Jhirka. EC varied between 661 µS/cm (Bhoond) to 55300 µS/cm (Nagla Shahpur) with an average of 9569 µS/cm and its variation is shown in Fig. 3. While, in monsoon season, EC of 29 samples varied between 628 µS/cm (Sheelkho) to 51000 µS/cm (Nagla Shahpur) with an average of 7345 µS/cm. Decline in EC values during monsoon may be due to the dilution effect.

Fig. 2: Field work for water sampling and DGPS survey.

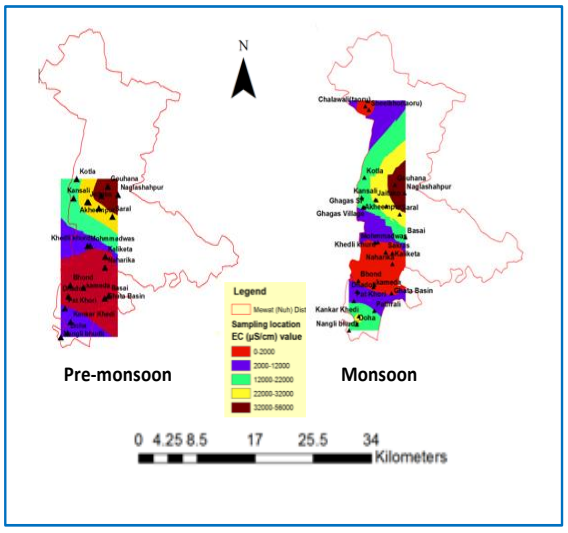


Fig. 3: EC variations during pre-monsoon and monsoon seasons.

Description of work planned:

- Setting up of experimental model
- Procurement of field instruments and their installation

Action plan:

Year	**Jan 2018 to Dec 2020** (Annexure 1)	**Remark**
2018 to 2020	Data collection on available groundwater studies including water table, water quality and other hydro-geological aspects in Mewat district Collection of water and soil samples to assess the salinity conditions Dissemination of outputs in a workshop/review meeting under the project	Report preparation as per Annexure 1

Study Benefits /Impact:

Problem of salinity to be identified

- Suggesting the suitable remedial measures

Specific linkages with Institutions: Irrigation Department, Haryana**,** IIT-Roorkee, Sehgal Foundation-Gurgaon

ACTIVITY SCHEDULE FOR THE BASELINE DATA COLLECTION AND ANALYSIS IN MEWAT, HARYANA (QUARTER WISE FROM JAN. 2018 TO DEC. 2020)

Item/Period quarterwise	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Data/literature collection												
Field Surveys												
Sample collection												
Analysis												
Data interpretation												
Suggestions/remedial measures												
Report writing/publications												

Data requirement & Expected source:

Hydro-meteorological data will be collected from the state departments.

IPR potential and issues : NIL

Major items of equipment needed: EC-probe for soil salinity and; water level and conductivity loggers.

9. PROJECT REFERENCE CODE: NIH/GWD/PDS/18-20

Title of the study : **Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin**

Type of study : Sponsored by NHP

Date of start (DOS) : January, 2018

Scheduled date of completion: December, 2020 (3 Years)

Location : Bhojpur District, Bihar (Figure 1)

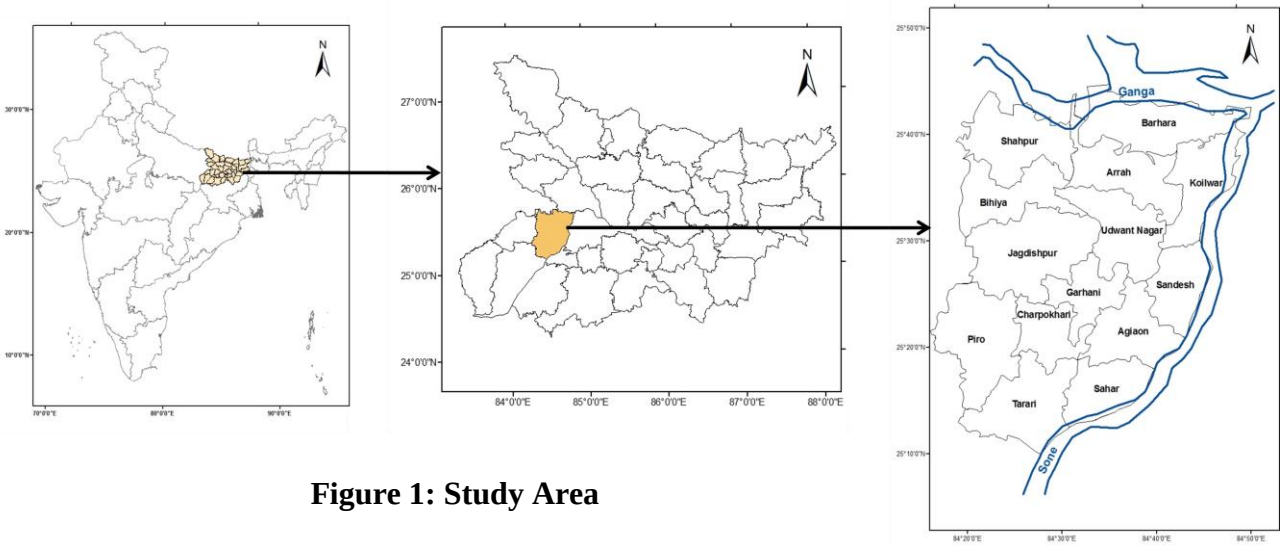


Figure 1: Study Area

Objectives:

- Determination of the spatio-temporal variation of arsenic along with other water quality parameters in groundwater.
- Delineation of arsenic safe zone for drinking water supply.
- Evaluation of the controls of regional and local hydrology on arsenic contamination through monitoring of contaminated aquifer.
- Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.
-

Statement of the problem:

Symptoms of chronic arsenic (As) from prolonged consumptions including skin lesions began early 1980 in residents of the lower Gangetic plains of West Bengal and adjoining Bangladesh. Subsequent research over the years reported that elevated As (relative to a 10 µg/L drinking-water standard of World Health Organization) is widely present in the potable groundwater, and as many as 15 million residents in West Bengal and 35 million residents in Bangladesh are at risk. This led to a huge number of hydro-geological studies in the lower Gangetic plain and delta for identification of the source and cause of As-contamination. But there is very little information available for central Ganges basin. The central Ganges basin comprises mainly Uttar Pradesh and Bihar is one of the largest fluvio-deltaic systems and most populous region\s of the India. In recent few decades, the increasing demand of groundwater for domestic, irrigation (round the year for food production) and industrial with the growing population rate led the extensive exploitations of fresh and potable groundwater. Now a day, there is problem of safe and potable groundwater in this region as most of the areas are contaminated by As.

In last decades, few investigators reported the elevated arsenic concentration and the process of the contamination in central Gangetic basin, but none seems to be studied the fate, transport and mobilization of the arsenic although initial estimates indicate that the poisoning might be widespread

and several million people may be at risk. The study is focused on the hydrogeological controls on arsenic mobilization, fate and transport in order to develop an understanding of arsenic release mechanism and demarcation of arsenic safe aquifer for Bhojpur district, Bihar (Central Ganges Basin). Inferences about the processes controlling the composition of groundwater will be evaluated from field measurements, statistical analyses and geochemical modelling. Column experiment will be performed to define the fate and contaminant transport; and conclusions would be made by combining the above mentioned techniques with geospatial analyses to identify the safe aquifer.

End Users/ Beneficiaries: Minor Water Resources Dept., Govt. of Bihar, Public Health Engineering Department, Govt. of Bihar, Ministry of drinking water and Sanitation, Govt. of India, NGOs, Local Community etc.

Objectives & Achievements

Determination of the spatio-temporal variation of arsenic along with other water quality parameters in groundwater.	First phase of WQ sampling has been completed during May, 2018 and chemical analysis has also been completed and interpretation of data is under progress.
Delineation of arsenic safe zone for drinking water supply.	Arsenic safe zone map will be prepared based on pre& post monsoon data after second phase of proposed sampling.
Evaluation of the controls of regional and local hydrology on arsenic contamination through monitoring of contaminated aquifer	Yet to start
Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.	Yet to start

Analysis and Results: Areas affected by arsenic in Bhojpur district have been identified through literature. To know the present status of As in the study area, sampling in the pre-monsoon, 2018 was done based on 4 x 4 km grid size (Figure 2). A total of 153 samples were collected from all fourteen blocks of the Bhojpur district. The chemical analyses have been completed and interpretation of data is under progress. The preliminary results revealed that the blocks situated along Ganga river are affected with As while blocks along Son river are not affected by the As. The Hydro-geological and geo-chemical study will be done to understand the behavior of aquifers in both the basin. Nest of piezometers will be installed in both the basin for continuous monitoring and the undisturbed soil sample will be collected for XRD & XRF analyses. Further, lab-scale column experiment will be performed to understand the fate and mobilization of Arsenic enriched groundwater.

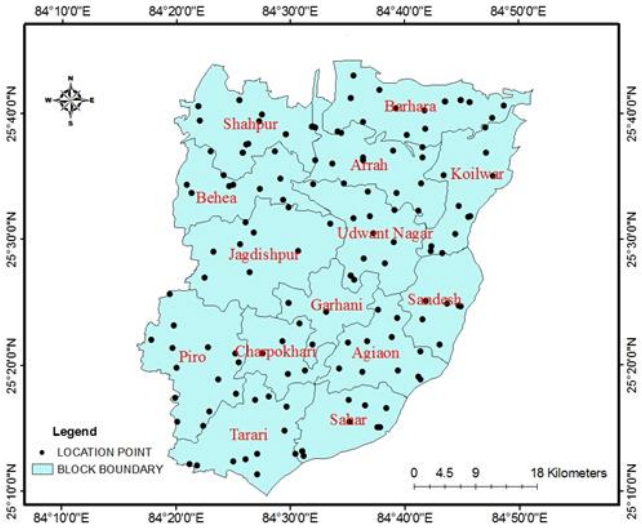


Figure2: Sampling location map of the study area.

10. PROJECT REFERENCE CODE: NIH/GWD/PDS/18-20

Title of the study: Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna basin up to Delhi

Study Team:

NIH Team:

Anupma Sharma (PI)

N.C Ghosh, Sanjay K. Jain, Archana Sarkar, M.K. Sharma, L.N. Thakural, Sumant Kumar, Suman Gurjar

Partner Organization:

Sanjeev Bansal (C.E, IWRD Haryana), Amod Kumar (Tech. Coord., GWD U.P), S.E. YBO, CWC New Delhi

Type of study: Special Study under Centre of Excellence in Hydrological Modelling (NHP)

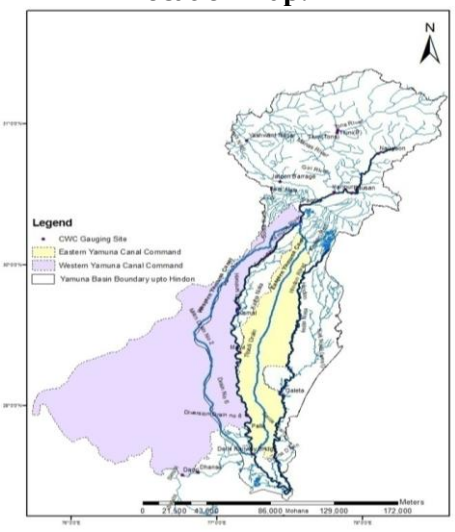
Date of start: April 2018

Duration of study: Four Years

Study objectives:

1. Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality.
2. Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons River.
3. Assessment of changes in baseflow contribution to River Yamuna.
4. Assessment of present and future water availability under alternate scenarios of climate change.
5. Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command.
6. Formulation of adaptation measures in the context of climate change.
7. Flood frequency analysis and flood plain mapping of River Yamuna
8. Assessment of anthropogenic activities on water quality.
9. Numerical modeling of groundwater recharge dynamics and impact of climate variability on renewable groundwater resources.
10. Roll out of technical know-how through training workshops for partner organizations.

Location map:



Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Data collection	Historical groundwater level data from State and Central Ground Water Depts., crop cultivation, meteorological data, relevant reports and maps, data collection during field visits, project partners.
Field experiments and Laboratory investigations	– One field visit in August for collection of water samples along Yamuna River – Chemical analysis of water samples in laboratory – Collection of soil samples and field, laboratory experiments
Database preparation	Geo-referencing and digitization of drainage network (including Himalayan terrain); Digitization of canal network in WYC Command and EYC Command; Watershed delineation of UYB upto confluence of Hindon with Yamuna; watershed delineation of Hindon River Basin; Geo-referencing and digitization of soil maps (1:50,000) initiated for area in UP, Haryana, Delhi, HP, Uttarakhand; LULC classification; Database preparation for SWAT, HEC-HMS, MODFLOW
Hydrological Modeling	Preliminary runs of SWAT and HEC-HMS for Upper Hindon Basin

Deliverables:

1) Application of various models pertaining to surface water hydrology, groundwater hydrology, basin planning, optimal water utilization and their inter-comparison in respect of UYB;

2) Evaluation of the impact of climate change, land use change and population growth on the water resources in UYB;

3) Assessment of changes in baseflow contribution to River Yamuna and strategies to enhance the contribution;

4) Evaluation of impact of climate variability on renewable groundwater resources;

5) Training Workshops for State Department officials of UP and Haryana.

11. PROJECT REFERENCE CODE: NIH/GWD/PDS/18-19

Title of the Project: Application for Conjunctive use management of SW & GW in Saryu Nahar Pariyojana, U.P. using "Strategic basin planning model for Ganga River Basin"

Project team:

a.	Project Investigator	Ms. Suman Gurjar
b.	Co- Project Investigator	Dr. Jyoti P Patil
c.	Investigator(s)	Dr. N C Ghosh
		Dr. Anupma Sharma
		Mr. Sumant Kumar
		Dr. Surjeet Singh

Type of study : Internal

Duration : April 2018-March 2019 (One Year)

Objectives:

- To understand the intricacy of the model for customization of the existing model for specific basin or sub-basin
- Impact assessment of developments / interventions by comparing water system indicators

Methodology:

Different models are combined in the river basin model to allow for the required integrated impact assessment. These models have been selected because they cover the dominant processes in the basin and allow for the assessment of the impact of future developments and interventions. The description of the hydrology has been divided over two different models: SPHY and Wflow. They are both fully distributed models working on a grid of square cells. SPHY is used to describe the hydrological process in the mountainous areas in the Himalaya. The rainfall-runoff processes for the non-mountainous part of the Ganga basin are simulated with the Wflow model. This is a general purpose hydrological model. The river discharges calculated by the SPHY model for the Himalayas are used as upstream boundaries for the Wflow model. Groundwater movement is simulated by the iMOD-MODFLOW model. The model uses the same calculation grid as the Wflow model. It is only applied to the alluvial part of the basin. Groundwater recharge is obtained from Wflow for the non-irrigated areas and from RIBASIM for the irrigated areas. RIBASIM also provides the data on water abstractions and river discharge. Based on river discharge, river water levels are derived and used for the calculation of the flux between the river and the groundwater. The water resources model RIBASIM describes the management and use of water. Its hydrological input is derived from the river discharges calculated by Wflow. RIBASIM uses a schematization of links and nodes to describe the flow of water in the rivers, the storage in reservoirs, the diversion into canals and the use and return flow by different functions.

Progress made so far:

- Explored the intricacy of each model used in the integrated system for "Strategic Basin planning of Ganga River Basin"
- Since the system was kept on updating till the final version received, the final version is not working properly and there are issues in running and customizing the network schematization, trying to get the solution with the consultant team.
- If these issues are resolved this would be a wonderful tool to use for Strategic basin planning for Ganga basin

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sudhir Kumar	Scientist G & Head
2	Dr. S D Khobragade	Scientist F
3	Dr. M S Rao	Scientist E
4	Sri S K Verma	Scientist D
5	Sri Rajeev Gupta	SRA
6	Sri U K Singh	SRA
7	Sri V K Agarwal	SRA
8	Sri. Raju Juyal	RA
9	Sri Vishal Gupta	RA

Work Programme for 2018-19

INTERNAL STUDIES:

SPONSORED PROJECTS: WORK PROGRAMME FOR 2018-2019

SN.	Project Title	Study Team	Duration	Remarks
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	Suhas Khobragade (PI) Sudhir Kumar Rajesh Singh M. Arora R. J. Thayyen S.K. Verma	5 Years (04/16-03/21)	NMSHE Project
2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar	3 Years (06/16 -05/19)	Project with GBPIHE
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	M. Someshwar Rao (PI) Sudhir Kumar C.K. Jain	3 Years (06/16 -05/19)	IAEA under CRP
4.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) C.K. Jain M. Someshwar Rao	3 ½ year (1/18 – 6/21)	PDS under NHP
5.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M. Someshwar (PI), Sudhir Kumar, A. R. Senthil Kumar V. S.Jeyakanthan	3 ½ year (1/18 – 6/21)	PDS under NHP
6.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Suhas Khobragade Sudhir Kumar	3 Years (1/18 – 12/20)	PDS under NHP
7	Climate resilient conservation & data management of spring water sources by strengthening monitoring mechanisms in drought prone areas of Sikkim	Sudhir Kumar Suhas Khobragade	6 months (11/18 – 04/19)	UNDP-India (**New Project**)

CONSULTANCY PROJECTS:

SN	Project	Sponsored by	Duration	Status
1	Hydro-geological study for Gadarwara super thermal power project, Madhya Pradesh	NTPC	07/15-06/16	Completed
2	Identification of source of seepage in the villages surrounding the Ash Dykes of Barh STPP	NTPC	3 months 03/17 – 06/17	Draft Final Report Submitted

3	Conservation, remedial and management measures for Nainital Lake	Uttarakhand Irrigation Department	9 months (12/17 – 08/18)	Draft Final Report Submitted
4	Isotopic and Chemical Analysis of groundwater from exploratory wells installed along paleochannel of Saraswati River Haryana State	WAPCOS	4 months (10/17-02/18)	Draft Final Report Submitted
5	Hydro-geological study for Darlipali STPP, Odisha	NTPC	9 months (09/15-07/16)	Draft Final Report Submitted
6	Hydro-geological and isotopic study for 1x660 MW Harduaganj PTS, UP	UPRVUNL	12 months (11/15-10/16)	Draft Report submitted
7	Hydrogeological Studies for Dewatering of Jhamarkotra Mines	RSMML	5 years (11/16 – 10/21)	Continuing
8	Pollution source identification using stable isotopic investigations in and around chemical division, GIL, Nagda, MP	NEERI	3 ½ years (10/18 - 03/22)	New Project

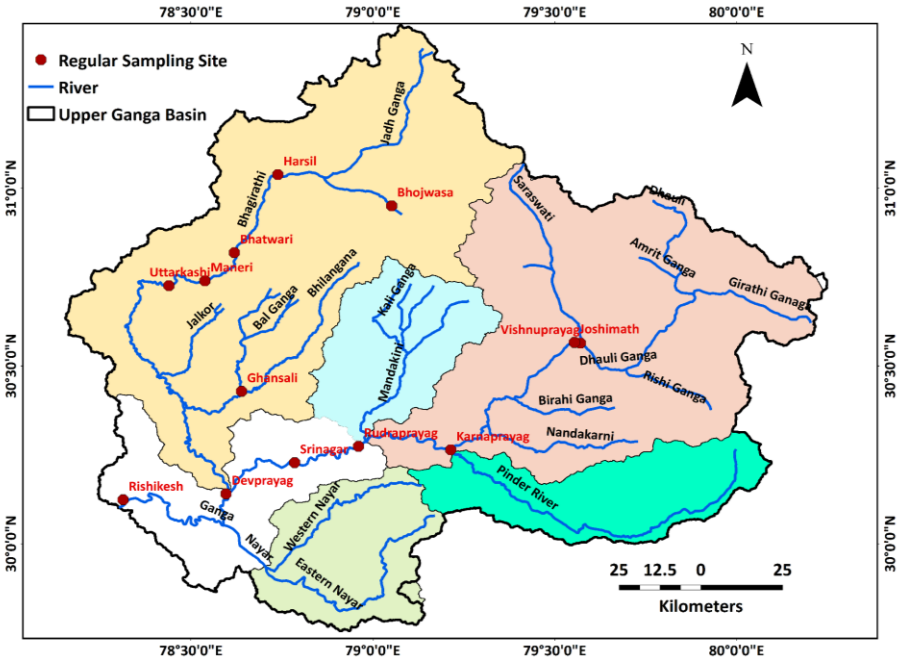
Sponsored Projects:

1. PROJECT REFERENCE CODE: NIH/HID/SPON/12-15

Title of the Study:	**Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques**
Study Team:	Dr. Suhas Khobragade (P.I.); Dr. Sudhir Kumar, Dr. Rajesh Singh; Dr. M. Arora, Dr. R. J. Thayyen, and Er. S. K. Verma
Type of Study	**S**ponsored (under NMSHE Project)
Collaborating agencies:	WIHG and HNB Garhwal University
Funding Agency	DST, Govt. of India
Budget	Rs. 177.228 lakh
Date of Start:	April 2016
Date of Completion	March 2021

Study Area

Study area encompasses Ganga River Basin upto Rishikesh. The two main tributary joins at Devprayag and combined flow is known as River Ganga. River Ganga and tributaries are fed by snow/glacier Melt during the lean flow period of summer months.



Study Objectives:

- **a)** Isotopic characterization of precipitation and identification of sources of vapor
- **b)** Runoff generation processes in headwater region of Ganga using isotope and modeling
- **c)** Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries.
- **d)** Contribution of transient groundwater and its role in sustainable flow of Ganga.
- **e)** Groundwater dynamics in mountainous area including identification of recharge sources and zones of major springs

Statement of the Problem:

The Himalayan mountain system is the source of one of the world's largest supplies of fresh water, which is under threat due to serious environmental degradation and climate change. Continuing

climate change is predicted to lead to major changes in the strength and timing of the Asian monsoon, inner Asian high pressure systems, and winter westerlies – the main systems affecting the climate of the Himalayan region. The impacts on river flows, groundwater recharge, natural hazards, and the ecosystem, as well as on people and their livelihoods, could be dramatic affected, although not the same in terms of rate, intensity, or direction in all parts of the region. Therefore, a thorough understanding of hydrological processes operating Ganga River Basin is a fundamental requirement.

Action Plan: (2016-2021)

Activities	1st Yr		2nd Yr		3rd Yr		4th Yr		5th Yr	
	I	II	I	II	I	II	I	II	I	II
Appointment of Project staff	√									
Procurement of instruments	√	√								
Literature Collection	√	√	√							
Sample collection and analysis of sample for stable and radio isotope		√	√	√	√	√	√	√		
Compilation of data, interpretation and analysis					√	√	√	√	√	
Organisation of training course and workshop				√		√		√		
Preparation of final report										√

Objectives vis-à-vis Achievements

Objectives	Achievements
Isotopic characterization of precipitation and identification of sources of vapor	Sampling of precipitation from different altitudes has been carried out and analysis is in progress Altitude effect in Alaknanda basin established
Runoff generation processes in headwater region of Ganga using isotope and modeling	Water samples from river, springs, snow and glacier melt have been collected for isotopic analysis. Analysis is under progress Spatial and temporal variation of isotopic signatures of river water samples for 9 stations Snow cover variation in different months during 2005-216 using MODIS data Preliminary analysis of variation in water chemistry of groundwater/springs
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	To cover the spatial and temporal variability, 9 sites from upstream to downstream have been developed for regular sampling from both Bhagirathi and Alaknanda. Detailed spatial and temporal variation of stable isotopes and tritium characteristics of Satopanth Glacier (i.e. snow and ice) has been carried out.
Contribution of transient groundwater and its role in sustainable flow of Ganga	Samples collected for tritium analysis of GW, river and precipitation under laboratory analysis
Groundwater dynamics in mountainous area including identification of recharge sources and zones of major springs	Few springs have been selected for detailed isotopic investigation in order to in order to determine the recharge zone.

Progress of Work/Results and Analysis

- 8 number of field visit were have been carried out so far including 3 in Satopanth glacier (i.e. September-2016, December-2016, February -2017, June- 2017, October- 2017, February-2018, June 2018, October, 2018).
- Total 21 sampling stations established (13 by NIH, 6 by WIHG, 2 by HNBGU) for sampling of rainfall, river, springs, snow/ice, groundwater) for stable isotope, tritium &chemistry. Rainfall data are also being collected.
- 13 data observes have been appointed for regular monitoring at sampling sites
- During field visits sample from springs and hand pumps are additionally collected

Details of samples collected and analysed:

Parameter	Samples collected	Samples analysed
Stable isotope	8000	5819
Tritium	750	147
Chemistry	482	274

Following analysis has been carried out so far:

- Spatial and temporal variation of isotopic signatures of river water samples for 9 stations
- Preliminary analysis of contribution of different tributaries in Alaknanda and Bhagirathi rivers
- Altitude effect for Alaknanda basin established
- Preliminary analysis of variation in water chemistry of groundwater/springs
- Detailed spatial and temporal variation of stable isotopes and tritium characteristics of Shatopanth Glacier (i.e. snow and ice)
- Snow cover variation in different months during 2005-2016 using MODIS data (by WIHG)

Important results obtained so far:

i) Whiskers and Box plot of δ^{18}Oat different location shows systematic pattern in Bhagirathi river basin, however the pattern is not systematic at Alaknanda basin due to contribution from major tributaries.

ii) Isotopic analysis of melt water shows different sources of vapour at Bhojwasa and Satopanth.

iii) Analysis of isotopic characteristics of river water at Bhijwasa shows that there is isotopic deplition from June to Mid Aug due to rainfall after which there is slight enrichment. Rainfall amount effect is clearly visible.

iv) Isotopic analysis of melt water at Satopanth Glacier shows isotopic deplition from June to Sep. Snow and Ice samples also have wide isotopic variation.

v) Spring located on either side of Alaknanda river at Srinagar and Chauras shows markedly differet isotopic characterstics.

vi) There is a spatial pattern in altitide effect, may be due to orographic effect

vii) Hot springs also showing depleted values then the other Groundwater samples.

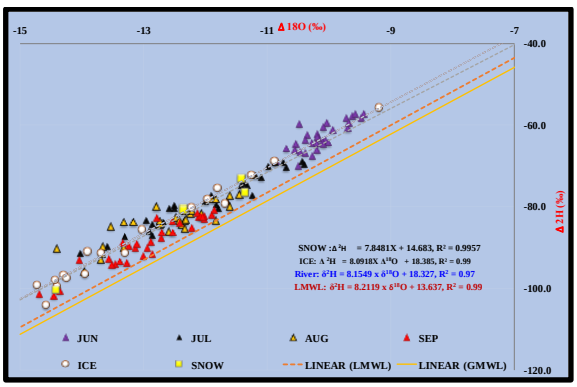


Fig. Isotopic characteristics of melt water at Satopanth Glacier snout during ablation period 2017

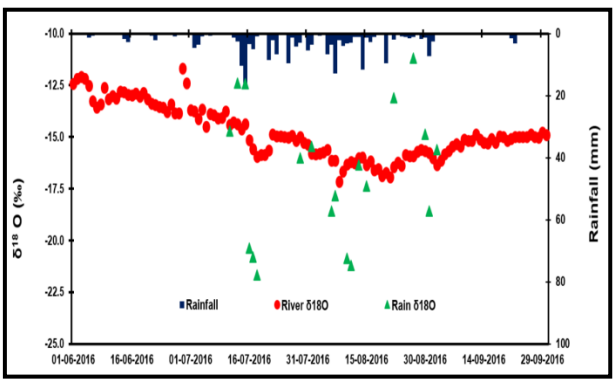


Fig. Isotopic characteristics of river (Bhagirathi) and rain water during ablation period in 2016 at Bhojawasa

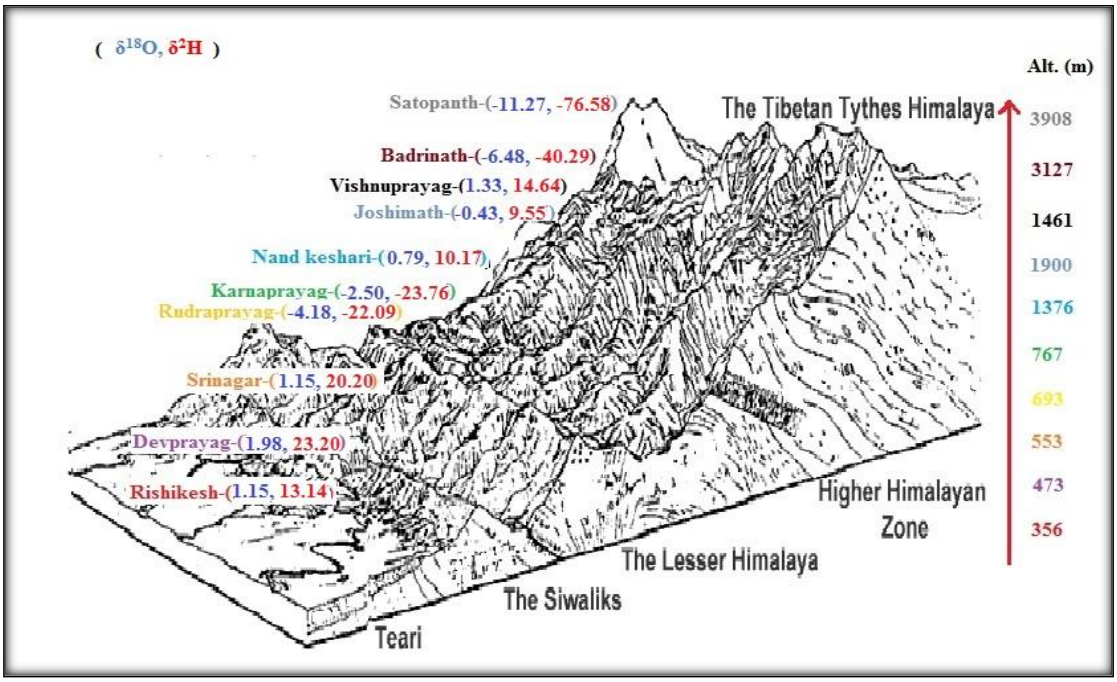


Fig.: Altitudinal variation in isotopic characteristics in the upper Ganga basin

Future Plan

- Preparation of detailed geomorphological map
- Measurement of Radon isotope
- Estimation of contribution of different tributaries in Alaknanda and Bhagirathi River
- Estimation of snow and glacier melt contribution in Alaknanda and Bhagirathi river
- Estimation of Recharge zones of springs.

Detailed results shall be presented during the working group meeting.

2. PROJECT REFERENCE CODE: NIH/HID/SPON/16-19/GBPIHED

Title of the Study:	**Rejuvenation of springs and spring-fed streams in Mid-Himalayan Basin using spring sanctuary concept**
Study Team:	Dr Sudhir Kumar, Sc. 'G' (PI)
Type of Study	**S**ponsored
Funding Agency	G B Pant National Institute of Himalayan Environment and Sustainable Development (GBNIHESD), Almora under NMHS
Budget	Rs. 15.00 Lakhs
Duration:	3 years
Date of Start:	01.04.2016
Date of Completion	31.03.2019

Objectives and Scope of Work:

Environmental Isotope application for study of regional scale altitude effect and recharge zone identification of springs in Lesser Himalaya and Terai regions in Garhwal and Kumaon

Study Area

The study area of Garhwal region of Uttarakhand is a part of Paschimi Nayar sub-basin (**Figure 1**) having highest elevation of 2143m to a lowest elevation of 700m.The study area is bounded between latitudes 30°00' N and 30°8' N and longitudes 78°45'E and 78°50'E. Geologically the study area falls in Lesser Himalaya, which ranges between 700-to-2500m high, and is represented by Pauri Phyllite and Khirsu Quartzite members of the Maithana formation in the Dudatoli Group.

Analysis and Results

Total 250 water samples, from springs, rainfall and air moisture have been collected from a watershed in Pauri District of Uttarakhand.

The plot of δD and $\delta^{18}O$ from 61 rainfall weekly integrated samples at four different locations within the study area is presented in Figure 2. The regression line drawn between $\delta^{18}O$ - δ D defines the monsoon period local meteoric water line (LMWL) and is represented by the equation $\delta D=7.986\ \delta^{18}O +9.976$. The LMWL matches quite well with the regional meteoric water line developed for western Himalaya $\delta D=7.95\ \delta^{18}O +11.51$ by Kumar et al. 2010.

d-excess also highlights the high temporal and spatial variability and indicative of recycled/re-evaporated source. The weekly to biweekly samples from the stream (outlet location) and spring falls on the LMWL indicative of common source of origin, i.e. by rainfall recharge.

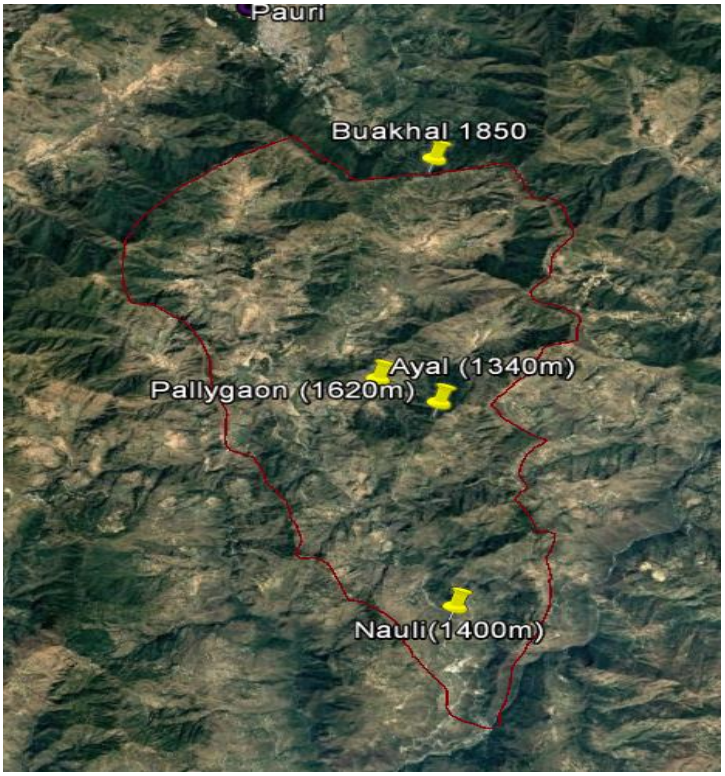


Figure 1: Map of Study Area

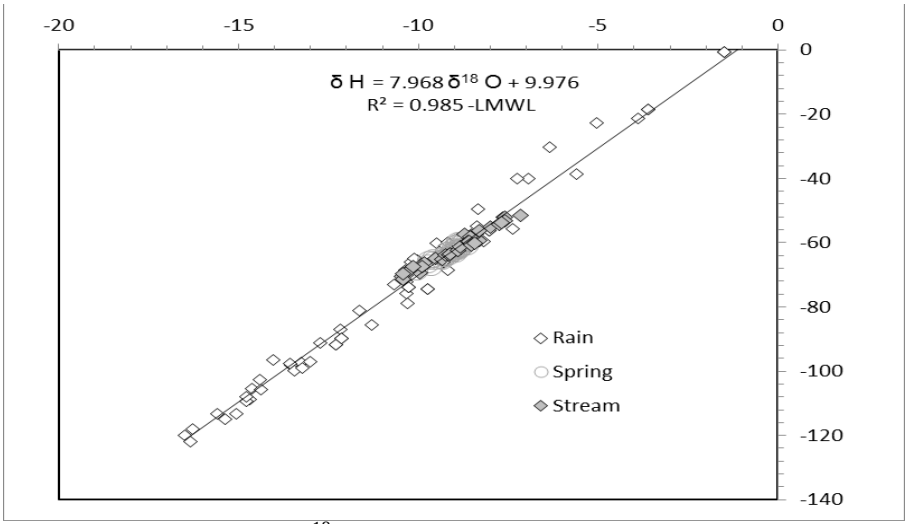


Figure 2: $\delta^{18}O$ – δD diagram for the study area

Future Plan:

- Interpretation of data and report writing.

3. PROJECT REFERENCE CODE: NIH/HID/SPON/16-19/IAEA

Title of the Study:	**Dating vary old groundwaters of deeper aquifers in Ganga Plains, India**
Study Team:	Dr M. Someshwar Rao Sc. 'E'(PI), Dr Sudhir Kumar, Sc. 'G'
Type of Study	**S**ponsored
Funding Agency	IAEA, Vienna (Austria)
Budget	18,000/- Euros
Duration:	3 years
Date of Start:	01.10.2016
Date of Completion	30.09.2019

The details are combined with new project "**Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin" (Project No. *NIH-26_2017_62).***

4. PROJECT REFERENCE CODE: NIH-26_2017_62

Title of the Study: Chemical and Isotopic Investigation of Groundwater in Deep Aquifers of Middle Ganga Basin, India

Study Group: Dr. Sudhir Kumar (PI), Dr.C.K.Jain, Dr.M. Someshwar Rao

Collaborating Institution: CGWB (MER, Patna & NER, Lucknow)

Funding Agency: PDS-NHP

Budget: Rs. 55.60 Lakhs

Nature of Study: Applied Research

Date of start: Jan, 2018

Scheduled date of completion: May, 2021

Duration of the Study: $3^{1}/_{2}$ Years

Study area: The study area is a part of Ganga basin falling in the alluvial plains of Uttar Pradesh in the region enclosed between the rivers Ghaghra and Yamuna of the Middle Ganga Basin. The Ganga basin is bounded in the north by the Himalayan frontal fault and by the peninsular fringe fault in the south. The alluvium thickness of basin increases from south to north and the basin slopes towards the southeast. From north to south, the Ganga Plain shows four distinct regions: (i) high permeable Bhabhar zone (10-30km wide) (ii) low permeable Terai zone (10-50 km wide and usually spotted with springs, ponds & small sandy rivers) (iii) the central Ganga plain (occupied by the main Ganga river, its flood plain and the network of Ganga canal) (iv) the marginal alluvium plains of low groundwater potential with aquifer thickness less than 200m.

Objectives:

i. To identify the various aquifers present in Upper / Middle Ganga Plains.
ii. To identify the source of recharge of deep aquifers
iii. To assess interaction of deep aquifer with overlying aquifers.
iv. Water quality of deep aquifer
v. Sustainability of deep aquifer for its exploration and future use

Statement of the Problem: Growing demand of food grain, speedy economic growth, agricultural droughts, climate change etc., are accelerating the water demand and thereby causing the groundwater depletion at an alarming rate. Today, in most part of the country the shallow aquifers are either dried up or nearly un-usable for economic use.

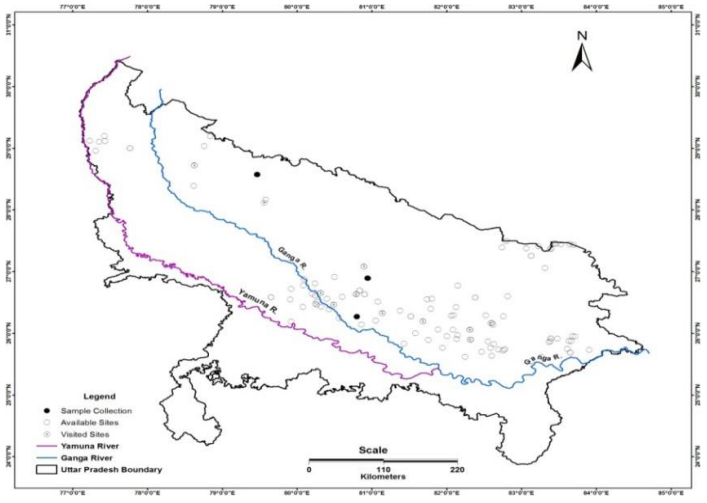


Figure 1: Study area map. Locations of deep wells (shown as hollow circles) in the study

Even the Ganga basin, one of the largest groundwater multi-aquifer systems in the world is witnessing the groundwater depletion and contamination problem. The Indo-Gangetic basin occupies nearly 26.2% of the total geographical area of India. Recent studies carried out by National Institute of Hydrology in support with IAEA, Vienna has revealed that deep groundwater of Ganga basin are older than 1,00,000 years, meaning that groundwater in deeper aquifer is relatively static in nature and therefore it is not accounted in the groundwater balance computation by CGWB, Govt of India. With the progressive water demand as the groundwater withdrawn is going to deeper depths, the deeper aquifers are coming under the influence of anthropogenic activities of groundwater depletion and contamination. Huge amount of groundwater withdrawal for irrigation is taking place all across the Ganga basin leading to dewatering of its shallow & middle aquifers and to small quantity from the deeper aquifers. It is not known what the composition of old is and modern groundwater in the total withdrawal. Shallow water table fluctuation data does not provide any clue to this problem. Isotopes helps trace groundwater, flow pattern and age. The present project is intended to investigate the quasi-static nature of deep aquifers of Ganga basin, their recharge sources, the pristine groundwater quality and sustainability for its use for the future.

Methodology:

Water sampling: In the study region, deep tube-wells of CGWB/ State owned wells are being examined and the selected for groundwater sampling. Water samples from surface water sources (rain, river canal etc) are also being sampled to fingerprint the recharging groundwater source.

Measurements: Physico-chemical parameters, major ions & trace metals concentration, bacteriological analysis, stable isotopes ($\delta^{18}O$, δD), tritium (^{3}H) content & ^{222}Rn concentration will be measured using the experimental facility available at NIH, Roorkee. For dating old samples, radiocarbon measurement facility will be developed in NIH Support of IAEA, Vienna will be taken for measurement of noble gas and for dating using $^{3}H/^{3}He$ and ^{36}Cl techniques.

Interpretation: Data will be interpreted in terms of its formation (recharge conditions & flow dynamics), turn over time etc. Noble gas data will be used to estimate the recharging source water temperature.

Knowledge dissemination: Annual/ interim reports, publications, thematic maps etc., will be prepared. The knowledge gained will be disseminated through organizing training programme, mass awareness programme etc.

Work Elements & Time Line:

Sl. No	Work Element	1st Yr				2nd Yr				3rd Yr				4th Yr	
		1	2	3	4	1	2	3	4	1	2	3	4	1	2
1	Appointment of project staff	✓													
2	Procurement of items, data & software				✓	✓	✓								
3	Collection of available literature, data from CGWB and State Groundwater Departments and identification of wells and aquifers to be tapped for groundwater sampling		✓	✓	✓	✓	✓	✓							
4	Preparation of thematic maps				✓	✓	✓	✓	✓	✓					
5	Water sampling for chemical, stable isotope analysis, ^{222}Rn, radiometric dating(^{3}H, ^{14}C, $^{3}H/^{3}He$) and noble gas analysis			✓	✓	✓		✓		✓		✓			
6	Development of radiocarbon dating line, procurement of standards from IAEA, Vienna, for calibration of the system			✓	✓	✓	✓	✓							
7	Chemical, bacteriological and isotopic analysis of water samples at NIH,					✓	✓	✓	✓	✓	✓				

	Roorkee and transport of samples to IAEA, Vienna for analysis														
8	Noble gas & $^{3}H/^{3}He$ analysis at IAEA, Vienna							✓	✓	✓	✓				
9	Data analysis & interpretation									✓	✓	✓	✓	✓	
10	Trainings and mass awareness programme								✓		✓			✓	
11	Interim reports & Final report				✓				✓					✓	✓

Achievement during last Qr_1 & Qr_2, 2018:

Objectives	Achievement
Appointment of project staff	Appointed
Procurement of items	Procurement processes initiated
Collection of available literature, data from CGWB and UPGWD and BGWD, identification of wells and aquifers for groundwater sampling	Data from CGWB, Lucknow collected
Development of radiocarbon dating line, procurement of standards from IAEA, Vienna, calibration of the system	Valves for radio-carbon line procured. Visited the AMS 14C dating facility at PRL, Ahmedabad.
Data collection	Lithological data of deep borewells from Central Ground Water Board, Lucknow has been collected. A field visit was made in the month of April, 2018 to physically verify the availability and condition of borewells drilled by CGWB.
Sample Collection	For noble gas analysis, 48 nos of copper tubes have been received from IAEA, Vienna. After fieldwork, samples will be sent to IAEA, Vienna for radiocarbon and noble gas analysis.
Field work	Wells and cluster of wells are identified in the study area (Figure 2). Four samples were sampled during the fieldwork for isotopic analysis. Results will be discussed in the working group.

Future Plan: Work Plan & Activity Chart for the period Oct 2018-Sept 2019

Sl. No.	**Work Element**	**2018**	**2019**		
		Oct-Dec	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**
1	Fieldwork to collect deep & shallow groundwater for isotopic ($\delta^{18}O$, δD, ^{3}H, ^{14}C, ^{36}Cl, Radon and noble gas) & water quality analysis.	✓	✓	✓	✓
2	Development of ^{14}C line, purchase of instrumental accessories, standards and calibration of ^{14}C line	✓	✓		
3	Organization of training programme		✓		
4	First year interim report		✓	✓	

5. PROJECT REFERENCE CODE: NHP-NIH-22_2017_38

Title of the Study: Integrated Study on Groundwater Dynamics in the Coastal Aquifers of West Bengal for Sustainable Groundwater Management

Study Group: Dr.M. Someshwar Rao (PI), Sudhir Kumar, Dr. A. R. Senthil Kumar, Dr. V. S.Jeyakanthan

Collaborating Scientist/Institutions: Er.Subrata Halder, Exe. Eng, State Water Investigation Directorate (SWID), Dept of Water Resou. Invest. & Develop. (DWRI&D), Govt. of West Bengal

Type of Study: NHP - PDS

Budget: Rs 51.0 Lakhs

Nature of Study: Applied Research

Date of start: January, 2018

Scheduled date of completion: July, 2021

Duration of the Study: $3^{1}/_{2}$ Years

Study area: The study area covers the coastal region of West Bengal falling in the districts of Purba Medinipur, South 24 Parganas and North 24 Pargana. Coastal zone occupies important position in West Bengal. It covers an area of 9630 km^2 and it extends over the coastal length 220 km. The important geomorphic features of the coastal zone includes estuarine plains, deltaic region, levees, sand beaches, saltpans & salt marshes, forest cover, islands separated by tidal channels, creeks, mangrove forest and mud flats. The coastal zone is getting invaded due to expansion of industrial establishments viz; petrochemical, thermal power, steel, automobile, transport, ship building/breaking, deep water port, tourism, coastal aquaculture, etc.

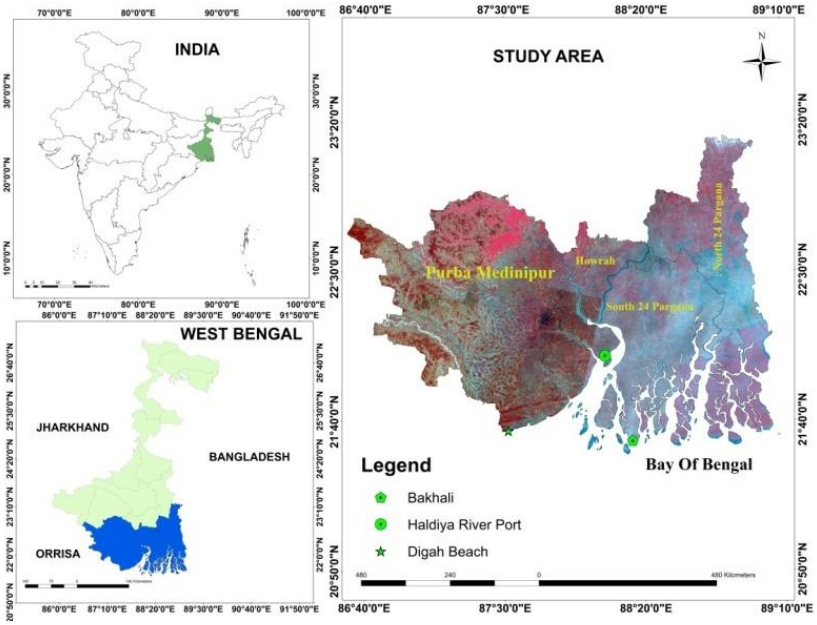


Figure 1: Study area map

Objectives:

1) Assessment of spatio-temporal variables (sea level change, variation in groundwater levels, rainfall trend etc) influencing dynamics between seawater & groundwater interface using archival data
2) Spatio-temporal variation map of fresh water – saline water interface from the present observations.
3) Identification of source of salinity in groundwater
4) Identification of groundwater recharges sources & flow pattern and temporal and spatial pattern of excess surface water available in the coastal zone for artificial recharge measures

5) Management measures for safe & sustainable coastal groundwater use

Statement of the Problem: Approximately, 22.74 million people residing in the 59 blocks of the three coastal districts of West Bengal viz., South24 Parganas, North 24 Parganas and Purba Medinipur are in the range of seawater-groundwater interaction zone and under the threat of changing groundwater salinity. The structure of the saline–freshwater interface is important in the assessment of (i) diminishing rate of fresh groundwater reserve (ii) fresh groundwater discharge to sea (iii) salt enrichment in the inland aquifers and (iv) pollution discharge into the marine environment. Isotopic & chemical tracer techniques are field based methods extensively used for investigating the dynamic state of the freshwater - saline water interface. In the present study, saline/freshwater interface and flow regime of coastal groundwater will be investigated using isotopic & chemical techniques in conjunction with the conventional data. The project involves investigation of seasonal variation in the seawater groundwater interface and the responsible factors affecting this dynamic condition in the coastal zone of West Bengal. The results from field based data and modeling exercise will be attempted to develop management strategies (protocol for groundwater withdrawal, artificial recharge measures etc) for long term groundwater sustainability. The project is undertaken jointly with Government of West Bengal. The West Bengal Govt is installing large number of piezometers in the coastal region under National Hydrology Project. The interpretation of the data will be done jointly. With the involvement of State Officers, the knowledge of the study can be more effectively disseminated to the stake holders in their native language.

Methodology:

1) Preparation of review/status report on seawater intrusion (SI) and submarine groundwater discharge (SGD)
2) Collection and analysis of archival data influencing SI & SGD processes. This include collection archival data on change in sea-level, groundwater level data, rainfall data, river stage etc. and, their trend analysis.
3) **Field work & sample analysis:** Water samples will be collected at uniform frequency for isotopic and chemical analysis (stable isotope, dating, major ion, radon concentration).
4) **Data synthesis**: Field data and archival data will be used to generate thematic layers on GIS environment. This will provide vulnerable zones for salinization, area-experiencing SGD; influence of natural and anthropogenic factors in SI/SGD etc. DEM, optical dataset, land use, soil texture, drainage, groundwater levels (pre & post monsoon), and water quality data will be used for preparing thematic maps. Data will be analyzed to estimate run-off excess for AR- measures and in controlling SI process.
5) **Management Measures:** Data will be interpreted in terms of augmentation of SGD and control over GW salinization.
6) **End use:** (i) Identification of recharge areas, adoptive management strategies for AR-measures, groundwater withdrawal strategies, knowledge dissemination jointly with State Department through mass interactive programmes and brochures in local languages (ii) Review report (iii) DPR will be prepared for field implementable programme.

Work Element & Time Line:

S. N.	Activity	2018				2019				2020				2021	
		1	2	3	4	1	2	3	4	1	2	3	4	1	2
1	Appointment of project staff	✓													
2	Literature survey writing of Status report, review report & interim report			✓	✓	✓	✓	✓		✓	✓	✓	✓		
3	Procurement of items (Datasets, Maps, Instruments, Software)	✓			✓										
4	Database preparation and preparation of various thematic maps		✓	✓											
5	Field survey for water sampling, sample & data		✓		✓	✓		✓	✓		✓	✓	✓		

	collection and monitoring of hydro-meteorological data														
6	Stable isotope, water quality, radon measurement and tritium analysis				✓	✓	✓	✓	✓	✓	✓	✓	✓		
7	Preparing of thematic maps, data analysis & modeling, identification of recharge areas, drawing inferences on coastal hydrological processes and suggesting adoptive measures to improve the groundwater conditions							✓	✓	✓	✓	✓	✓	✓	
8	Publications									✓	✓	✓	✓		
9	Writing of Status report, review report & interim report			✓		✓	✓	✓		✓	✓	✓	✓		
10	Trainings and mass awareness programme					✓			✓		✓		✓	✓	
11	Final report													✓	✓

Work accomplished during the last nine months (Jan-Sept, 2018):

Objectives	**Achievement**
Appointment of project staff	Appointed
Literature Survey	Literature collected related to seawater intrusion in coastal area (Global and regional both), geology and hydrogeology of study area and remote sensing.
Database preparation	Downloaded Data-ALOS PALSAR DEM
Thematic Maps	Drainage maps, Geomorphology, Salt affected area and Water logged area, Soil moisture.
Data collection	Groundwater quality data from West Bengal Pollution Control Board, relevant reports and maps, Sea level data.
Piezometers installation	1. Identified suitable locations for more than 100 cluster piezometers (@3 piezometers per cluster intercepted at different depth up to 100 m, 200 m, 300 m per cluster) in 59 coastal blocks of West Bengal 2. Drilling and installation of 18 cluster Piezometers in 9 coastal blocks of Purba Medinipur District has been completed by SWID, WB.
Procurement of items	Two instruments for measuring radon in groundwater have been sent to USA for repair and calibration. The instruments are expected to be delivered to NIH very soon.

Future Plan: Work Plan & Activity Chart for the next 1 year (Oct 2018-Sept 2019)

SN	Work Element	2018	2019		
		Oct-Dec	Jan-Mar	April-Jun	July-Sept
1	Data procurement from NRSC, NDC, S&LUSI	✓			
2	Preparation of thematic maps	✓			
2	Analysis from LISS IV dataset	✓	✓	✓	
3	Interim Report	✓	✓		
4	Field survey for water sampling, radon measurement, Stable isotope, water quality, and tritium analysis	✓	✓	✓	✓
5	Runoff Estimation (using rainfall data, drainage map, soil map, DEM and land use land cover, River Discharge)		✓	✓	✓
6	Data Check and Validation				✓
7	Training programme		✓		

6. PROJECT REFERENCE CODE: NIH/HID/NHP/2018-21/1

Title of the Project:	**Development of a Comprehensive Plan for Conservation and Sustainable Management of Bhimtal and Naukuchiatal Lakes, Uttarakhand**
Project team:	S.D. Khobragade **(PI),** Sudhir Kumar, C. K. Jain and team from IRI, Roorkee
Collaborating agency:	**IRI, Roorkee**
Type of Study:	**Study under NHP**
Duration:	**3 years**
Date of Start:	**1st January, 2018**
Date of Completion:	**31st December, 2020**
Budget :	**36 Lakh**

Statement of Problem:

The lake region of Kumaon Himalayas comprising a number of lakes such as Khurpatal, Nainital, Sattal, Nal Damyanti Tal, Bhimtal and Naukuchiatal is known for its biodiversity and socio-economic value. The catchment areas of the lakes is a hot spot of biodiversity with about 500 species of resident and migratory birds, 20 species of mammals, over 525 species of butterflies and over 11,000 species of moths, beetles, bugs and other insects. Bhimtal and Naukuchiatal lakes, have traditionally been used as a primary sources of drinking and irrigation water for the Kumaon region. However, anthropogenic disturbances in the lake catchment over the last few decades, are threatening the existence of the lakes with problems such as heavy sedimentation, pollution etc. As such, the lakes need a comprehensive conservation plan. The lakes have been identified for conservation under the National Lake Conservation Plan (NLCP) of the Government of India. However, conservation plan for any lake needs proper understanding of the hydrology of the lake ecosystem. Many studies have been reported on the Bhimtal and Naukuchiatal lakes on water quality, ecology and sedimentation but there are no reported hydrological studies. The lakes are owned by the Irrigation department, Uttarakhand who want to rejuvenate the lakes, particularly the Bhimtal and Naukuchiatal, as these are prime sources of drinking water.

Keeping in view the expertise on lake hydrology available at NIH, Roorkee it was felt to undertake collaborative studies with the institute related to detailed hydrological investigation of the lakes including water balance, sedimentation and water quality and to integrate the various components along with the available information to develop a comprehensive conservation plan for the two lakes.

Objectives:

- **i)** To assess the seasonal water availability of the lakes and assess its adequacy in meeting future demands
- **ii)** To assess the water quality of the lakes and possible causes of its degradation
- **iii)** To estimate sedimentation rate and expected life of the lake
- **iv)** To suggest a comprehensive conservation and sustainable management plan for the lakes

Brief Methodology

i) Ground surveys and field surveys including the bathymetric survey
ii) Collection, processing and analysis of the available data
iii) Generation of additional required data.
iv) Field investigations and field surveys
v) Sample collection and laboratory analysis
vi) Data interpretation and analysis

For the assessment of the water balance components, the inflow and outflow and the water level in the lake would be monitored. Lake evaporation would be estimated using Penman Method. Groundwater-lake interaction will be studied using conventional technique and isotope technique. Ground water levels in the lake would be monitored Morphmetric characterization and morphological analysis would be carried out using remote sensing and GIS techniques. Lake sedimentation would be studied using bathymetric survey method or isotope techniques. Water quality status of the lake would be assessed from the water quality data of the lake. Water and sediment samples from the lake would be collected and analyzed in the laboratory.

Achèvements vis-à-vis Objectives

Objectives	**Achievements**
To assess the seasonal water availability of the lakes and assess its adequacy in meeting future demands	Rainfall and water level data have been collected. 3 ORG installed for rainfall samples and data
To assess the water quality of the lakes and possible causes of its degradation	Water quality samples have been collected from both the lakes. Analysis is in progress.
To estimate sedimentation rate and expected life of the lake	Bathymetric survey have been carried out for both the lakes
To suggest a comprehensive plan for conservation and sustainable management of the lakes	--

Progress Report/Results and Analysis

- Filed visits undertaken during August and September, 2018. Water quality and isotope sampling completed for monsoon period.
- About 30 samples have been collected for isotope and WQ analysis.
-
- Bathymetric surveys have been carried out for both the lakes. Survey daa are being processed.
- Installation of 3 nos of ORG in the study area has been completed and f data observers have been identified.
- Data on rainfall and lake levels for the period of 2004 to 2018 have been collected for both the lakes
- Catchment map showing drainage, slope map and DEM of catchment have been prepared.

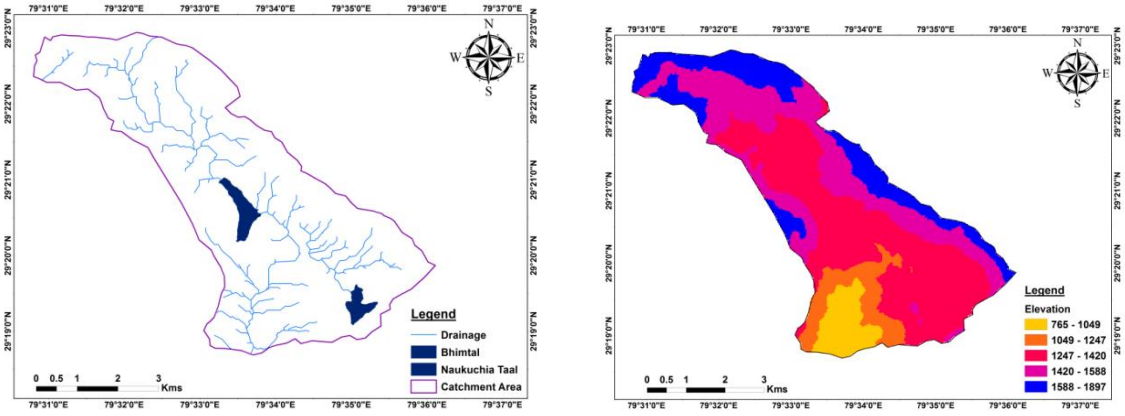


Fig: Catchment map with drainage and DEM of the study area

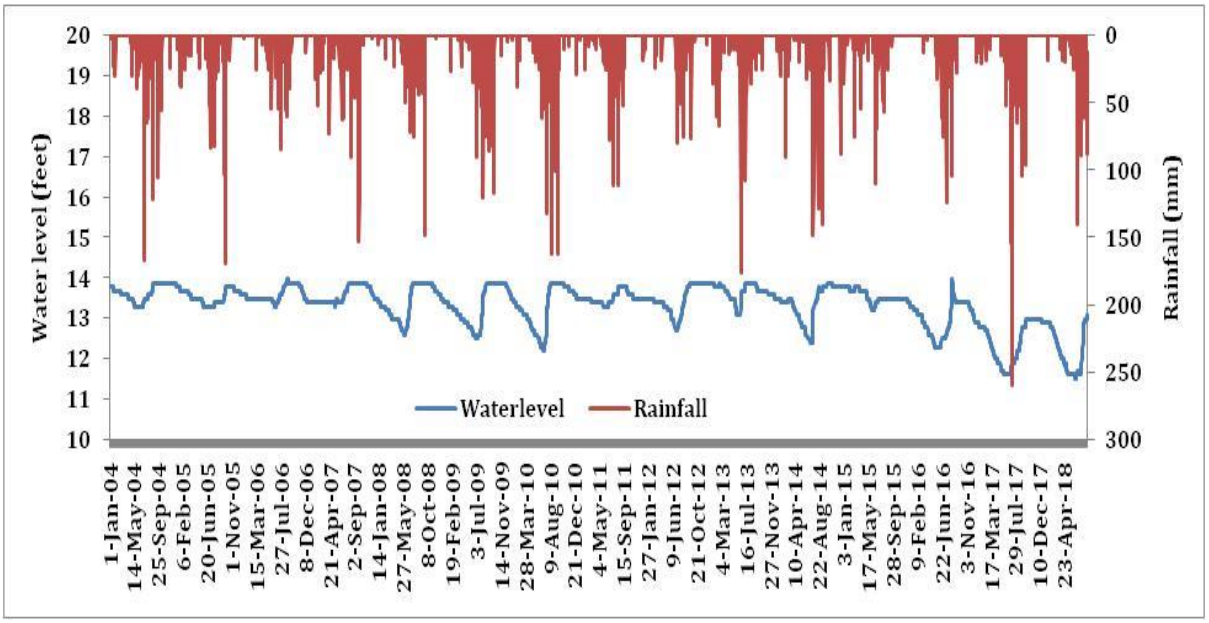


Fig.: Water level variation for Naukuchiyatal lake vis-à-vis rainfall

Action Plan: Combined activity schedule of NIH & IRI

SN	Activity	Quarter											
		Year- I				Year- II				Year- III			
		1	2	3	4	1	2	3	4	1	2	3	4
1.0	**PREPARATORY WORK**												
1.1	Reconnaissance survey & finalization of various sampling locations	√											
1.2	Recruitment of project staff	√											
1.3	Collection & Review of all available data/information	√	√	√									
1.4	Compilation of existing data/information	√	√	√	√								
1.5	Identification of Data Gaps	√	√										
1.6	Procurement of instruments and peripherals	√	√	√									
1.7	Purchase of Remote Sensing Data	√	√										
1.8	Purchase of meteorological Data	√	√										
1.9	Installation of equipment in field	√	√										
1.10	Preparation of basic maps of lake and catchment		√	√									
1.11	Installation of piezometers	√	√										
1.12	Arrangement for discharge measurement	√											
2.0	**FIELD WORK**												
2.1	Generation of hydro-meteorological		√	√	√	√	√	√	√	√			
2.2	Collection of water samples for water quality analysis		√	√	√	√	√	√	√	√			
2.3	Collection of water samples for isotope analysis		√	√	√	√	√	√	√	√			
2.4	Collection of sediment samples			√									
2.5	Infiltration tests to determine Infiltration rates			√	√								
2.6	Monitoring of discharge		√	√	√	√	√	√	√	√			
2.7	Bathymetric Survey of lake		√										
2.8	Monitoring of lake water levels levels		√	√	√	√	√	√	√	√			
2.9	Monitoring of ground water levels		√	√	√	√	√	√	√	√			
3.0	**LABORATORY ANALYSIS**												
3.1	Analysis of samples for Water Quality		√	√	√	√	√	√	√	√			
3.2	Analysis of water samples for isotope characterization		√	√	√	√	√	√	√	√			
3.3	Analysis of sediment samples			√	√								

4.0	**DATA INTERPRETATION & ANALYSIS**												
4.1	Processing of bathymetric data			√	√								
4.2	Development of depth-area-capacity curve for the lake				√								
4.3	Preparation of other maps, morphometric characterization and morphological analysis			√	√								
4.4	Analysis of rainfall and other meteorological data									√			
4.5	Estimation of evaporation losses from the lake										√		
4.6	Assessment of lake-ground water interaction										√		
4.7	Estimation of water balance of the lake										√	√	
4.8	Isotopic characterization of waters of study area									√			
4.9	To develop local meteoric water line										√		
4.10	To estimate sedimentation rate of the lake										√		
4.11	To assess the water quality of the lake			√		√		√		√			
4.12	Assessment of suitability of lake water for various uses											√	
4.13	To develop conservation plan for the lake											√	
5.0	**PREPERATION OF REPORT**												
5.3	Preparation of Interim Project Report				√				√				
5.4	Preparation of Final Project Report												√
6.0	**ORGANIZATION OF TRAINING WORKSHOP**	Post-Project											

7. PROJECT REFERENCE CODE: NIH/HID/SPON/18-19/1 (New Study)

Title of the Study:	**Climate proofing of Spring-shed development programme (Dhara Vikash) through Science & Technology interventions in drought prone areas of Sikkim**
Study Team:	Dr. Sudhir Kumar (P.I.), Dr. Suhas Khobragade
Type of Study	**S**ponsored
Funding Agency	UNDP (India)
Budget	Rs. 52.426 lakhs + GST as applicable
Date of Start:	November 2018
Date of Completion	April 2019

Statement of the Problem

'Mountain springs', a lifeline of Himalayan habitants, are affected by climate change in different ways. Reduction in spring discharge is being experienced as a common phenomenon across the Himalayan region. This is primarily due to reduction of rainfall, its uneven spread and reduced infiltration as the main factors for the reduction in dry period spring discharge. However, the finer impacts on these springs are governed by aquifers, where groundwater is stored and discharged to these springs under different geological conditions. Without a proper understanding of aquifers, any study of groundwater remains incomplete. Study of springs, with a strong hydrological and geohydrological contexts are especially relevant to the conservation, protection of the springs in order to adapt to various fluxes imposed by the overarching climate change phenomenon.

Drinking water requirement dependent on rainfall is likely to become scarce as rainfall may increasingly get restricted to only monsoon period (as is the present situation) and there might be a reduced amount of rainfall spread as the number of rainy days will decrease. Since spring water in the mid hills of the Himalayas is mainly rainwater; the above changes are likely to induce variation in spring discharge. Increase in intensity of rainfall will lead to high run off and less infiltration, and consequently adversely affecting spring recharge, whereas increased drought like situations due to the overall decrease in the number of rainy days. Further, increased water temperature may lead to lower availability of dissolved oxygen. Altered ice-free period, increased biological activity exhausting oxygen in water, and changed pattern of thermal mixing in water bodies to create anaerobic conditions leading to eutrophication or hypertrophication.

Recognizing that climate change is central to policy imperatives, Sikkim has developed a State Action Plan on Climate Change (SAPCC) to prioritize strategies and pilot activities. Based on the objectives of SAPCC and general vulnerability assessment conducted in Sikkim, it was found that water is one of the most vulnerable sectors in Sikkim. As of date, the Sikkim Govt. department has very little quantitative data and more of qualitative data to back up the positive impact of the initiative. It still lags in creating an extensive scientific database and hydro-metrological characteristics of springs due to the resource constraints. The lean period discharge was not recorded, making any conclusive impact assessment impossible. Further, as the programme gathered momentum, its positive effects generated demand for scaling up with appropriate scientific interventions, which could not be met due to the limited number of trained staff on analysis of water scarcity due to climate change. Trenches for groundwater recharge were initially dug on the thumb rule basis without adherence to geo-hydrological requirements and climate variability, thus making them ineffective and unsustainable.

On this back drop, UNDP through its 3 SCA projects has formulated an integrated approach for climate proofing of Spring-shed Development Programme (Dhara Vikash) in Sikkim through Science and Technology Interventions**.** For the sustainable development of springs, it is essential to understand the hydro metrological and the surface water features in the region. On a scientific platform, analysis of spring discharge with meteorological data can provide insight on behavioral aspects of the aquifer - how it stores and transmits water, hydraulic conductivity, specific yield, time lag etc., which can help in short term forecasting of water availability. An analysis of long-term data is helpful to compute water models for long term availability, which in turn may be useful for prediction of future water availability.

Objectives:

1. To setup monitoring mechanism (instrumentation) including portable water quality instruments to serve as observatory for monitoring of hydrological, water quality and meteorological parameters
2. To build capacity of the RM&DD officials to monitor the various parameters (including spring water quality using portable instruments)
3. To train the RM & DD officials in data collection, retrieval, storage, processing and analysis

Methodology

i) Reconnaissance Survey shall be carried out to get information and idea about the field conditions in the study area, geological conditions, nature of springs, feasibility of instrumentation, types of instrumentation, site selection etc.

ii) Collection, Review and compilation of all existing data/information.

iii) Finalization of methodologies of discharge measurements. Depending upon the field conditions and nature of springs, use of siphon type discharge measurement or V-notch/Weir arrangement shall be decided.

iv) Procurement of identified hydrological, water quality and meteorological Instruments. Purchase of Remote Sensing & Meteorological Data

v) Installation of equipment (AWS &rain gauges) in field.

vi) Training of the RM&DD officials to build capacity to monitor the various hydro-meteorological parameters (including spring water quality using portable instruments).

vii) Provide monitoring plan for the various hydro-meteorological and water quality parameters.

viii) Organization of training workshop to train the RM & DD officials in data collection/ retrieval, storage, processing and analysis.

ix) Preparation of Report

Action Plan:

Tasks	**Tasks Activities**	**Deliverables**	**Timeline**
Task 1:	Scoping of the tasks	Inception report	Nov'18
Task 2:	**Preparatory work:** 1. Reconnaissance survey & finalization of equipment for each location sites. 2. Collection and review of all available data and information. 3. Compilation of existing data/information 4. Procurement of instruments and peripherals. 5. Purchase of Remote Sensing & Meteorological Data. 6. Preparation of basic maps of study areas.	Procurement Plan and report with detail specification of instruments and data sets	Dec'18
Task 3:	**Field Work:** 1. Installation of equipment (AWS & Rain gauges) in the field. 2. Arrangement for discharge measurement. 3. Generation of metrological data 4. Collection of water samples for water quality and analysis in the Lab. 5. Monitoring of spring discharge.	Field Report	Dec'18 – Mar'19

	6. Analysis of rainfall and other meteorological data.		
Task 4:	**Training and capacity building:** 1. Morphological analysis of study area. 2. Analysis of rainfall and other meteorological data. 3. Analysis of discharge data of springs 4. Identification of recharge areas of springs 5. Assessment of the water quality of the springs 6. Data collection/ retrieval, storage, processing and analysis. 7. Preparation of monitoring plan for parameters.	Training reports	Jan'19 – Apr'19
Task 5:	**Preparation of Report** 1. Preparation of Interim Project Report 2. Preparation of Draft Final Project Report		Apr'19

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Rakesh Kumar	Scientist G & Head
2	Dr. J V Tyagi	Scientist G
3	Dr. A K Lohani	Scientist G
4	Dr. R P Pandey	Scientist G
5	Dr. S K Singh	Scientist F
6	Dr. Sanjay Kumar	Scientist E
7	Dr. Archana Sarkar	Scientist D
8	Dr. L N Thakural	Scientist C
9	Sri J P Patra	Scientist C
10	Dr. Ashwini A. Ranade	Scientist C
11	Sri Sunil Gurrapu	Scientist C
12	Sri N K Bhatnagar	Scientist B
13	Sri R K Neema	PRA
14	Sri Hukum Singh	PRA
15	Sri Om Prakash	SRA
16	Sri Jatin Malhotra	SRA
17	Sri T R Sapra	RA

Work Program for 2017-18

S. No. & Ref. Code	Title	Study Team	Duration
COMPLETED & PRESENTED IN PREVIOUS WORKING GROUP MEETNG			
1.NIH/SWHD/NIH/15-18	WaterRAIN-Him: Changes in v Resources and Adaptation option Indian-Himalayan basins	Archana Sarkar Sanjay K Jain	**Sponsored by SMHI Sweden** 3 years (1 Jan2015 to 31 Mar. 2018)
2.NIH/SWHD/NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani S.K. Jain	**Internal** 3 years (April 2015 to March 2018)
3.NIH/SWHD/NIH/17-18	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments	Sushil. K. Singh	**Internal** 1 year (April 2017 to March 2018)
4.NIH/SWHD/NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Archana Sarkar Vaibhav Garg N.K. Bhatnagar	**Internal** 3 years (April 2015 to March 2018)
5.NIH/SWHD/NIH/14-18	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar N.K. Bhatnagar Vaibhav Garg Rakesh Kumar	**Internal** 4 years (April 2014 to March 2018)
6.NIH/SWHD/NIH/16-18	Snow cover variability in the Upper Yamuna Basin	Naresh Kumar Manohar Arora Rakesh Kumar	**Internal** 2 years (April 2016 to June 2018)

Work Program for 2018-19

ONGOING STUDIES(Sponsored)			
1.NIH/SWHD/NIH/16-21	Hydrological modeling in Alaknanda basin and assessment of climate change impact	A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	**Sponsored by NMSHE** 5 years (April 2016 to Mar. 2021)
2.NIH/SWHD/NIH/17-20	Water efficient irrigation by using SCADA system for medium irrigation project (MIP) Shahnehar	R.P. Panday J. Patra Rajesh Singh N.K. Bhatnagar	**PDS under NHP** 3 years (Dec 2017-Dec 2020)
3.NIH/SWHD/NIH/17-19	Impact Assessment of Climate Change on Water Resources and Agriculture in Banas basin in Western India using Climate change Indicators (CII's). **Approval for signing the sub-contract with SMHI and transfer of funds to NIH has not been received. Therefore, NIH continues in the consortium as "In Kind Partner". The objectives of CII development and script writing will be taken up by the core team at SMHI with help from NIH**	Archana Sarkar Surjeet Singh T. Thomas	1.5 years (Sep. 2017 to Feb. 2019)
4.NIH/SWHD/NIH/14-18	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	**Sponsored by SERB-DST** 4 years (Oct. 2014 to Nov 2018)
ONGOING STUDIES (Internal)			
5.NIH/SWHD/NIH/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin Subzone 3(f)	Sanjay Kumar Rakesh Kumar J. P Patra Pankaj Mani	4 years (April 2017 to March 2021)
6.NIH/SWHD/NIH/15-19	Study of Hydrological Changes in selected watersheds in view of climate change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay Kumar Jain Sharad Kumar Jain	4 years (April 2015 to March 2019
7.NIH/SWHD/NIH/17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P. Patra Rakesh Kumar Pankaj Mani Sanjay Kumar	3 years (April 2017 to March 2020)
8.NIH/SWHD/NIH/18-21	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario	Ashwini Ranade Archana Sarkar	3 years (April 2018 to March 2021)
NEW STUDIES			

9.NIH/SWHD/NIH/	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2 years (Nov 2018 to October 2020)
10.NIH/SWHD/NIH/18-21	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent	Sunil Gurrapu	3 years (Nov 2018 to March 2021)
11.NIH/SWHD/NIH/18-20	Evaluation of Water Quality of Government Schools in Roorkee Block, District Haridwar	N. K. Bhatnagar M. K. Sharma L. N. Thakural Reena Rathore	2 years (Oct 2018 to Sept 2020)

ONGOING SPONSORED PROJECTS

1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-21

1	Project Title: **Hydrological modeling in Alaknanda basin and assessment of climate change impact**	
2	DST's Reference No.: **DST/SPLICE/CCP/NMSHE/TF-4/NIH/2015-G**	
3	Project details	
	a. Names and contact details of PI/Co-PIs	Dr. A.K. Lohani, Scientist 'G' (PI)
	b. Institution	NIH, Roorkee
	c. Dates of superannuation of PI/Co-PIs	**PI: 31st May 2025**
	d. Date of starting, completion and total duration of the project	5 year
	e. Total cost of the project	42.296 Lakh
	f. Total amount spent so far (in figure and also as % of total cost)	***
4	Approved objectives/work plan of the programme/project **Objectives** • To model stream flow/snow melt runoff in Alaknanda Basin. • To investigate the impact of likely future changes in climate on stream flow in the study area using future climate scenarios. • To estimate seasonally varying Temperature Lapse Rate (TLR) using LST data estimated from thermal satellite image in Alaknanda basin.	
5	Data, Equipments and Manpower	
	a. Data used	**Temporal Data:** Rainfall, Min/Max Temperature, Relative Humidity, Gauge and Discharge, Sunshine hours, Wind Speed, etc. **Spatial Data:** DEM, FAO Soil Map, LULC, Elevation Map, Snow cover Data etc.
	b. Equipments procured	Desktop, Computer Tables, Revolving Chairs, UPS, Portable Hard disk etc.
	c. Manpower deployed (against sanctioned manpower)	2
6	Brief description of methodology/ techniques/approach adopted **VIC Model:** Hydrological Modelling **SnowMOD:** Hydrological Modelling **ERDAS**: DEM correction and generation from toposheets **ArcGIS**: Spatial analysis and Map preparation **Matlab**: long-term data extraction and analysis **Fortran**: IMD 0.25x0.25 gridded Data extraction **Python**: ERAdata extraction from NetCDF format **SWDES**: Hydrometeorology data base management **HYMOS**: Data Analysis; Consistency check; Missing values quantification; Data correction; data error check **eSWIS**: Online data management **IDW** interpolation technique has been utilized for spatial map preparation from point data.	
7	Summary of results and conclusion	
8	Quantitative Outcome in terms of (If required, please include this as an annexure).	
	a. Research papers published (Please provide a list along with their impact factors)	**Lohani, A.,** Naha, S., Jain, S.K., Thakural, L.N. (2017) "Snowmelt

		runoff modelling in a subbasin of the Ganga Basin" 3rd International Conference on the Status and Future of the World's Large" New Delhi India, April 18-21, 2017.
	b. Reports/Monographs/Internal publications brought out (please give list)	-
	c. New techniques/models developed, if any	-
	d. Patents filed/awarded, if any.	-
	e. Details of workshop/ conferences/ seminars/capacity building programmes organised (Please give complete list along with topics, dates, duration, number of participants, details of reports published, etc)	**Workshop cum capacity building programmes:** 1. SWDES (Data entry and execution with NIH scientists) – 3 days 2. eSWIS (Data entry and execution with CWC experts) – 2 days 3. ERDAS 2016 (Software demonstration and utilization) 2 days 4. ArcMap-10.4 (Software demonstration and utilization) 2 days
	f. Number of personnel trained (Please provide a list of courses along with number of people trained)	1. SWDES (Data entry and execution with NIH scientists) 2. eSWIS (Data entry and execution with NIH/CWC experts)
	g. Number of post-graduate/doctoral candidates completed their courses (Please give a list of such candidates)	-
	h. Foreign deputation/visit of PI/Co-PIs/students, if any	-
9	Progress made against the set targets/deliverables of the project (If required, please include this as an annexure). Were there any deliverables (as per approved work plan) which could not be achieved so far? If so details and justification thereon. Whether these will be completed in the remaining period of project? **(See at the last)**	
10	Whether the project could bring benefit to the society? If so provide details **NA**	
11	Whether the programme could create linkages with policy makers such as government officials and policy institutions? If so please provide details	
12	Whether any web site/portal has been set up under the project? If so please provide details (Ref: Sub-Project-1, outcome of the study to be published on NMSHE website of NIH)	
13	Please provide details of the strategic/new knowledge generated under the project.	
14	**Applicable only to those projects which are nearing completion** Do you wish to continue your present project into the next phase? If so, how do you take this project forward? Please give complete justification.	
15	Any other information you wish to add	

Note:

1. *Kindly provide brief and to the point information and avoid giving unnecessary background, introduction, references, etc.*
2. *Please include tables and figures wherever necessary*
3. *The length of the report should not exceed 12 pages with 12 pt Ariel font and single space*
4.

9. Progress made against the set targets/deliverables of the project

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Procurement of satellite data, collection of DEM of the study area, collection of hydrological and hydro-meteorological data from various agencies										
Generation snow cover area maps, elevation zone area maps.										
Processing and analysis of hydrological data										
Development of seasonally varying Temperature Lapse Rate (TLR)										
Development, calibration and validation of snowmelt runoff model.										
Development of future climatic scenarios and investigation of the impact of likely future changes in climate on stream flow in the study area.										
Capacity building										

1. **Procurement of satellite data, collection of DEM of the study area, collection of hydrological data from various agency:** The satellite imageries and DEM have been downloaded from various sites as per requirements. Further, letter has been sent to different agencies for hydro-meteorological data collections. Collection of data in progress.
2. **Generation of snow cover area maps and elevation zone area maps:** Different snow cover maps have been prepared with respect to different time interval. Elevation zone mapping has been done for the study area (*please refer end of this report*). Further progress is ongoing.
3. **Processing and analysis of hydrological data**: Spatio-Temporal processing has been done as per data availability. For the meteorological data a latter has been sent to IMD on dated 22-02-2017.
4. Development of seasonally varying Temperature Lapse Rate (TLR): The processing of TLR is ongoing.
5. Capacity Building: To be planned for capacity building programme related with research area.

Project Summary for NMSHE Sub-Project – 06

Progress

- Various maps such as basin map, drainage map, landuse map, DEM (Fig. 2), snow cover area maps of the basin have been prepared.
- Grided rainfall data of the study basin have been collected and processed.
- Snowmelt runoff model is being setup for the study basin.
- Flow data is required for the calibration and validation of the model.
- Available G& D data in the basin has been identified and efforts are being made to collect these data.

Variable Infiltration Capacity Model: The distinguishable features of this model are

- Grid based macro-scale hydrological model (1 km)
- Sub-grid variability in land surface vegetation classes
- Sub-grid variability in the soil moisture storage capacity
- Drainage from the lower soil moisture zone (base flow) as a nonlinear recession
- Inclusion of topography that allows for orographic precipitation and temperature lapse rates resulting in more realistic hydrology in mountainous regions

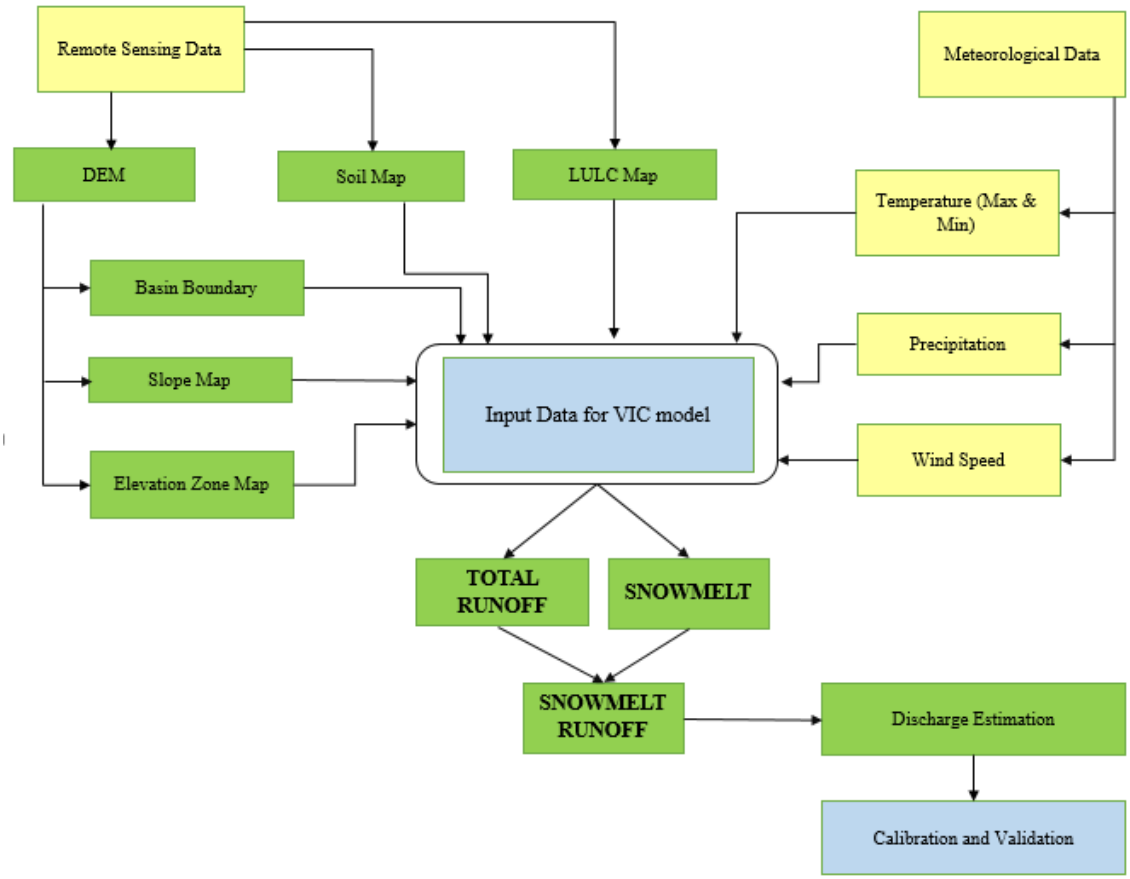
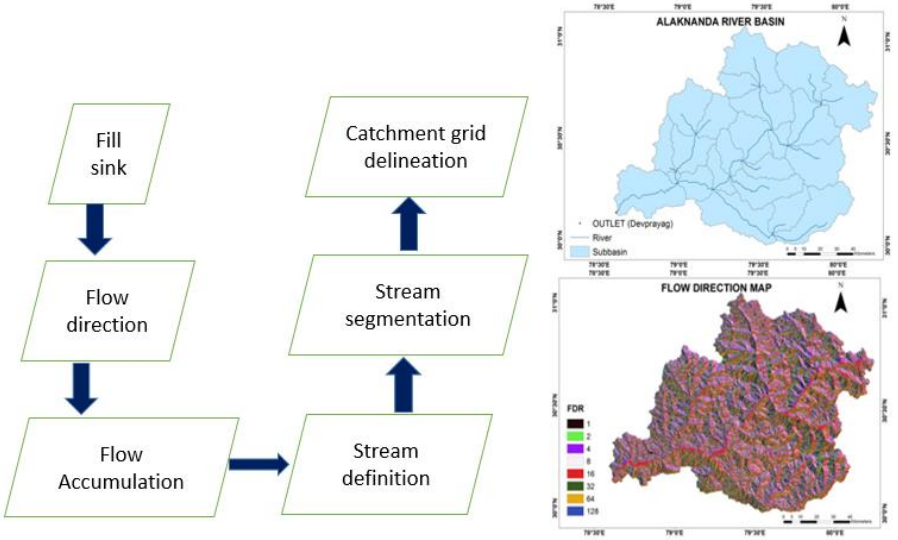
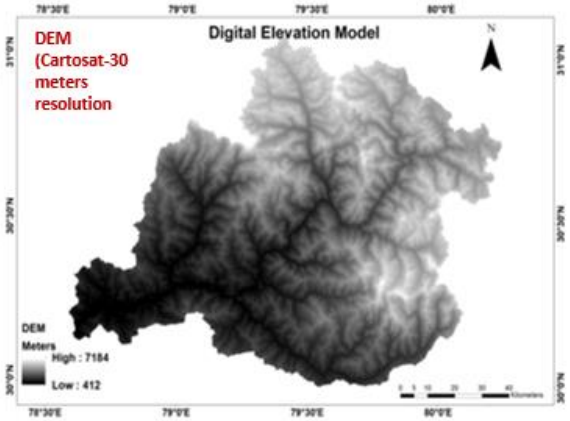


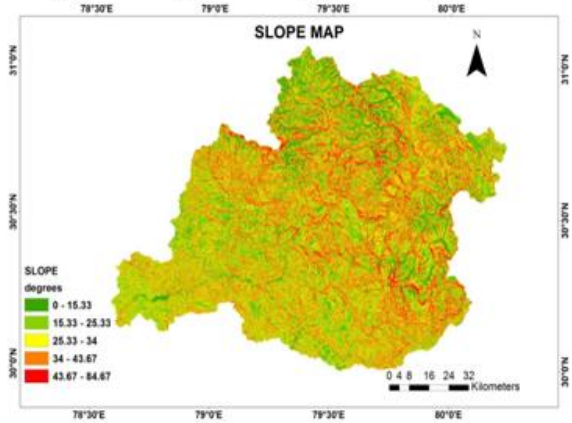
Figure 1: Process Flow chart of VIC Model

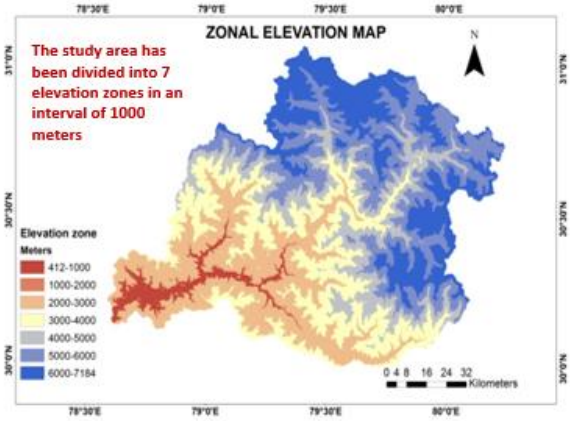
Hydro-processing

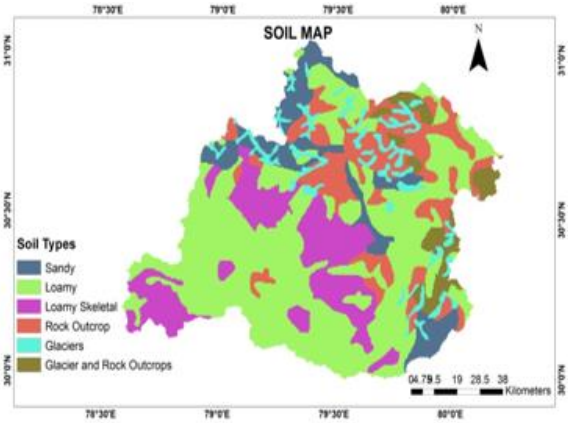


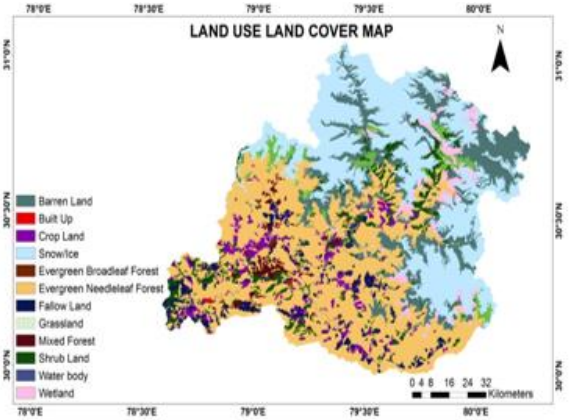
Flow Direction map

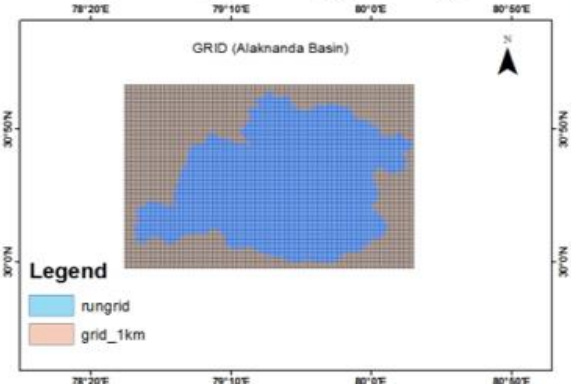


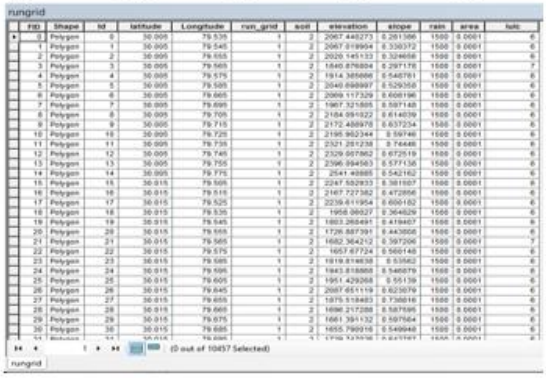










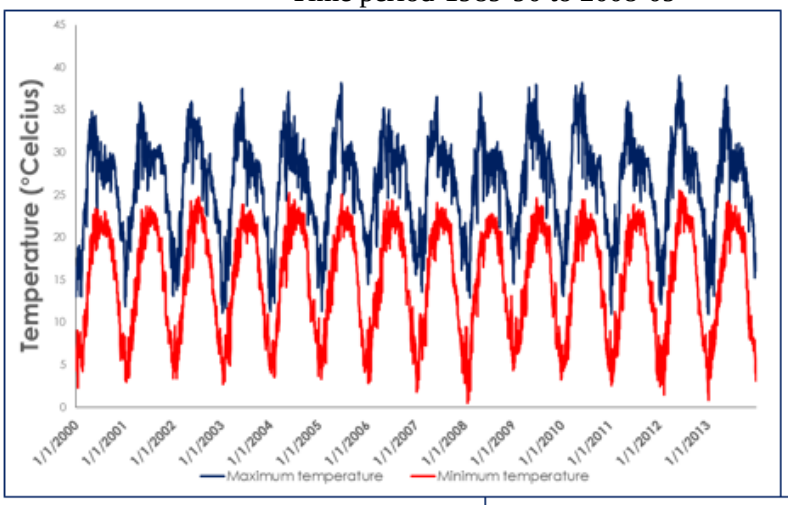


Temporal Data Preparation

Meteorological Forcing's preparation

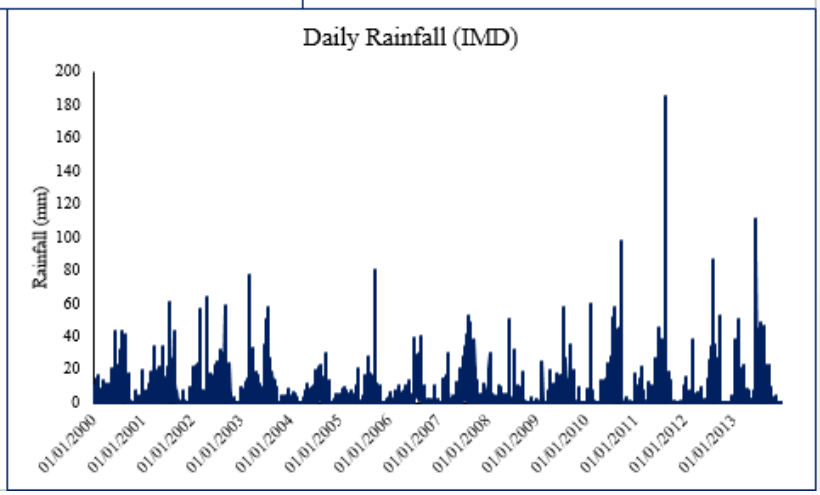
- Maximum temperature
- Minimum temperature
- Daily rainfall
- Wind speed

- **Indian Meteorological department (IMD)** Gridded datasets has also been used for VIC simulation . The temperature datasets were available at a resolution of **1°x1°** and rainfall at a resolution of **0.25°x 0.25°**
- **ERA-Interim** datasets from ECMWF of **0.75 °** interpolated to **0.125 °** has been downloaded and processing is being done.
- **G & D data:**
  - ***Alaknanda upto Joshimath***
    - Catchment area (km^2)- 1285
    - Time period-1989-90 to 2008-09
  - ***Rudraprayag -G5 (after confluence) Alaknanda***
    - Catchment area (km^2)- 10675
    - Time period-1989-90 to 2008-09



Maximum and Minimum temperature (IMD)

Daily rainfall (IMD)



Preparation of MODIS Snow Cover Area (SCA) Map

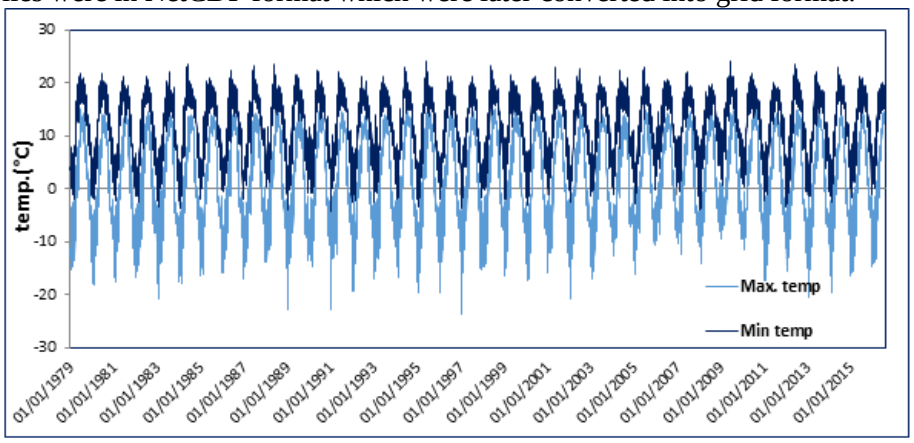
- **SPATIAL COVERAGE-** N: 90, S: -90, E: 180, W: -180
- **SPATIAL RESOLUTION** -500 m x 500 m
- **TEMPORAL COVERAGE** -24th February 2000 to present
- **TEMPORAL RESOLUTION-** 8 days
- **PLATFORM**- Terra
- **SENSOR** -MODIS
- **FORMAT**- HDF-EOS
- **PARAMETERS** -Snow/Ice/Lake/Cloud

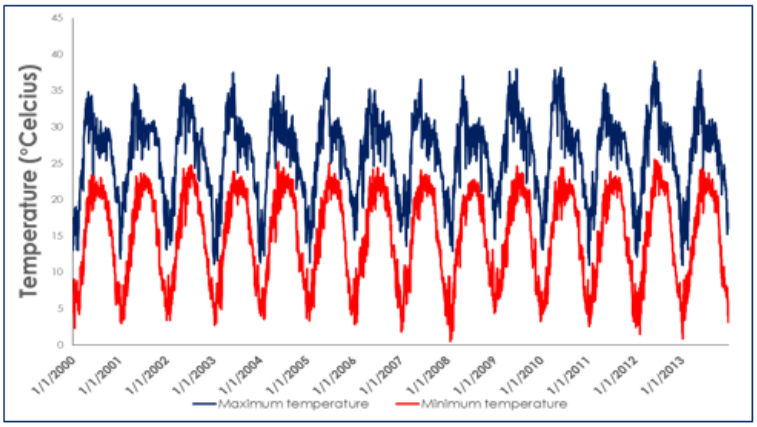
Execution of Model

- The VIC model have been developed for use on LINUX and UNIX platforms.
- To use VIC on a Windows platform, a free UNIX emulator such as Cygwin is used.

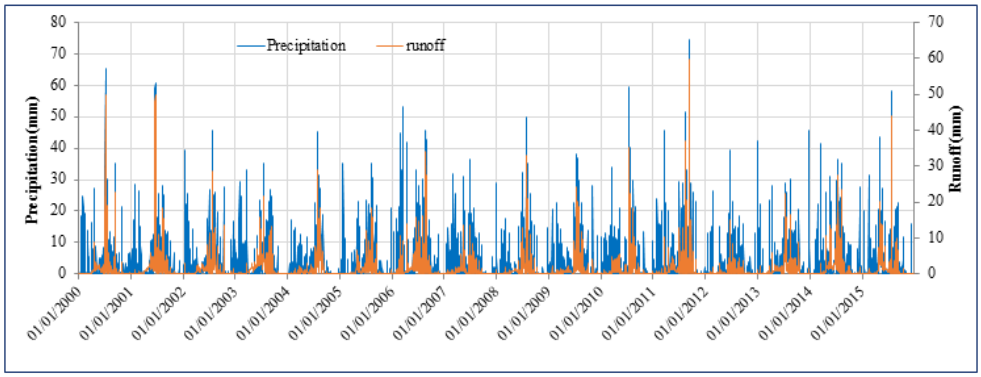
- VIC model has been run using rainfall, maximum and minimum temperatures from IMD initially
- But, as the minimum temperatures given by IMD are not minimum enough so as to generate snow fluxes, only water balance fluxes were simulated.
- Later on, Maximum and minimum temperatures from ERA-Interim (ECMWF) has been downloaded .Files were in NetCDF format which were later converted into grid format.

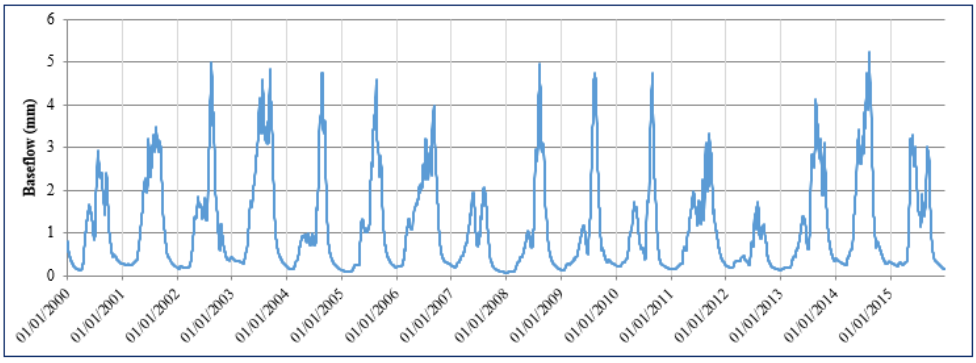
Maximum and Minimum temperature (ERA-Interim)



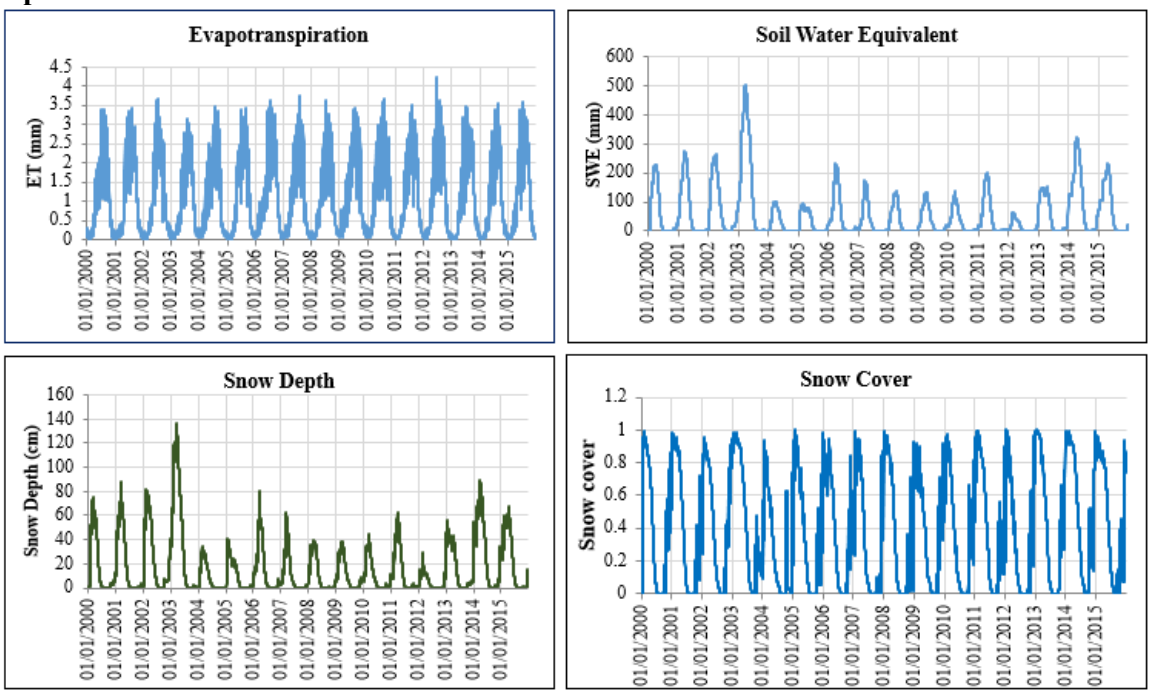


Maximum and Minimum temp. (IMD)



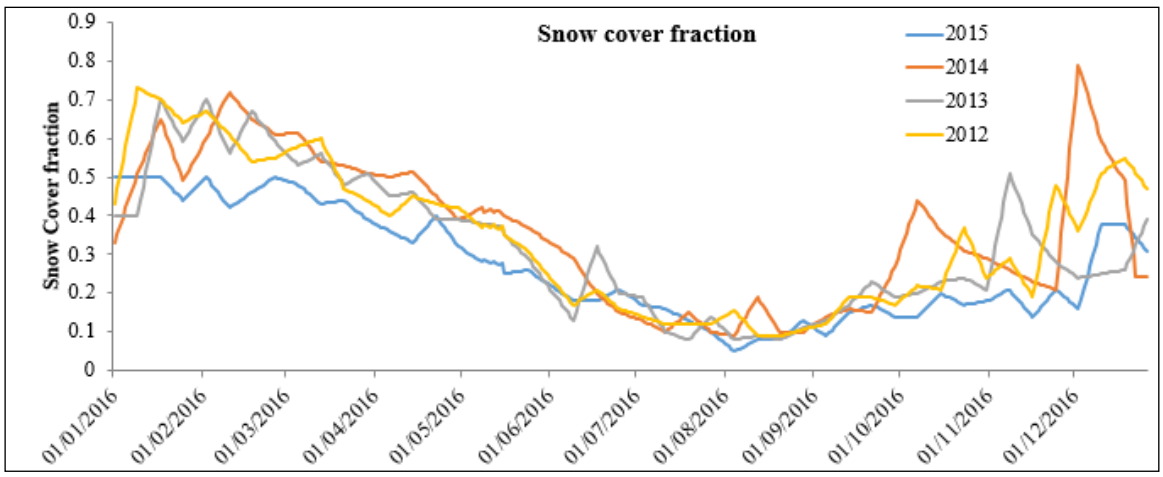


Graphical Presentation of Data



MODIS time series data (SCA)

- MODIS data (MOD10A2) ,8 day composite SCA data downloaded from www.nsidc.org
- Pre-processed (Projections, Resampled and mask extraction has been done using the basin file)
- Cloud cover has been removed based on Temporal and Spatial variations.
- 8 day Time series (SDC curve) has been derived and interpolated to derive the daily snow cover area.

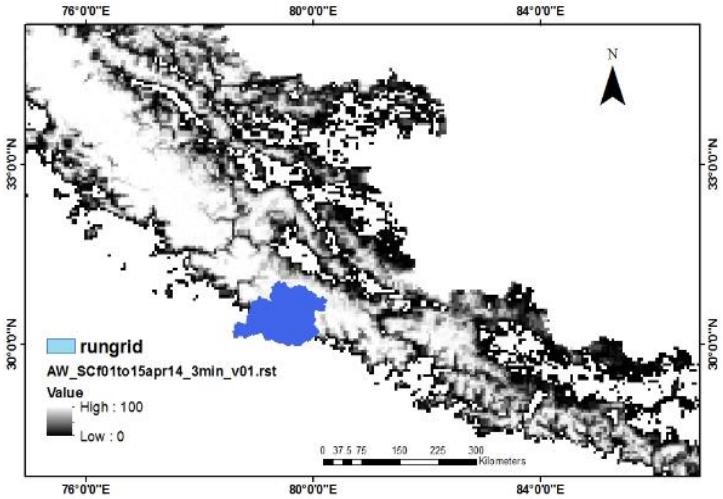


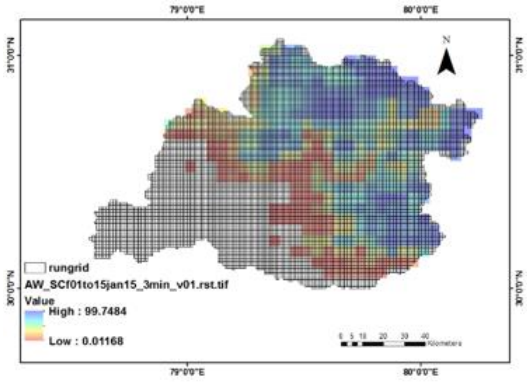
Validation of MODIS Data

- MODIS 8-day Snow cover area products are of coarse resolution when compared to AWIFS snow cover area data of 56m resolution.

- So AWIFS data has been downloaded from Bhuvan. SCA data of time period (2014-2016) has been used depending on the availability.

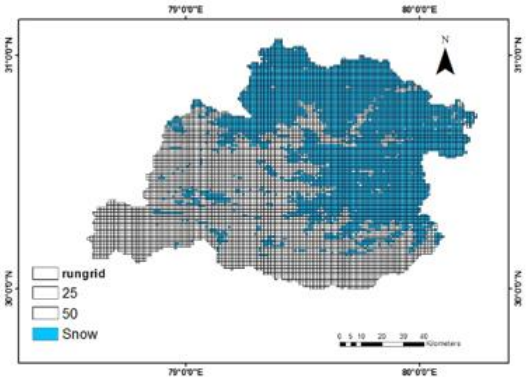
- AWIFS data preprocessed (projected, resampled and mask extraction)

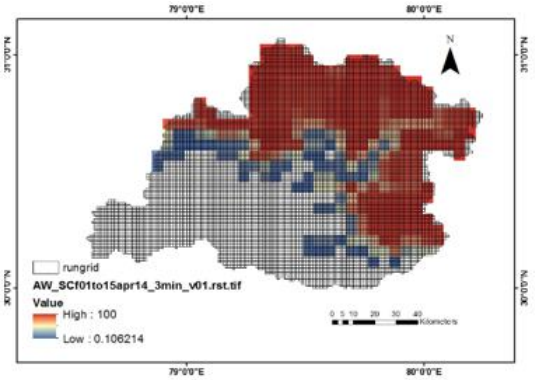




AWIFS
15TH JAN,15
Data (SCA)

MODIS
15TH JAN,15
Data (SCA)





AWIFS
15th April,14

MODIS
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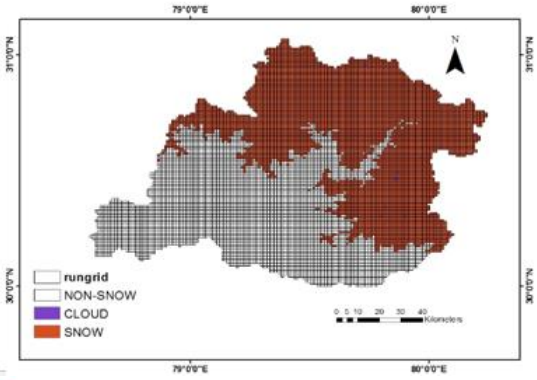
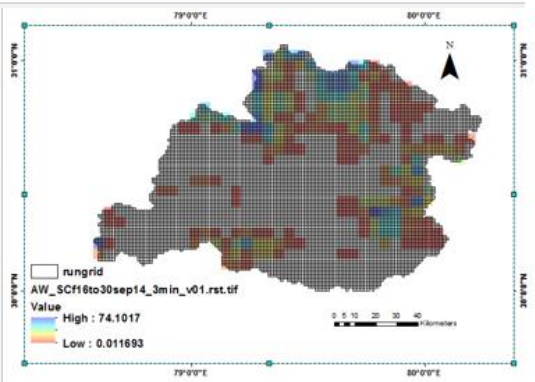
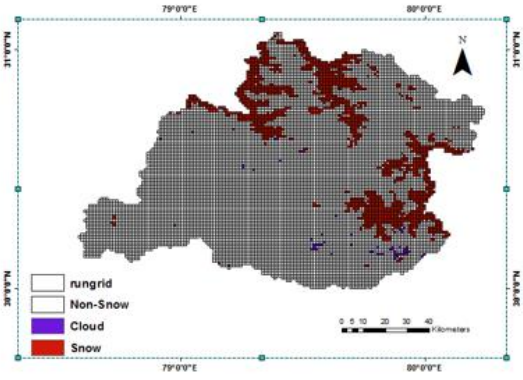




AWIFS
30th Sept,14

AWIFS
30th Sept,14



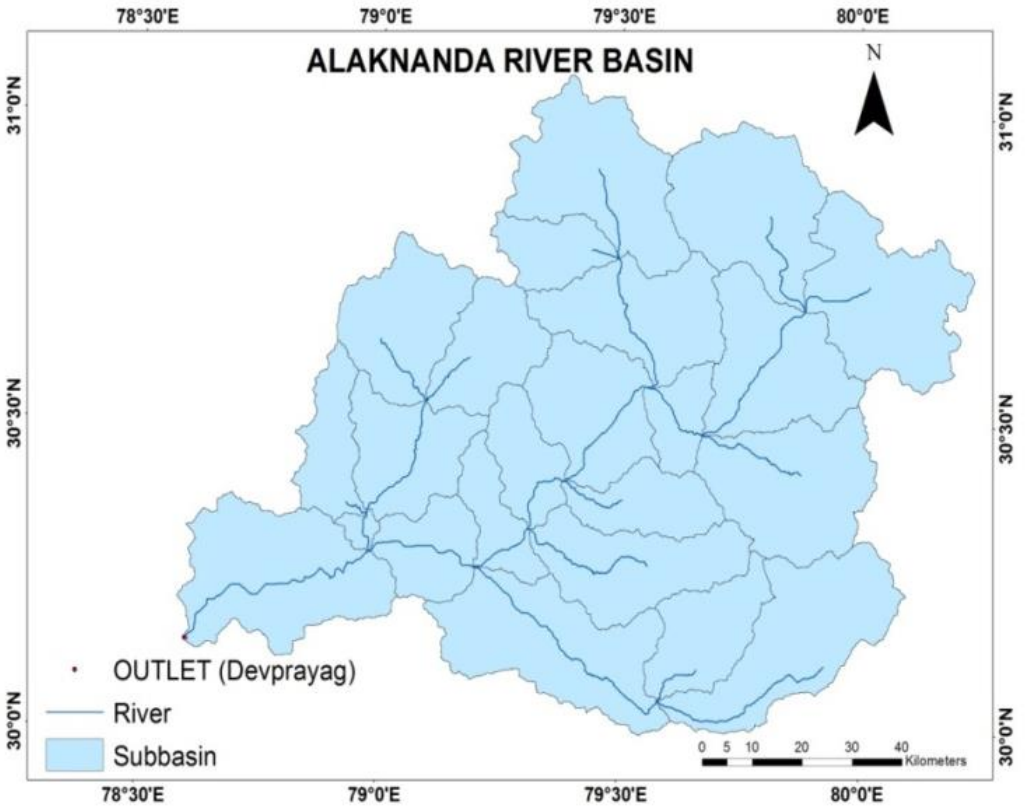


Figure 4: Location map of study area

2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/17-20

Title of the study : **WATER EFFICIENT IRRIGATION BY USING SCADA SYSTEM FOR MEDIUM IRRIGATION PROJECT (MIP) SHAHNEHAR**

Project team

Name of PI: **Dr. R.P. Pandey, Scientist G**.
Name of Co-PI: **Er. Jagdeesh Patra, Scientist C**
Dr. Rajesh Singh, Scientist C,
Sh N. K. Bhatnagar, Scientist B

Type of study: PDS

Collaborating Institutions

Department of Irrigation & Public Health Engg. (I&PHE), Hydrology C&M Division, Tutikandi, Shimla-4. Himachal Pradesh	**National Institute of Hydrology Roorkee -247667**

Total Project Cost: Rs.75.0 lakh (**Funded by NHP)**
NIH Cost Allocation Rs. 15.0 lakh

Project Duration: **3-years**

Date of start: **December, 2017**

Scheduled Date of Completion: **December, 2020**

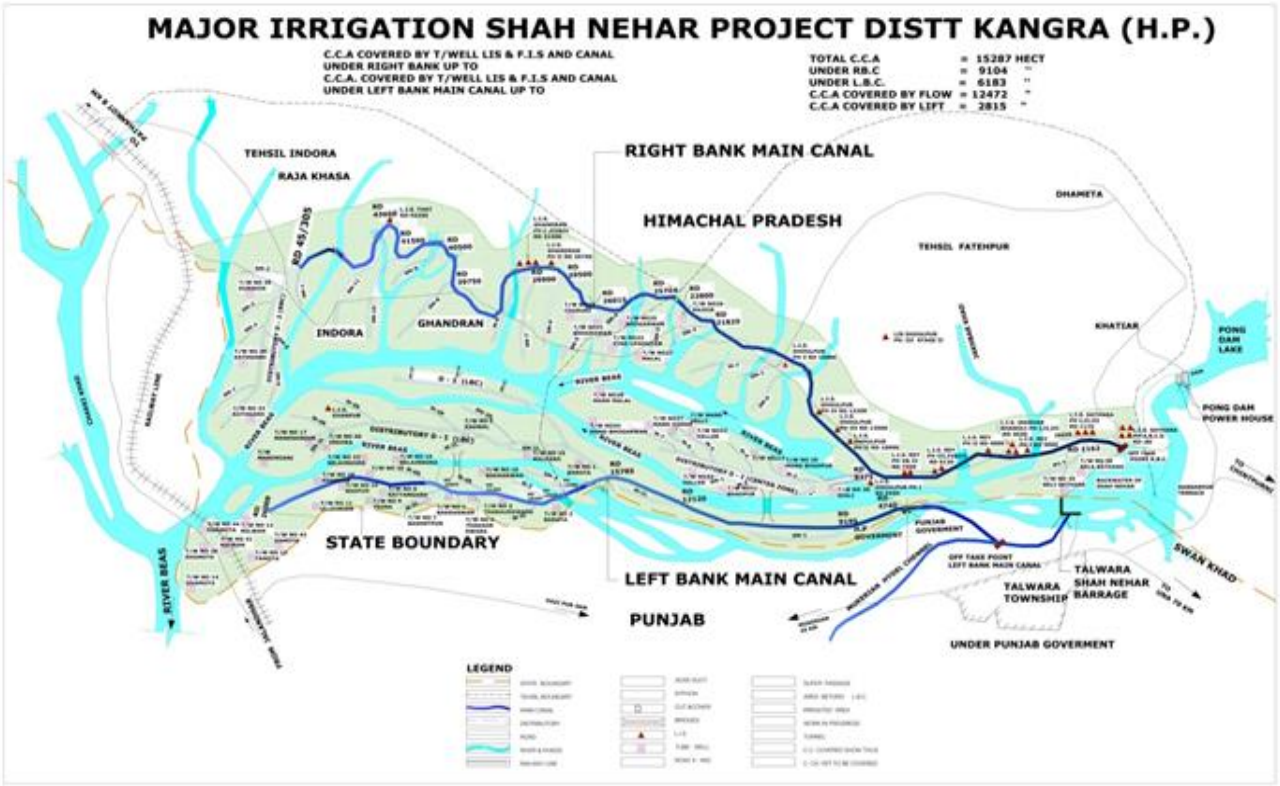
OBJECTIVES OF THE STUDY:

The primary objectives of this study is to **Devise a suitable approach to improve irrigation water use efficiency in Shah Nehar Project.** The specific objectives of the study are as follows:

- To develop monitoring, supervisory control and modernize system for Agriculture Irrigation water.
- Paradigm shift in the approach from a supply-based system to a demand-based sustainable system.
- Real time monitoring of water availability at head works.
- Performance evaluation of Left Bank Canal and Right Bank Canal of MIP Shah Nehar Project.
- Identify issues that need to be addressed to improve project performance
- Suggest measures to improve water use efficiency & sustainability up to farm level.
- Integrating Warabandi with SCADA system.

Study Area : <u>Shah Nehar Command Area, Himachal Pradesh</u>

Shah Nehar Irrigation Project in District Kangra, Himachal Pradesh is first Major Irrigation Project of the state amounting to Rs.143.32 crore was approved by the HP Govt to irrigate 15287 hectares of land of 93 villages situated on right and left bank of river Beas by constructing two numbers of main canals on each bank with a length of 45.30 and 25.69 km respectively. The water was fetched from outfall of Pong Dam by signing agreement between Govt. of HP and Punjab Govt. on 4/8/1983.The index map of Shah Nehar project command area is given in Figure below.



Whole of the Right bank canal enroots through the jurisdiction of Himachal Pradesh whereas about 4.0 Km of LBC out of 25.69 km falls in the state of Punjab. Out of total cost of Rs 143.32 crore the Govt. of Punjab was to share Rs 88.49 crore and remaining Rs 54.83 crore was to be borne by the Govt. of H.P. Later on due to price escalation revised DPR was prepared and approved to the tune Rs 387.17 crores at price level 2010 in 110th meeting of advisory committee of CWC. The project was included under Accelerated Irrigation Benefit Program (*AIBP*) with 90% Central Aid and balance 10% had to be shared by Govt. of Punjab and HP in the ratio of 61.74% and 38.26%.

Description of the Problem

At present the Shah Nehar project experiences improper distribution of water into the agricultural fields resulting into low yield of crops and therefore necessity of water efficient irrigation system by using SCADA. The primary objectives of the proposed study are to enhance water use efficiency, minimize water losses and to increase productivity in the command area of Shah Nehar project. The Shah Nehar project is first major Irrigation project in Himanchal Pradesh. Presently, water is being supplied to 93 villages comprise of 15287 hectares Culturable Command Area (CCA) through several outlets provided in the main canal. From each outlet the water is transported by gravity or lift scheme to each chak proposed in the command area development. The water demand of each outlet is based on the cropping pattern proposed in the respective chak. The roster of water demand is based on the warabandi schedule prepared by the Irrigation & Public Health Department in consultation with Krishi Vikas Sangh/Water User Associations.

It is proposed to quantify available water at the head-works of the canal system during cropping period, estimation of irrigation water requirement for existing cropping pattern, assessment of losses at the conveyance, distribution and application of water in the command area. The study will be helpful in identification of the potential area which requires appropriate land and water management intervention for improvement of water use efficiency. Further the study will be useful in quantifying the potential of improvement in irrigation water use efficiency in the Shah Nehar command area.

The HP IPH Department has listed the problems of irrigation water management in the Shah Neha Project based on input received from the farmers, observations made during their field visits and consultation with specialized agronomists as follows:

- ✓ Non availability of water during peak demand of crops at the tail end of command area.
- ✓ No check over theft of water from the main canals.

- ✓ Irrigation systems play vital role for sustainable agricultural development in Himachal Pradesh, but major problem of which is rather low efficiency of water use.
- ✓ No accountability due to absence of water accounting & audits.

- ✓ Poor and low consistency management of the irrigation systems efficiency.
- ✓ Lack of reliable monitoring network and supervisory control for irrigation systems.
- ✓ Non availability of effective decision making tool to improve irrigation management.
- ✓ Huge water loss due to random irrigation process.
- ✓ Lack of awareness about modern and water efficient irrigation methods.

Proposed Methodology

The purpose of the proposed study is to examine the present status of the Shah Nehar Irrigation Project water use efficiency, quantify the water losses in the main canal system & distributaries, water courses and field application. Determination of time based crop water demand and supply for existing cropping pattern and identification of irrigation system components needing water management interventions to improve water use efficiency of system and maximize the benefit from the Shah Nehar project. The work component will include the following:

1. Monitoring of supply and distribution of water in conveyance, distributary outlets and the on form irrigation application at selected experimental sites.
2. Assessment of the real time availability of water at head works, at various outlets in the main canal and tail ends of distribution system during the Rabi, Kharif and Zaid crop period.
3. Assessment of site specific water requirement for suitable time-steps during cropping periods in different seasons
4. Devising a methodology regarding equitable distribution of water to the farmers in each crop period from head to tail reaches by using SCADA.
5. Develop a system of water supply database of quantum of water used to each beneficiary so the charges can be levied accordingly.
6. Devising a possible system of change in cropping pattern owing to real time monitoring of available water at various reaches of the canal.
7. Identification and evaluation of intervention to minimize water losses throughout the canal and distribution system, water courses and in the field application to enhance the water use efficiency.

From the data collection and analysis of the data, Water efficient Irrigation by using SCADA System will be provided so that water can be used more efficiently and hence it will increase the effectiveness of the Irrigation Project.

Progress of Work

The team NIH Scientist visited study area and conducted detailed survey of Shahnehar Project Command Area, along with Himachal Pradesh I &PHE department officials. Detailed plan for the selected experiment sites was prepared after discussion with I&PHE officials. after field survey to finalize the project modalities and work plan for the study. The pilot sites for detailed experimentation have been identified. Field investigation and instrumentation for field experimentation for the study has been finalization after meeting with the project team of the lead organization (I&PHE, Shimla) to setup monitoring schedule.

The irrigation command site for SCADA implementation has been finalized.

1. The meteororlogical data for the assessment of present irrigation requirement has been collected from BBMB meteorological station at pong dam site.
2. The estimation of Pet and the crop water requirement for the study has been worked out.
3. The Himachal Pradesh I &PHE department has been further requested to obtain data from Kangra Agriculture College/other stations in the vicinity of the project site.
4. The experimental sited identified are as follows:
   i. Lift Irrigation Scheme (LIS) Sthana, Terrac Sub-Division—for SCADA experimentation.
   ii. Selected sites/field plots in distributary-1 (D-1) command area –Badukhar Sub-Division -- for experimentation-1 in middle reaches.
   iii. Selected sites/field plots in distributary-2 (D-2) command area- for experimentation-2 in tail reaches.

5. Base maps for the study sites have been prepared.
6. Further field observation are being recorded for the study and analysis of various components of the project.

Deliverable:

1. Estimates of water availability at headwork's and irrigation water requirements for various crops a different growth stages & time period.

2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.

3. Identification of components of irrigation system needing intervention to enhance water use efficiency.

4. Experimental assessment of SCADA based approach in the enhancement of water use efficiency.

3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/17-19

Progress of Studies

1. Impact Assessment of Climate Change on the Water Resources and Agriculture in Banas basin in Western India using Climate Change Indicators (CII's)

The above international study of 18 months was taken up in Sept 2017 in collaboration with SMHI, Sweden (lead organization) and 12 other countries which has been funded by ECMWF (through SMHI, Sweden) with an objective of applying the products of GLORIOUS C3S Global Service for water resource and agriculture in an Indian basin. Based on the objectives, the Banas basin was taken up for the study. However, **the approval for signing the sub-contract with SMHI and transfer of funds to NIH has not been received. Therefore, NIH continues in the consortium as "In Kind Partner". The objectives of CII development and script writing will be taken up by the core team at SMHI with help from NIH**. During the last one year, the NIH team participated in various webinars listed below and carried out the stakeholder meetings in the field at various offices of Water resources department, Agriculture department of the government of Rajasthan.

- What is bias correction/adjustment and downscaling
- Why should we use bias adjustment/correction
- How to select appropriate bias correction and/or downscaling methods
- What methods can I use for bias correction/adjustment and downscaling
- What method was used in C3S Global Impact service
- Good practices and tips for interactive atlases
- Story map demo
- What is Quality assurance checklist (QUACK) and why should we use it
- How to implement Quality assurance checklist (QUACK)

Besides above webinars and stakeholder meetings, one team member also participated in the General Assembly of the project at SMHI, Sweden in April 2018.

4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/14-18

Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India

Title of Study: 'Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India'

Study Group: Dr. Ashwini Ranade, Scientist 'C' (Principal Investigator)

Role of Team members: completion of the project successfully

Type of Study: Sponsored Research

Sponsoring Agency: Science and Engineering Research Board (SERB), Department of Science and Technology, New Delhi

Budget sanctioned: 12.6 lakh

Date of Commencement: 17 October 2014

Scheduled date of completion: 25 Nov 2018

S**tudy Area:** The proposed work is for the Asia-pacific monsoonal regime (25^0- 150^0E; 25^0S 150^0N) with special emphasis on the Indian subcontinent.

Objectives:

1. To investigate underlying mechanism of intensification and weakening of Asia-Pacific monsoon circulation intensity in the backdrop of heterogeneous global temperature change.
2. Determination of commencement and cessation dates of monsoon circulation and start and finish of monsoonal rains.
3. To understand structure of the monsoon circulation associated with large-scale extreme rain events over and across India.

Statement of the problem:

Monsoon is one of the oldest observed weather phenomena noticed by seafarers globally. It is the prime weather system for the summer seasonal rainfall in tropical Asia-pacific region. The strongest monsoon is encompassed in the Indian sector. The earliest start of the *Asia-Pacific Monsoon* is over Southern Bay of Bengal in late April, then over south china sea and Indochina Peninsula in mid-May and Northeast India and South India in late May and then it progresses north and northwestward into the Indian subcontinent, lastly reaches Japan in late June and early July. The start and finish dates of the monsoon rains, popularly known as onset and withdrawal, is very valuable information for the water-related sectors like agriculture, water resource management etc. Several criteria have been proposed so far based on the meteorological parameters (wind, relative humidity, OLR, etc.) along with rainfall; parameters other than rainfall or only with rainfall to determine the start and finish of monsoon rains over different parts of the monsoonal regime. Some of the important parameters other than rainfall used for the declaration of the onset and withdrawal dates for India are e.g relative humidity, 850hPa zonal wind, OLR, mean tropospheric temperatures, wind shear, kinetic energy etc. Most of the objective criteria suggest climatological onset and withdrawal dates or onset date for Kerala only. Dates for the advancement of monsoon across the country is still not resolved satisfactory. In addition to start and finish, rainfall amount and its space-time distribution is also of great significance for the people working in operational meteorology, hydrology, water resources and Agricultural sectors. For the country like India, start of the monsoonal rains, its advancement and duration of the season shows large variations from one area to other. A uniform robust objective

criterion for the determination of start and finish of monsoon rains across the country is challenging task due to segregation of pre and post monsoon rainfall and avoiding bogus onset.

Objectives vis a vis Achievements:

Sr. No.	Objectives	Achievements
1.	To investigate underlying mechanism of intensification and weakening of Asia-Pacific monsoon circulation intensity in the backdrop of heterogeneous global temperature change.	Under Progress
2.	Determination of commencement and cessation dates of monsoon circulation and start and finish of monsoonal rains.	Completed/ under submission
3.	To understand structure of the monsoon circulation associated with large-scale extreme rain events over and across India.	Completed/published

Analysis and Results:

Routine observations of real-time daily weather charts revel that, large-scale atmospheric general circulation parameters show significant transformations in their values from one season to another. They can be used as indicators for the onset and withdrawal of monsoon circulation across Asia-Pacific. After detailed monitoring of the annual cycle of the large-scale atmospheric parameters, a five-stage approach has been suggested for the yearwise commencement and cessation dates of monsoon circulation and monsoonal rains over 19 subdivisions of India. NCEP Climate Forecast System Reanalysis (CFSR) 6 hourly products from 1979-2016 at 2.5X2.5 degree resolution (Temperature, Geopotential height, U and V wind at 12 isobaric levels, Mean sea level pressure, and Precipitable water) and 0.25 degree gridded rainfall data from India Meteorological department are used in this study.

1. Structured 5-Level Approach to Commencement and Cessation

We understand that, Monsoon evolves in association with spreading and intensification of equatorial atmospheric condition (warm-moist-low pressure with lower tropospheric convergence and warm-high upper tropospheric divergence). For the development of the criteria, normal daily charts of equatorially-conditioned (difference from corresponding equatorial value of each grid cell) parameters (temperature, geopotential height, wind speed at 12 isobaric levels, precipitable water and mean sea level pressure) have been prepared.

Starting from the commencement of effective summer(winter) over northern(southern) hemisphere (effective NH-SH contrast and effective warming of Tibetan plateau), spreading of the favorable global weather regime conditions from surface to troposphere, attainment of effective Indian monsoon condition (equatorial weather condition) over the subregions to the occurrence of monsoon rains, a five-stage approach (subjective and numerical) has been suggested to determine robust start and end dates of monsoon circulation and monsoon rains over 19 subdivisions of India.

(1) *Quantitative determination of start and end of effective global atmospheric condition*:
Tropospheric temperature-thickness index (TZI) has been developed with the combination of standardized tropospheric temperature and thickness in order to determine the effective seasonal transition across the globe. Effective summer over NH, winter over SH, effective NH-SH contrast and effective warming over the Tibet are said to be attended when the corresponding TZI exceeds ±0.5 (Fig1). The latest start of the above four seasonal transitions are considered as the date for the robust effective start for the effective global atmospheric thermal structure (EGATS), and earliest of above four dates as robust effective finish of the EGATS.

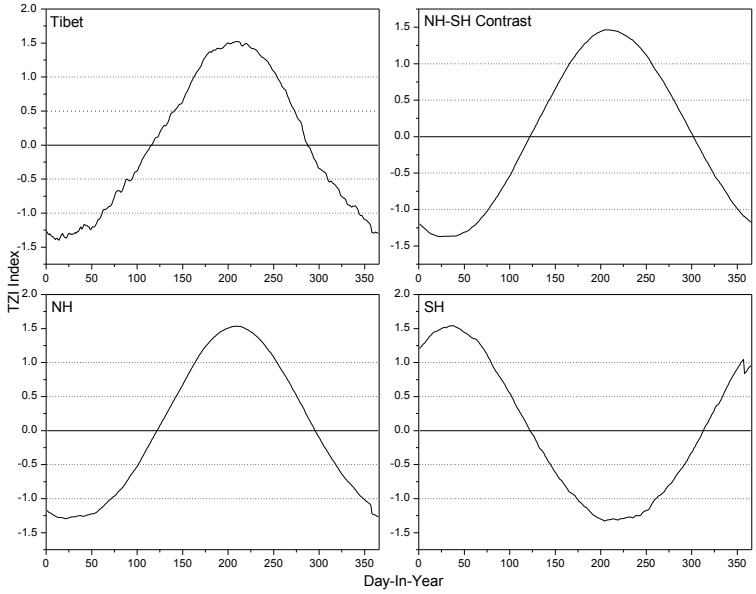


Fig.1 Normal annual cycle of Tropospheric temperature-thickness index (TZI)

(2) Qualitative analysis of charts showing global weather regimes (GWRs), streamlines and globally-conditioned wind speed (difference from global mean)

Global weather charts showing four different types of GWRs (combination of equatorially conditioned temperature and geopotential height), streamlines and GC-windspeed at different isobaric levels are monitored on daily basis in order to mark the area under warm-moist-low pressure area with lower tropospheric convergence and warm-high upper tropospheric divergence representative of arrival of monsoon circulation. Continuous monitoring of the spreading of GWRs at all levels is required in order to define area under large-scale monsoon circulation system.

(3) Qualitative analysis of charts showing area under effective Indian monsoon condition

Area under monsoon condition across the globe on daily basis has been demarcated after the satisfaction of the more than intense equatorial condition in the following parameters:

i) lower tropospheric temperature (1000-700hPa), EC-T_{LTT} >0;
ii) precipitable water, EC-PPW >0;
iii) pressure, EC-mslp < 0; and
iv) 600 hPa geopotential height, EC-Z_{600} <0.

Continuous real-time monitoring of the area under monsoon condition across the globe is necessary to determine robust dates for start and end of effective monsoon circulation and monsoon rains over different parts of the country. Fig.2 shows the normal area under monsoon condition, superimposed on 600-hPa streamlines across Indian subcontinent during monsoon season.

(4) Quantitative determination of commencement and cessation of Indian monsoon condition over 19 subdivisions across India

Latest date of the accomplishment of the four criteria mention in stage 3 individually for each subregion gives the start date for the commencement of Indian monsoon condition and non-occurrence of the above along with the monitoring of the ATS qualitatively marks the cessation date of monsoon activity over a particular subregion.

(5) Quantitative determination of start and end dates of Indian monsoon rains across 19 subdivisions.

After satisfaction of the all above conditions, region specific purpose driven (agricultural, hydrological, meteorological etc.) rainfall threshold can be used for the determination of start and end dates of effective monsoon rainfall.

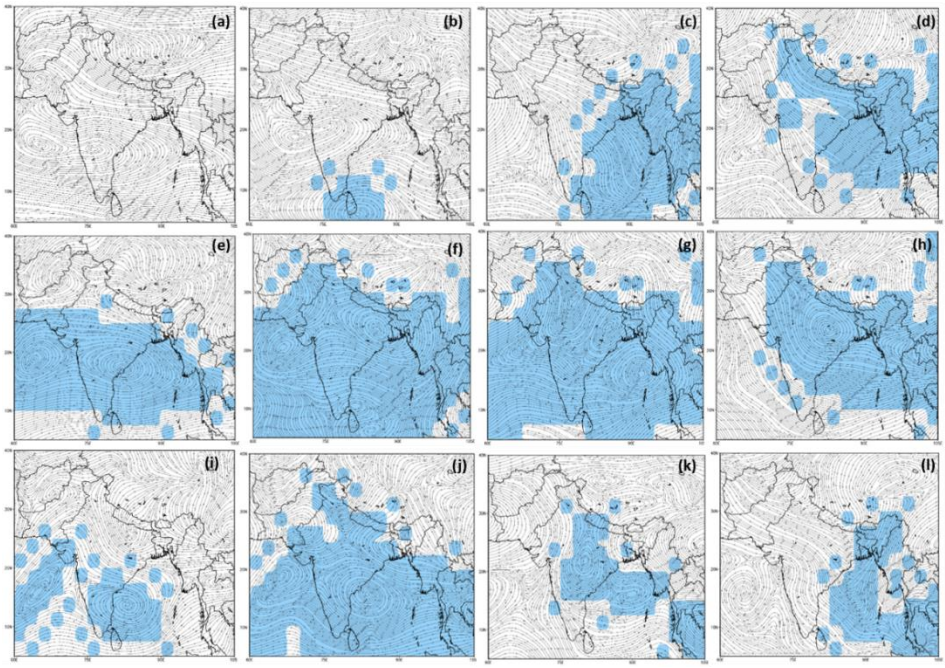


Fig.2 Area under monsoon condition; aqua blue shaded), and 600-hPa streamlines across Indian subcontinent from a)30 April through l)15 October at fortnight interval normally.

2. Important results:

1. Normally, robust effective global atmospheric thermal condition established on 30 May (± 4 days) and finishes on 28 September (±5 days).
2. Normally, monsoon condition sets-in first over Tamilnadu region on 31 May and latest on 19 June over Rajasthan region.
3. Monsoon condition finishes from Rajasthan subregion on 10 September, Kerala 22 September and southern East Coast 27 September. Standard deviation of interannual variation of starting (ending) date of the monsoon condition is 6 days (7 days) across the country.
4. Monsoon rains starts on 31 May over Tamilnadu region, and 20 June over Rajasthan region. Monsoon rains ceases from Rajasthan around 7 September, and from kerala 17 September. Standard deviation of starting and ending dates of the monsoon rains across the country is 7 days and 9 days respectively.

Adopters of the results of the study and their feedback:
Operational Forecasters, Agencies in water related sector

Major items of equipment procured:
i) Workstation**; ii)** Printer; iii) UPS

Lab facilities during the study: None

Data generated in the study:
Climatological and Yearwise start and end dates of summer monsoon over 19 subdivisions of India during 1979-2015.

Study Benefits/Impact:
The results from this study will be helpful in order to develop operational forecasting scheme for the start and end of monsoon rains across the country. The study will also give insight about the relationship between occurrences of extreme rain events and changes in general circulation features in order to cope up their consequences in advance.

Specific linkages with Institutions/beneficiaries: None

Shortcomings/Difficulties: Shortage of high resolution observed data of meteorological parameters in order to validate the results

Future Plan: Development of 'Users friendly, near real-time global weather monitoring system'.

ONGOING INTERNAL STUDIES

5. PROJECT REFERENCE CODE: NIH/SWHD/NIH/17-21

Title of Study: Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin Subzone 3(f)

Study Group - Sanjay Kumar, Sc-E, PI
Rakesh Kumar Sc-G, Co-PI
J. P Patra Sc 'C'
Pankaj Mani, Sc 'E'

Objectives of the study: The objectives of the study are:

- To develop regional relationships for (surface) water availability analysis.
- Development of at site and regional flood frequency analysis using L Moments.
- Development of at site and regional rainfall frequency analysis using L moments.
- Development of regional relationships for Nash and Clark IUH models parameters.
- Impact of climate change on flood estimates.

Statement of the problem:

The surface water availability analysis is the foremost task for planning any project on a river. Accurate estimation of the total quantity of surface water availability and its variation is important for the success of any project. Depending on the type of data availability different methods and regional relationships would be used/ developed for water availability computations.

The study would also estimate design flood for various return periods needed for different types of water resources structures. These structures are often planned in regions with less or no hydro-metrological information/data. Studies carried out for such conditions are limited and based on various types of conventional techniques. This study specifically focuses on developing design flood estimation methods for such partially gauged or un-gauged regions based on the concept of regionalization. In regions where only rainfall data is available, the study would carry out at-site and regional rainfall frequency analysis using L-moments. The study would also develop relationship between mean annual peak floods and physiographic characteristics of the basin and develop regional relationships for NASH and Clark IUH model parameters. These developed relationships would finally used for estimation of floods of various return periods. The impact of climate change on flood estimates would also be evaluated.

Methodology:

For estimation of T-year return period flood at a site, the estimate for mean annual peak flood is required. For gauged catchments, such estimates can be obtained based on the at-site mean of the annual maximum peak flood data. At-site and regional flood frequency analysis will be performed using the L-Moments approach, which includes various frequency distributions: viz. Extreme value (EV1), Generalized extreme value (GEV), Logistic (LOS), Generalized logistic (GLO), Normal (NOR), Generalized normal (GNO), Uniform (UNF), Pearson Type-III (PE3), Exponential (EXP), Generalized Pareto (GPA), Kappa (KAP), and five parameter Wakeby (WAK). Screening of the data, testing of regional homogeneity and identification of distribution will be carried out.

However, for ungauged catchments at-site mean cannot be computed in absence of the flow data and in such a situation, a regional relationship between the mean annual peak flood of gauged catchments in the region and their pertinent physiographic and climatic characteristics is needed for estimation of the mean annual peak flood. For example, the form of this regional relationship may be:

$$\overline{Q} = a\, A^{b} S^{c} D^{d} R^{e}$$

Here, ($\overline{Q}$) is the mean annual peak flood, A is the catchment area, S is the slope, D is the drainage density, R is the annual normal rainfall or rainfall for the duration of annual maximum peak flood for the catchment etc., a, b, c, d, and e are the regional coefficients. Further, relationship of various other characteristics like length of main stream (L), centroidal longest flow path (L_c) etc. with peak flood will also be evaluated. The regional coefficients will be estimated using the mean annual peak floods of the gauged catchments and their pertinent physiographic and climatic characteristics for a region. The physiographic and climatic characteristics which are considered pertinent for generation of annual maximum peak floods from a catchment and can be obtained from the observed records e.g. rainfall for the duration of occurrence of the annual maximum peak floods and derived from the toposheets/maps of the gauged catchments may be considered for development of this relationship. Downscaled climate change projections would also be used for evaluation of impact on flood estimates.

Deliverables

- Regional relationships for water availability analysis,
- Flood estimates for various return periods for gauged catchments.
- Regional Relationship between mean peak floods of various return periods with catchment characteristics.
- Regional Relationships for estimation of floods of various return periods for un-gauged catchments.
- Regional relationships for Nash and Clark IUH model parameters.
- Impact of climate change on flood estimates.

Research papers and Report

Progress

Hydro-meteorological data at various gauging sites in this basin is being collected from various agencies. Secondary data from other sources such as Flood Estimation Reports, PMP atlases and similar studies in other basins, is also being collected. Compilation and statistical analysis of the collected data is under progress. L moments for annual maximum series at some sites have been estimated for at-site frequency analysis.

6. PROJECT REFERENCE CODE: NIH/SWHD/NIH/15-19

1. Title of the Project - Study of hydrological changes in selected watersheds in view of climate change in India.

2. Project team:

a. Project Investigator : Dr. L. N. Thakural, Sc-C, PI
b. Co-PI Project Co-Investigator(s) : Er. D. S. Rathore, Sc-F
Dr. Surjeet Singh, Sc-D
Dr. Sanjay Kumar Jain, Sc-G
Dr. Sharad Kumar Jain, Sc-G

3. Objectives-

- Development of database related to hydro-meteorological data.
- Long-term spatio-temporal analysis of hydro-meteorological variables.
- Assessment of variation in surface water and groundwater availability.
- Spatial variation of Ground water levels.
- Drought characterization.
- Climate change scenarios/analysis.
- Inter-comparison of water resources variability in selected basins and suggestions for IWRM.

4. Present state-of-art

The climate of earth has never been stable for any extended period but varying naturally on all time scales. Climate change has greatly affected the characteristics of climatic variables globally. These changes are not uniform but vary from place to place or region to region. Probable climate change and its perilous impacts on the hydrologic system pose a threat to global fresh water resources and aquatic ecosystems worldwide.

The present study is envisaged in this context to take up the study on the assessment of hydrological changes in different watersheds in India under changing environment.

5. Methodology-

- Literature survey on the guidelines and pre-requisites for the selection of watersheds.
- GIS database development.
- Field visits for ground truth and data collection of exiting hydro-meteorological and groundwater related data and processing of data.
- Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches.
- Application of lumped conceptual rainfall-runoff model (NAM) for assessment of surface and ground water availability.
- Computation of SPI, hydrological drought indices, analysis of change in rainy days.
- Downscaling of meteorological data, generation of climatic scenarios based on IPCC-SRES using actual data
- Impact of climate change on streamflow using statistically downscaled data for each catchment
- Inter-comparison of watersheds and suggestion for irrigation water management.

6. Research outcome from the project

The outcome of the study will help in assessment of water resources availability and impact of climate change at basin scale.

7. Progress of Work

Four different watersheds located in different climatic regions namely Dhadhar river basin (Gujarat), Ramganga up to Kalagarh (Uttarakhand), Bina River basin (M.P) and Chaliyar river basin (Kerala) as shown in Figure 1. have been selected for the present study. The hydro-meteorological data pertaining to the four river basins namely Ramganga, Bina, Chaliyar and Dhadhar have been processed to meet out different objectives of the study. The various inputs for the hydrological model such as Digital Elevation Model (Dem), landuse/landcover, soil map etc. have been prepared.

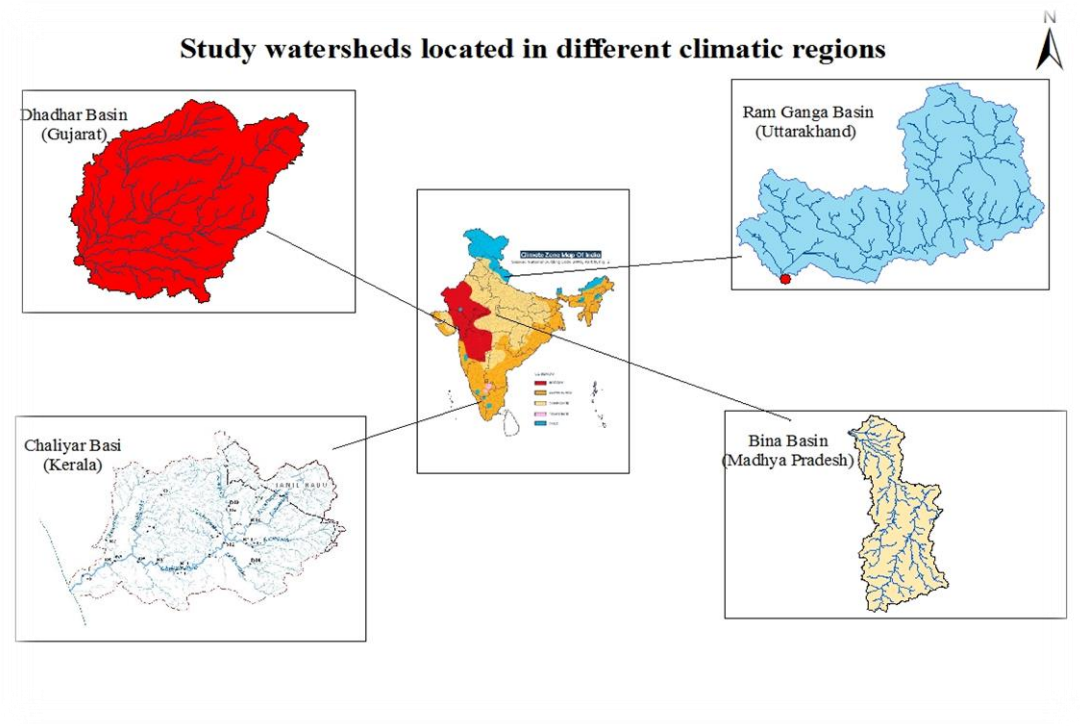


Figure 1: Study watersheds located in different climate regions of India

Digital elevation models (DEMs) are grid-based GIS coverages that represent elevation. Downloaded DEM was processed for removal of sinks, thereafter the filled DEM has been used to generate the flow direction, flow accumulation maps in the GIS environment for the delineation of drainage networks and watershed boundaries for the four watersheds. Moreover, land use/land cover, soil map etc. thematic maps esstential for the modeling have also been prepared for the study areas. Statistical methods for spatio-temporal temporal analysis of meteorological data using parametric and non-parametric approach have been applied to determine the trends in the rainfall time series. Moreover, spatial variation of ground water levels along with drought characterization for the river basins have been carried out. The hydrological models (NAM and SWAT) have been setup for the river basins.

8. Progress since last working group

Input databse namely Landuse/landcover, DEM, Soil/Satellite data for the Dhadhar basin has been completed. The hydrological model have been calibrated and validated for the Dhadhar river basin. Grided data of rainfall and temperature of IMD of four watresheds have been prepared for downscaling using SDSM. Moreover, downloaded Canadian Earth System Model (CanESM2) scenarios for the study area.

7. PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-21

1. Title of the study: Development of regional methods for design flood estimation in Uttarakhand.

2. Study group: J. P. Patra, Sc. 'C'; Dr. Rakesh Kumar, Sc. 'G' & Head, Pankaj Mani, Sc. 'E', CFMS, Patna; Sanjay Kumar, Sc 'E'
Technical assistance: T. R. Sapra, RA.

3. Duration of study: 3 Years (April 2017 to March 2020) : Ongoing

4. Type of study: Internal.

5. Location map

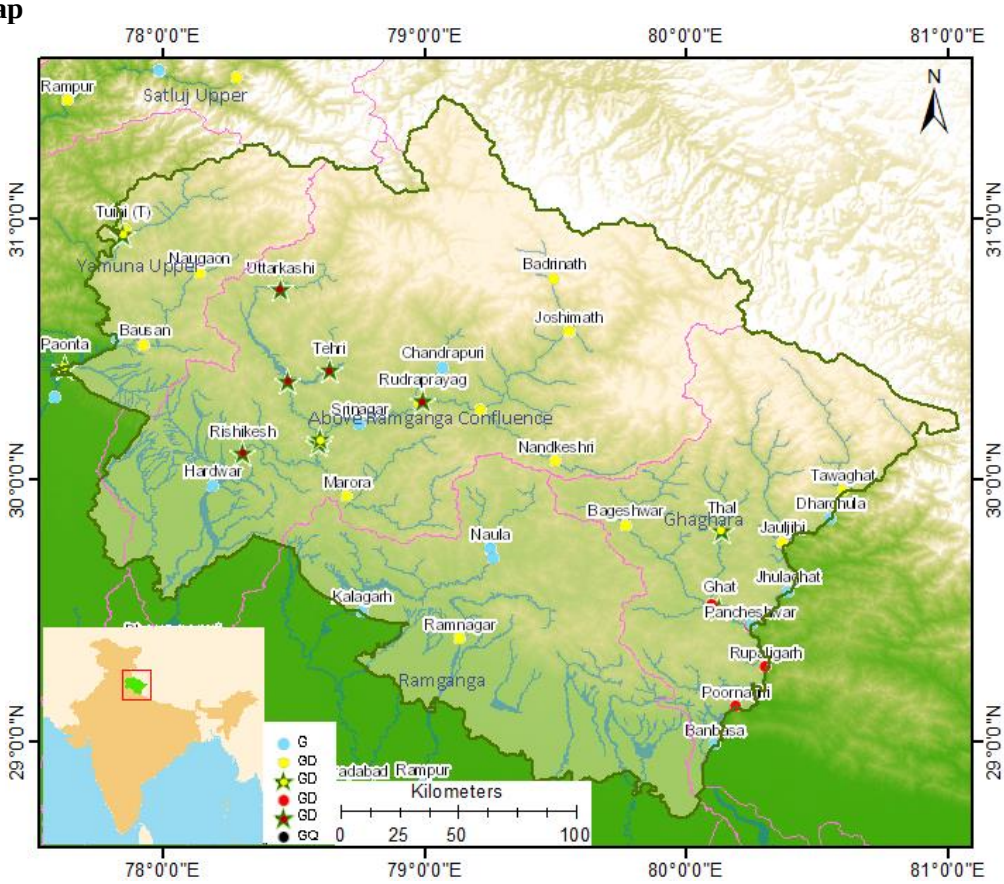


Fig. 1: Location map of study area.

6. Study objectives:

a) Development of at-site flood frequency relationships using L-moments.
b) Development of at-site and regional flood frequency relationships using L-moments.
c) Development of regional relationships between mean annual peak floods and physiographic and climatic characteristics.
d) Development of at-site rainfall frequency relationships using L-moments using point rainfall data.
e) Development of at-site and regional rainfall frequency relationships using L-moments using gridded rainfall data of various sources.
f) Development of regional relationships for the Nash and Clark IUH model parameters.
g) Estimation of floods of various return periods for Ganga basin in Uttarakhand.
h) Development of flood frequency relationships under climate change scenarios.

7. Statement of the problem

The commonly used design floods estimation approaches can be categorized as: flood formulae, flood frequency analysis and hydrometeorological approach (CWC, 2010). Various empirical flood formulae have been developed for regions. These include Dicken's, Ryve's, Nawab Jung Bahadur, W P Creager's, Jarvis f, Modified Myer's etc. When long term and short term rainfall and runoff records are not available the design flood is obtained using these formulae. However, the value obtained from these can only be used for preliminary estimates for small catchments and the concept of return period flood is generally not included in this approach. The flood frequency approach can be adopted in case data of peak floods series are available for a longer period of time. In, Indian generally Gumbel or Generalized Extreme Value (GEV) distributions are fitted to the peak flood series without considering other available frequency distributions. Flood estimation reports for various sub zones have been prepared with joint efforts of Central Water Commission (CWC), India Meteorological Department (IMD) and Research Design and Standards Organisation (RDSO) of Ministry of Railways and Ministry of Surface Transport (MOST) for estimating design floods of 25, 50 and 100 year return periods for design of waterways, bridge, culverts etc having small and medium catchments where hydrological data are inadequate or totally absent. Recently, PMP atlas for various basins of India has been developed by CWC and IMD for assessment of design storm as required in the assessment of design flood for any water resources development project. The point rainfall at various raingauge stations are analysed and rainfall of various return periods have been estimated by fitting a two parameter Gumbel frequency distribution. Various new techniques of flood frequency analysis are being developed by various researchers for selecting candidate frequency distribution, parameter estimation etc. (L-Moments, PWM etc.). There is a need to use better parameter estimation technique for estimation of parameter of candidate distribution.

In India for many catchments, stream flow data are not available or the data are inadequate at the site of interest. In such cases the methods of frequency analysis using data from a single site have limited applicability because of large sampling errors, and as a result, regional flood frequency analysis is performed. The various commonly used methods of regional flood frequency analysis are: USGS method, Pooled curve method, analytical method and L-moments approach. Hosking and Wallis (1997) presented the L-Moments based regional frequency analysis approach. The authors mention that regional flood frequency analysis resolves the problem of short data records or unavailability of data by "trading space for time"; as the data from several sites are used in estimating flood frequencies at any site. Kumar et al. (2003, 2005, 2015) applied L-moments approach for development of regional flood frequency relationships for some of the regions of India. Komi et al. (2006) carried out regional frequency analysis based on L-moments and identified three homogeneous based on cluster analysis and a homogeneity test. Finally, regression models of the mean annual flood with the size of the drainage area, mean basin slope and mean annual rainfall are proposed to enable flood frequency estimation of ungauged sites within the basin. Design flood estimates in the United Kingdom are routinely obtained by using the improved Flood Estimation Handbook (FEH) statistical procedure (Kjeldsen, 2015). The author assessed uncertainty of design flood estimates at ungauged catchments for a range of return periods. The results show that the inclusion of data from nearby gauged catchments increases the reliability of the estimates when compared to an automated application of the improved FEH methods relying on catchment descriptors only. Analysis of 190 storm events in seventeen small Northern Ireland catchments, along lines developed by the UK Institute of Hydrology, shows that the time-to-peak of the instantaneous unit hydrograph can be estimated from catchment characteristics and from the time between the centroid of mass of a flood-producing rainfall event and of the resulting peak flow, but that equations calibrated on British data overestimate the time-to-peak (Gardner and Wilcock, 2003). This might be due to the distinctive hydrology of Northern Ireland. Kumar et al. (2007) developed geomorphological instantaneous unit hydrograph (GIUH) based Clark and Nash models and applied for simulation of the direct surface run-off (DSRO) hydrographs for ten rainfall-runoff events of the Ajay catchment up to the Sarath gauging site of eastern India. The GIUH is derived from the geomorphological characteristics of a catchment and it is related to the parameters of the Clark instantaneous unit hydrograph (IUH) model as well as the Nash IUH model for deriving its complete shape. Inter comparison of the performances of the GIUH based Clark and Nash models shows that the DSRO hydrographs are estimated with comparable accuracy by both the models.

Over the year, efforts have been made toward regionalisation of catchment model parameters of various complexity and scale (Seibert, 2009; Merz and Blöschl, 2004; Littlewood, 2004; Heuvelmans et al., 2006; Bastola et al., 2008; Bárdossy and Singh, 2011; Beck et al, 2016). A comparison of regionalisation methods for catchment model parameters is provided by Parajka et al., (2005). Hydrologic model parameters obtained from regional regression equations are subject to uncertainty. Consequently, hydrologic model outputs based on the stochastic parameters are random. The uncertainty associated with linear reservoirs (N) and storage coefficient (K) of Nash's IUH are assessed by various researchers. The uncertainty from regional regression equations is some time too significant to be ignored (Yeh et al., 1997). The assumption of the parameter K having the same value in all reservoirs is obviously unphysical as it results in the estimated value of N not being integral (Li, et al. 2008). Seong et al. (2007) proposed a practical approach to determining a regionalized Clark instantaneous unit hydrograph (IUH) model in limited data availability condition. The proposed model is described in terms of the synthetic time–area concentration curve, the concentration time, and a special regional similarity value that is valid in the whole basin. By introducing the regional similarity value into a Clark IUH, a statistically best estimate of IUH for given data conditions and its quantified degree of uncertainty were realized. Application of the model to Wi River basin in Korea showed a reliable estimation of hydrograph within the study area even with limited data availability. Considerable work has been done to estimate flood characteristics and long-term mean annual flow using regression relationships with catchment parameters in Indian, but most of these methods were developed a long time ago and may need to be revisited Jha and Smakhtin (2008). Goel (1998) presented the details of flood estimation procedures for Indian catchments in general and for mountainous watersheds in particular

8. Approved action plan and timeline

S.N.	Work Element	1st Year	2nd Year	3rd Year	Status
1	Collection of hydro meteorological data, satellite images, thematic maps etc.				Under Progress
2	Compilation, statistical analysis of rainfall and river discharge				Under Progress
3	At-site frequency analysis for point rainfall and gridded rainfall data				Under Progress
4	Regional frequency analysis for point rainfall and gridded rainfall data				Under Progress
5	Preparation of isopluvials maps for various return periods.				Yet to start
6	At-site and regional flood frequency analysis for gauged catchments				Under Progress
7	Estimation of catchment characteristics and parameters of UH				Yet to start
8	Development of regional relationships for peak floods with catchment characteristics.				Under Progress
9	Rainfall frequency relationships under climate change scenarios				Yet to start
10	Report				

9. Role of team members

S. N.	Role / Action	Member/(s)
1	Collection of hydro meteorological data, satellite images, thematic maps etc.	JPP, RK, SK, TRS
2	Compilation, statistical analysis of rainfall and river discharge	JPP, SK , TRS
3	At-site frequency analysis for point rainfall and gridded rainfall data	JPP, RK
4	Regional frequency analysis for point rainfall and gridded rainfall data	RK, JPP, SK

5	Preparation of isopluvials maps for various return periods.	JPP, RK ,PM
6	At-site and regional flood frequency analysis for gauged catchments	RK, JPP,SK
7	Estimation of catchment characteristics and parameters of UH	PM, JPP, SK
8	Development of regional relationships for peak floods with catchment characteristics.	RK ,JPP,SK
9	Rainfall frequency relationships under climate change scenarios	RK ,JPP,SK
10	Report	JPP, RK, PM, SK

JPP = J. P. Patra, RK = Dr. Rakesh Kumar, PM = Pankaj Mani, SK = Sanjay Kumar, TRS =T. R. Sapra

10. Brief Methodology

This study aims at development of at-site and regional flood frequency relationships using L-moments approach for Uttarakhand state (Figure 1), perticularlly in Ganga basin up to Rishikesh. For estimation of T-year return period flood at a site, the estimate for mean annual peak flood is required. For gauged catchments, such estimates can be obtained based on the at-site mean of the annual maximum peak flood data. At-site and regional flood frequency analysis will be performed using the L-Moments approach, which includes various frequency distributions: viz. Extreme value (EV1), Generalized extreme value (GEV), Logistic (LOS), Generalized logistic (GLO), Normal (NOR), Generalized normal (GNO), Uniform (UNF), Pearson Type-III (PE3), Exponential (EXP), Generalized Pareto (GPA), Kappa (KAP), and five parameter Wakeby (WAK). Screening of the data, testing of regional homogeneity and identification of distribution will be carried out. However, for ungauged catchments at-site mean cannot be computed in absence of the flow data and in such a situation, a regional relationship between the mean annual peak flood of gauged catchments in the region and their pertinent physiographic and climatic characteristics is needed for estimation of the mean annual peak flood. For example, the form of this regional relationship may be:

$$\overline{Q} = a\, A^{b} S^{c} D^{d} R^{e}$$

Here, ($\overline{Q}$) is the mean annual peak flood, A is the catchment area, S is the slope, D is the drainage density, R is the annual normal rainfall or rainfall for the duration of annual maximum peak flood for the catchment etc., a, b, c, d, and e are the regional coefficients. Further, relationship of various other characteristics like length of main stream (L), centroidal longest flow path (L_c) etc. with peak flood will also be evaluated. The regional coefficients will be estimated using the mean annual peak floods of the gauged catchments and their pertinent physiographic and climatic characteristics for a region. The physiographic and climatic characteristics which are considered pertinent for generation of annual maximum peak floods from a catchment and can be obtained from the observed records e.g. rainfall for the duration of occurrence of the annual maximum peak floods and derived from the toposheets/maps of the gauged catchments may be considered for development of this relationship. The lengths of historical data records are very less, particularly in hilly areas. Considering this aspect frequency analysis using L-moments will be carried out using gridded rainfall data of various sources (IMD, APHRODITE) and will be compared. Regional Nash and Clark IUH models will be developed for Uttarakhand. Floods of various return periods for selected locations of Ganga basin in Uttarakhand will be estimated.

This study will also investigate the consequences of using a stationary assumption as well as the alternative: a non-stationary framework that considers temporal changes in statistics of extremes base on characteristic of time series. The estimates for various return periods using non-stationary i.e. General Extreme Value distribution with time-dependent parameters will be analysed. In addition, it is planned to analyse an ensemble of reference periods (past and future events) for rainfall frequency analysis. The future periods would be obtained various downscaled models. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset comprised of downscaled climate scenarios derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5) and across RCP 4.5 and RCP 8.5 from the 21 models. The spatial resolution of the dataset is 0.25 degrees (~25 km x 25 km) and the periods from 1950 through 2005 (Retrospective Run) and from 2006 to 2099 (Prospective Run). The World Climate Research Programme (WCRP) Coordinated Regional Climate Downscaling Experiment (CORDEX) dataset for South Asia region are derived from the Atmosphere-Ocean coupled General

Circulation Model (AOGCM) runs conducted under the CMIP5 for RCP 4.5 and RCP 8.5. The CORDEX South Asia dataset includes dynamically downscaled projections from the 10 models for about 50 km regional climate change projections.

11. Results achieved with progress/present status

The peak annual maximum flood series data of ten gauging sites are collected from CWC (Figure 2). The box plot of annual peak flood at ten gauging sites is shown in Figure 3. At site flood frequency analysis is carried to estimated design floods of various return periods at these locations using L-moments approach. The estimated floods of 50 year and 100 year return period along with observed maximum discharge plotted against catchment area for three locations is shown in Figure 4. Further, power equation in the form of $Q_T = a_T \times A^{b_T}$ is also fitted to estimate T-year design flood (Q_T) with catchment area of known A. Daily station rainfall data of 33 raingauge stations are collected from IMD along with gridded rainfall data from 1901 to 2013. The location of raingauge stations and box plot of 1day annual maximum rainfall is shown in Figure 5. These datasets are being analysed for various statistical properties and annual maximum rainfall series are extracted for rainfall frequency analysis. The APHRODITE monsoon Asia Precipitation grided daily data from 1951 to 2007 are also downloaded. Both at site and regional rainfall frequency analysis is in progress using a stationary assumption.

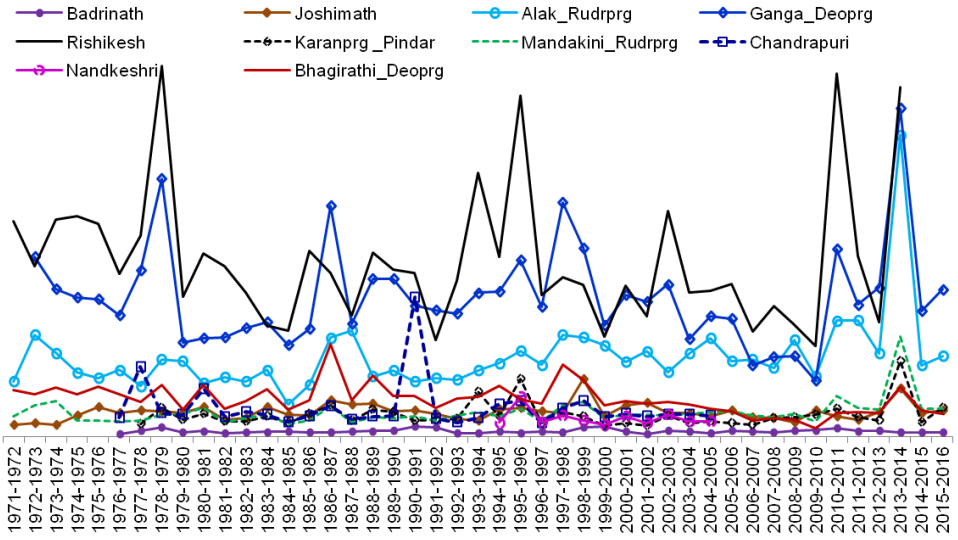


Fig. 2: Observed annual maximum flood series.

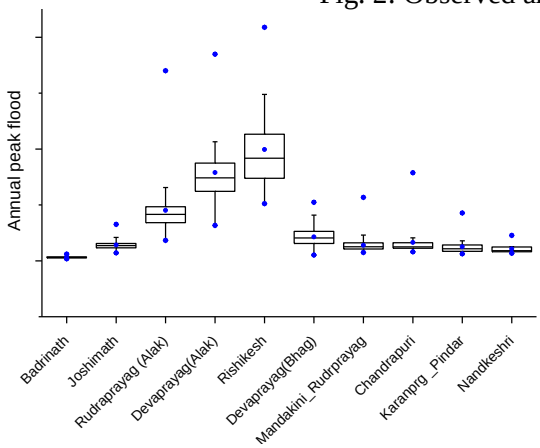


Fig. 3: Box plot of annual peak flood

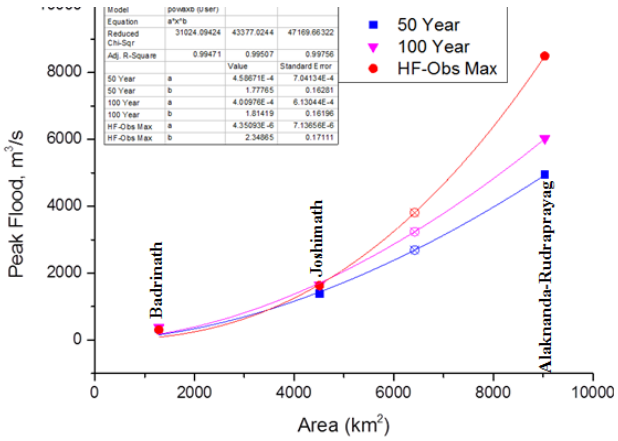


Fig. 4: Floods of various return periods

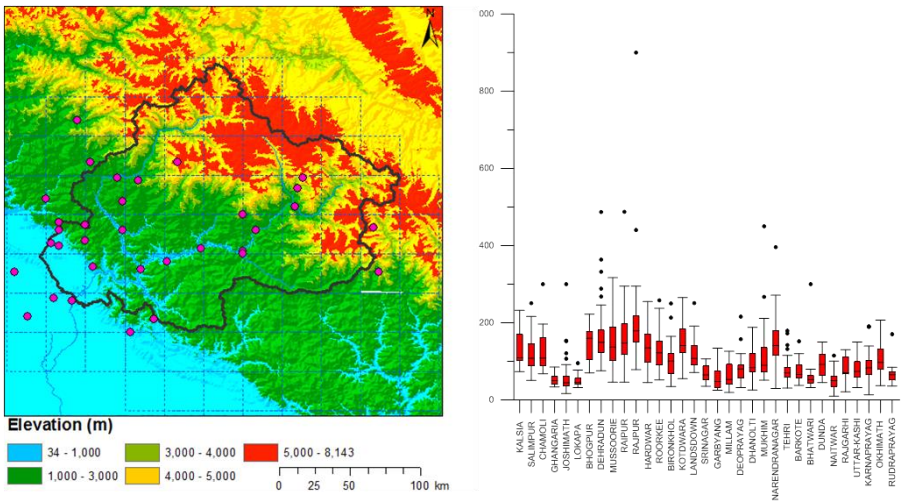


Fig. 5: Location of raingauge stations and 1 day annual maximum rainfall

12. Action taken on comments of previous working group meeting

There were no specific comments.

13. List of deliverables

- Design floods of various return periods at river gauging locations.
- Isopluvial maps of various return periods (Viz. 10 year, 25 year, 50 year, 100 year etc.) for Uttarakhand.
- Assessment of usefulness and limitation of gridded rainfall data for estimation of rainfall for various return periods.
- Development of relationships between mean peak floods of various return periods with catchment characteristics.
- Research papers and reports.

14. Data collected/generated

- DEM of the study area is 90 m SRTM and 30 m CartoSat.
- Peak annual maximum flood series for ten gauging sites.
- 0.25 x 0.25 deg grided daily rainfall data from 1901 to 2013 from IMD
- 0.5° and 0.25° grided, daily data from 1951 to 2007 from APHRODITE monsoon Asia Precipitation data.
- Daily rainfall data of 33 raingauge stations.

15. Involvement of end users/beneficiaries

The study has been proposed with after discussion with Irrigation department of Uttarakhand. It is expected that outcome of study will be helpful for estimation of design floods for various water resources projects.

8. PROJECT REFERENCE CODE: NIH/SWD/NIH/18-21

Thrust area under XII Plan: Impact of climate change on water resources and hydrology of extremes

Title of the Project: **'Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario'**

Project team: Dr. Ashwini Ranade, Scientist 'C'(PI)
Dr. Archana Sarkar. Scientist 'D'(Co-PI)

Type of Study:

Status: ongoing

Duration: 3 years

Date of Start: 1 April 2018

Scheduled date of completion: 31st March 2021

Objectives

1. Updation of longest instrumental area averaged monthly rainfall series (1813-2000) of 11 major and 36 minor river basins of India and to document climatological and Fluctuation features of annual, seasonal and monthly rainfall
2. Time series modeling of the longest instrumental monthly rainfall series (1813-2015) of major and independent minor river basins for their extrapolation for 2 to 10 years
3. Identification of different types of seasonal extreme rain events concerning rainfall amount, rainfall intensity and duration over four homogenous rainfall zones of India during 1951-2015.
4. Evaluation of 3D global atmospheric parameter changes conducive for the occurrence of large-scale extreme rain events over seven homogeneous rainfall zones during different seasons.

Statement of the problem

Asymmetric global tropospheric temperature patterns over the last few decades have been observed to make spatiotemporal distribution of global rainfall. Potential climate change and its impacts on rainfall distribution pose a threat to water resources throughout the world. The Intergovernmental Panel on Climate Change (IPCC) concluded that, the Indian subcontinent will be adversely affected by enhanced climate variation, rising temperature, and substantial reduction in summer rainfall with water stress in some areas by 2020. Annual, seasonal, and monthly rainfall across India shows strong spatiotemporal variation and large departures from normal. Many of the studies show an overall decreasing trend in monsoonal rainfall over a major part of the country. However, in our earlier studies, we did not find any significant long term trends in wet season parameters of 11 major and 36 minor basins, but noticed a declining tendency in wet season rainfall in some major basins of the Central India. In a monsoon season, extreme events occur surprisingly even during large-scale drought years also. So there is pressing need in hydrology, to better understand the ongoing changes in hydro-meteorological extremes in order to comprehend the impact of climate change on water resources in different parts of the country. Recent understanding through global climate models predicts that, the hydrological cycle will accelerate as climate warms, and leads to changes in patterns of extreme floods and droughts. We have seen that, the small-scale, short-duration EREs are embedded in large-scale, long-period intense wet spells, and rainwater generated during the main monsoon wet period is highly correlated with the Asia-Pacific monsoon intensity. Abrupt warming and cooling in the atmosphere drastically modulates the monsoon circulation and intensify the associated weather systems causing heavier rains over a region. Types of weather systems and

general and monsoonal circulation associated with the occurrence of extreme rain events in different parts of the country could be different.

Keeping in mind recent changes in global surface temperature, monsoon circulation pattern, and occurrence of EREs, the aim of the present study is to understand the nature of short-term to long-term rainfall variability across river basins of India using the area averaged longest instrumental basin scale rainfall dataset (1813-2015) and to determine the causal factors of the dominant modes of its variability.

Objectives vis a vis Achievements:

Sr. No.	Objectives	Achievements
1.	Updation of longest instrumental area averaged monthly rainfall series (1813-2000) of 11 major and 36 minor river basins of India and to document climatological and Fluctuation features of annual, seasonal and monthly rainfall	Under progress

Dataset used:

1. The longest instrumental area-averaged monthly rainfall series for 11 major river basins and 36 minor river basins earliest from 1813-2000) and updated up to 2015.

2. 1 degree and 0.5 degree gridded daily rainfall data from India Meteorological Department from 1951-2015

3. Atmospheric variables (Temperature, Geopotential ht, mslp, ppw etc.) from 'Climate System Forecasting (CFSR) reanalysis dataset.

Study Area:

- For the present report classification of the country's river systems into major and minor basins by K. L. Rao (1975) is adopted. 11 Major basins and 36 minor river basins are selected for the updation of monthly rainfall series upto 2015 and its extrapolation.
- Evaluation of seasonal extreme rain events will be studied over four homogeneous subzones (North Mountainous India, North West India, North Central India, North East India, West Peninsular India, East Peninsular India, South Peninsular India)

Analysis and results:

1. Updation of river basin rainfall series:

Longest instrumental area averaged basin-scale monthly rainfall dataset of 11 major basins, 36 minor basins, west coast drainage system and for the whole country available from 1813 to 2000 has been updated from 2001 to 2015 in this study. The starting year of the dataset varies from one basin to another. For the major basins the starting years are: *The Indus 1844; The Ganga 1829; The Brahmaputra 1848; The Sabarmati 1861; The Mahi 1857; The Narmada 1844; The Tapi 1859; The Godavari 1826; The Krishna 1826; The Mahanadi 1848; The Cauvery 1829; The West coast drainage system 1817; and All India 1813*. For independent minor basins the start is: *Chenab* 1891; *Beas* 1853; *Satluz* 1844; *Yamuna* 1844; *Ramaganga* 1844; *Gomati* 1844; *Ghaghara* 1844; *Gandak* 1848; *Kosi* 1870; *Mahananda* 1837; *Chambal* 1844; *Sind* 1860; *Betwa* 1844; *Ken* 1844; *Tons* 1844; *Son* 1842; *Tista* 1869; *Brahmaputra* 1848; *Dhansiri* 1871; *Wainganga* 1844; *Wardha* 1826; *Penganga* 1865; *Godavari* 1844; *Indravati* 1871; *Krishna* 1836; *Bhima* 1826; *Tungabhadra* 1837; *Luni* 1856; *Surma* 1848; *Kasai* 1831; *Damodar* 1829; *Subarnarekha* 1848; *Brahmani* 1871; *Penner* 1813; *Palar* & *Ponnaiyar* 1853; *Vagai* 1846 and The *West Coast Drainage System(WCDS)* 1817.

Longest possible monthly rainfall series earliest from 1813 to 2015 have been developed in three different phases. In the first phase, for the period 1901 to 2000, simple arithmetic mean of all available gauges in the basin from fixed well spread instrumental network of 316 raingauge stations have been used. In second phase the dataset has been extended backward from 1900 to 1813 by applying theoretically vindicated numerical method on limited available observations (Sontakke and Singh, 1996). In the third phase, the dataset has been updated by using 1-deg gridded daily rainfall with the ratio method suggested by Rainbird (1967) and approved by WMO. In the first two phases, station datasets were used for the construction, while in third phase, each station value has been extracted from the corresponding value of the grid from the gridded rainfall dataset.

2. *Chief statistical features of seasonal rainfall*

Area-averaged monthly, seasonal (Jan-Feb, March-April-May, June-July-Aug-Sept and Oct-Nov-Dec) and annual rainfall series for all basins, WCDS and All India have been developed and analyzed. Climatological and fluctuation features of all the time series have been calculated and documented. Normally the mean annual rainfall of all major river basins varies from 742.8mm over Sabarmati to 2478.3mm over Brahmaputra. The WCDS gets 2528.5 mm annual rainfall in normal year. The coefficient of variation of the annual rainfall varies from 9.6% (Brahmaputra) to 36.2% (Sabarmati). The year-wise highest rainfall normally varied between 1116.4 mm (Krishna) and 3161.6mm (Brahmaputra), while that of lowest from 248.9mm (Sabarmati) to 1979.2mm (Brahmaputra). For the country as whole, All India gets 1165.9mm rainfall annually with the highest rainfall as high as 1435.3mm and as low as 895.7mm. For independent minor basins, the mean annual rainfall varies form 487.7mm over luni to 2519.5mm over Surma. The coefficient of variation varies from 12.1%(Surma) to 37.4% (Luni). The year-wise highest annual rainfall was for Surma (3352.5mm) and the lowest for Luni 9167.5mm).

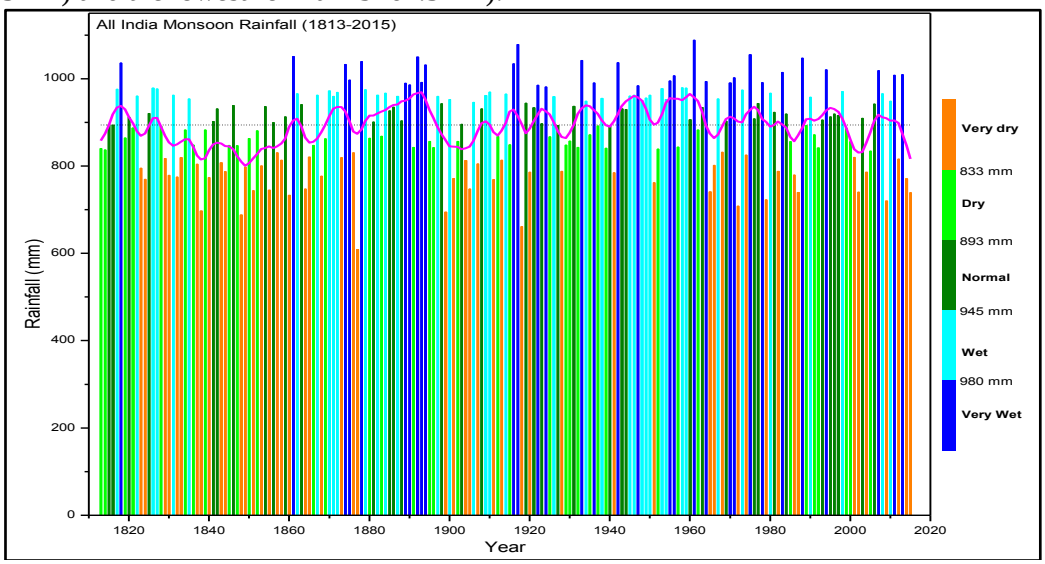


Fig.1 Inter-annual variations in All India summer monsoon rainfall from 1813-2015.

Inter-annual variations in annual, seasonal and monthly rainfall are filtered with 9-point filtering technique in order to suppress the high frequency components and understand the variability in low frequency mode. The smoothed series display many aperiodic fluctuations. Epochs with persistently large-or smaller period under wet or dry condition (with respect to climatological normal) can be seen in the graphs. Seasonal and annual rainfall condition of a particular year are categorized as *very dry*, *moderately dry*, *normal*, *moderately wet and very wet* by using quintiles as a threshold calculated from the dataset of 1901-2000. Categorized rainfall time series for all major and minor basins have been prepared and analyzed. The inter-annual variation in the categorized monsoonal rainfall during 1813 to 2015 for the country as a whole is shown in fig.1. For All India monsoon rainfall series rainfall less that 833mm is considered as very dry, 834-894mm dry, 895-945mm normal, 945-980mm wet and more than 980mm very wet. Distinct epochs can be identified in the rainfall fluctuations of all India monsoon rainfall. From the visual examination, major epochs noticeable in the monsoon rainfall fluctuations are: 1821-1861 dry, 1862-1897 wet, 1898-1931 dry, 1932-1964 wet, 1965-1988 dry, 1989-1999 wet, 2000-2015 dry. Epochal patterns for major river basins are also documented.

3. *Short-term and Long-term rainfall variability*

Visual examination of each time series of the individual basin revels that, monthly, seasonal and annual rainfall is found to exhibit wide range of fluctuation characteristics across the country, such as short-term–long-term rising–falling trend, stationary, among others. The Cramer's t_k statistics (WMO 1966) has been applied to moving averages of each of the time series to determine the broad nature of (+ve and –ve) short-term tendencies (15-year), medium-term fluctuations (31-year), long-term trend (51-year), and secular trend (101-year). The test compares the means of the

sub-periods to the mean of the entire record. Fig.2 represent the Cramer's t_k statistics for All India monsoon rainfall during 18913-2015. The t_k is calculated and significance is tested for times series of all major and independent minor river basins.

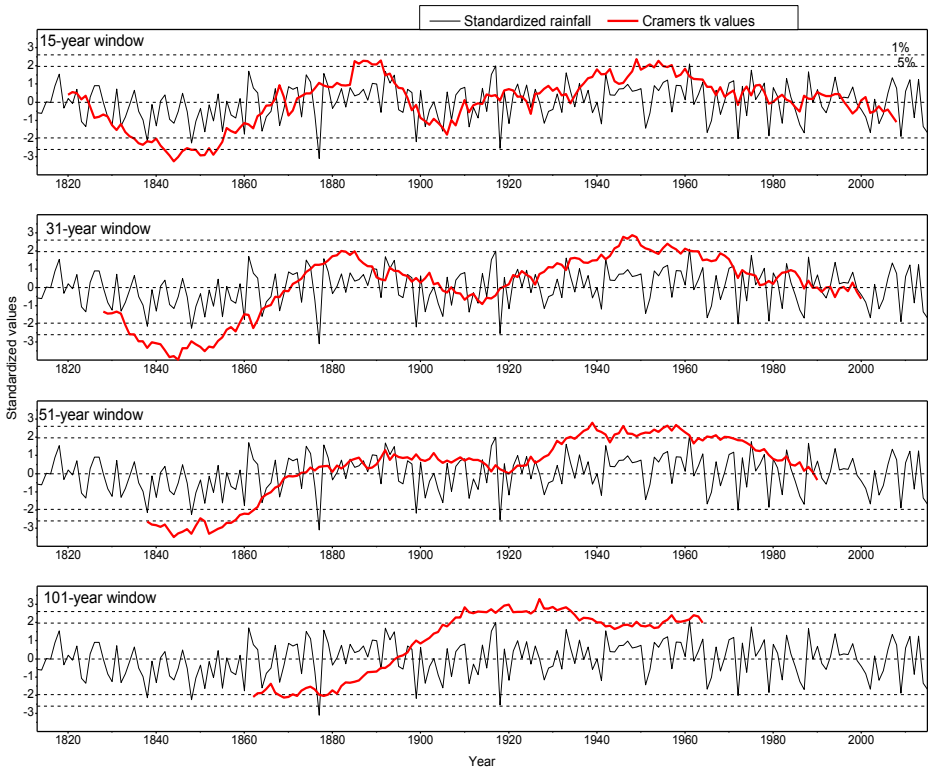


Fig.2. Cramer's t_k statistics for sub-periods of 15-, 31-, 51- and 101-year moving averages of All India Monsoon rainfall.

4. Important results so far:

- Normally (1901-2000) the mean annual rainfall of all major river basins varies from 742.8mm over Sabarmati to 2478.3mm over Brahmaputra. For the country as whole, All India gets 1165.9mm rainfall annually with the highest rainfall as high as 1435.3mm and as low as 895.7mm. For independent minor basins, the mean annual rainfall varies form 487.7mm over Luni to 2519.5mm over Surma.
- In recent 15 years (2001-2015), summer monsoon rainfall of Ganga major is decreased by 7.4% (5% level), Brahmaputra major 10.5% (1% level) and Cauvery 19.8% (1% level) compare to corresponding rainfall of entire period.
- In recent 31-years (1985-2015), statistical significant (5% level) percentage decrease in summer monsoon rainfall is noticed for Brahmaputra major (-4.4%), Cauvery (-5.9%) river basins with respect to entire period rainfall.
- In recent 51-years (1965-2015) statistical significant (1% level) percentage decrease in summer monsoon rainfall is seen for Brahmaputra (-4%) and Mahanadi (-6%) river basins with respect to entire period rainfall.
- Statistically significant (5% level) long-term secular increasing trend is noticed in recent 101 years (1915-2015) of summer monsoon rainfall of Krishna major (2.7%), Tapi (3.6%), WCDS (2.3%) and All India (1.4%) compare to corresponding entire record.

Deliverables

1. Longest instrumental area-averaged monthly, seasonal and annual rainfall series for 11 major basins and 36 minor basins from (1813-2015).
2. Recent year changes in annual seasonal and monthly rainfall of river basins and different extreme rain events in four homogeneous subzones of India.
3. Extrapolated seasonal rainfall series of major river basins

4. Potential causes of occurrences of extreme rain events in different parts of the country

It is expected that the results from this study will be useful for water resource management and regional hydrological modelling across India.

Adopters of the results of the study and their feedback:

From hydrology and water resources sectors

Major items of equipment procured: None

Lab facilities during the study: None

Specific linkages with Institutions/beneficiaries: None

Shortcomings/Difficulties:

1. Shortage of observed station rainfall data for the updation of longest instrumental monthly rainfall series
2. Shortage of manpower

Future Plan:

To understand the relationship between changes in global atmospheric parameters and observed climatic changes in river basin rainfall at different timescales.

NEW STUDIES
9. PROJECT REFERENCE CODE: NIH/SWHD/NIH/18-20

1. Title of the Study: Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin

2. Study Team: Dr. Archana Sarkar, Sc D, SWHD (PI)
Dr. Surjeet Singh, Sc E, GWHD (Co-PI)
Mrs. Suman Gurjar, Sc C, GWHD
Mr. Sunil Gurrapu, Sc C, SWHD

3. Type of Study: Internal

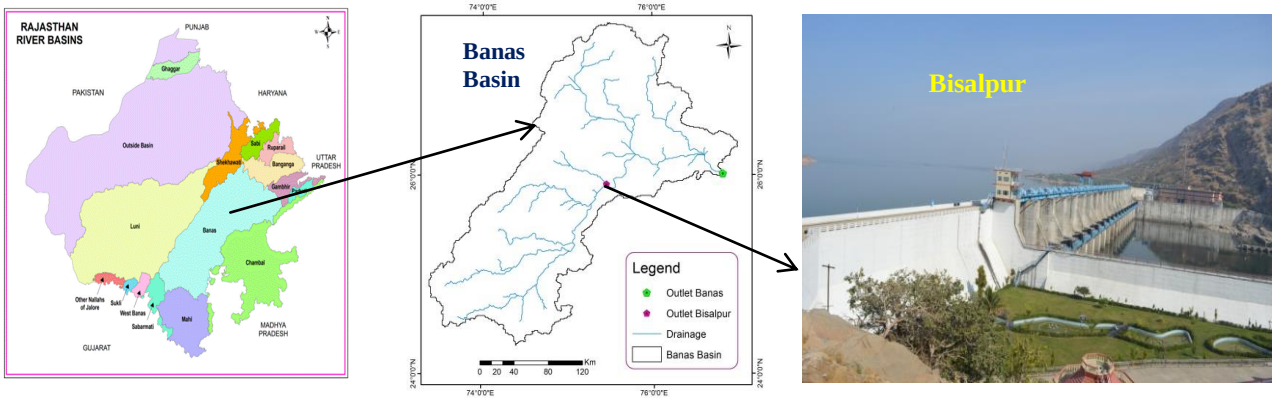
4. Date of Start: 1 Nov. 2018

5. Scheduled date of completion: 31 Oct. 2020

6. Nature of Study: Scientific Analysis

7. Location Map:

The study area is the Banas river basin up to the Bisalpur Dam and command area in Rajasthan.



River Banas is located in east-central part of Rajasthan State in India. It originates in the Khamnor hills of the Aravali range and flows in Rajasthan. Banas is a major tributary of the River Chambal, which is again a tributary of River Ganga. The total catchment area is about 51,779 km2 with a length of about 512 km. The Banas River passes through the 13districts namely, Sawai Madhopur, Jaipur, Ajmer, Tonk, Rajsamand, Banswara, Chittaurgarh, Udaipur, Bhilwara, Dausa, Sikar, Nagaur and Karauli. The Banas Basin may be classified as tropical grassy plains, semi-arid and hot, on the basis of Koppen's classification of climatic patterns. Orographically, the western part of the Basin is marked by hilly terrain belonging to the Aravali chain. East of the hills lies an alluvial plain with a gentle eastward slope. Ground elevations in the western hilly part range approximately 900 meters, while the alluvial plain elevations range approximately from 650 meters. The mean annual rainfall over Banas Basin is around 585 mm of which about 95% falls during the four Monsoon months (June-September). The average temperature in the basin varies from 19°C to 33°C with the maximum going above 45°C during summers.

8. Study Objectives:

1. Analysis of the historical & future patterns of rainfall and temperature in Banas basin up to Bisalpur Dam and command area.
2. Rainfall-runoff modelling in the catchment of Bisalpur dam.
3. Estimation of inflow and water availability in Bisalpur reservoir.
4. Assessment of irrigation demands in the command area of Bisalpur dam.

5. Scenario analysis of future water availability under climate change and measures to address the gaps in supply-demand scenario.

9. Statement of the problem:

The Banas River Basin is the largest river basin (45833 km^2) within the Rajasthan State of India. Banas is a seasonal river that dries up during the summer, but it is nonetheless used for irrigation. Bisalpur drinking water cum irrigation project is constructed across river Banas in 1991 with an ultimate irrigation potential of 55224 hectare (irrigation during the months of October to March for the Rabi crop), besides providing 458.36 million m^3 of drinking water for Jaipur, Ajmer, Beawar, Kishangarh, Nasirabad and other enroute cities, towns and villages. An estimated 150 million USD of extra agriculture was produced in 2014-2015. An increase in temperature in this region has been observed from historical data. This may lead to shortening of the crop growth period, increase in crop water requirement and reduction in crop yield. The water availability in this reservoir in coming years will play a crucial role in the overall economy of the entire region including other socio-economic issues.

10. End users/beneficiaries of the study

Water Resources Department and Agriculture Department in particular and people at large in general.

11. Methodology

The methodology to be adopted shall include the following.

(i) Trend analysis of the historical & future patterns of rainfall and temperature time series in Banas basin up to Bisalpur Dam and command area will be carried out using modified Mann-Kendall's technique and Sen's Slope method. The future data time series will be taken from the GCM downscaled data of the Copernicus website which consists of data of 19 GCMs under two RCPs (RCP4.5 & RCP 8.5).

(ii) Rainfall-runoff modelling in the catchment of Bisalpur dam will be carried out using SCS curve number method or MIKE NAM model depending on the availability of discharge data.

(iii) After the calibration of the rainfall-runoff method, estimation of inflow and water availability in the form of dependable flows in Bisalpur reservoir will be carried out.

(iv) The assessment of crop water requirements for the various crops grown in the selected commands/basin shall be carried out based on the FAO software for crop water requirements viz., CROPWAT based on the crop coefficients during the various crop growth stages and effective rainfall.

(v) Based on the GCM downscaled data of precipitation and temperature, future water availability as well as future crop water requirement will be assessed. Based on this analysis the gaps between the demand and supply can be ascertained so as to decide the quantum of additional water that is required to satisfy the unmet demands.

12. Action plan and timeline

S. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collection of information and Hydro-meteorological data from field, Preparation of base maps								
2	Trend analysis of historical data								
3	Downloading and bias correction of GCM data								
4	Input data preparation for Rainfall runoff model and CROPWAT								
5	**Preparation of Interim Report**								
6	Calibration and Validation of rainfall runoff model								
7	Assessment of crop water requirement for the present cropping pattern using								

	CROPWAT								
8	Inflow forecasting for the Bisalpur Dam								
9	Climate change scenario analysis for future water availability								
10	Climate change scenario analysis for future crop water requirement								
11	Recommendations to address the gaps in future water availability-demand scenario								
12	Preparation & Submission of **Final report**								

13. Data requirements

Daily data of rainfall, temperature, wind speed, humidity, sunshine hours and discharge. Remote sensing data and Survey of India toposheets

14. Deliverables: Research papers, reports, stakeholder engagement.

15. Adopters of the results of the study and their feedback:

Water Resources Department, Agriculture Department, Govt of Rajasthan.

The methods and results generated in the present study will help the Water Resources Department and Agriculture Department of Rajasthan State for the assessment of impacts of climate change in the basin and develop policies accordingly for the improved water resources management and best agricultural practices.

16. Cost Estimate

a. Total cost of the project: Rs. 11.6 lacs
b. Source of funding : Internal funding from NIH
c. Sub Headwise abstract of the cost

Sl.No.	Sub-head	Amount (in Rupees)
1.	Salary	6,60,000
2.	Travelling expenditure	2,50,000
3.	Infrastructure/Equipment	-
4.	Experimental charges/data	1,00,000
5.	Misc. expenditure	1,50,000
	Grand Total:	**11,60,000**

d. Justification for Sub-head-wise abstract of the cost

Salary: Full time one personnel (junior resource person) for the project will be required for assistance in the field data collection, data processing and technical analysis.

Travel: Travels would be essential for data collection, ground truth survey in the study area and stakeholder meetings

Infrastructure/Equipment: Rainfall and hydrological information will be obtained/procured from the agencies that are operating in the area. Also the required data will be procured/ purchased from IMD, CWC, NRSA and other State govt agencies.

10. PROJECT REFERENCE CODE: NIH/SWHD/NIH/18-21

Title of the Project: Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent

Project team: Mr. Sunil Gurrapu, Scientist 'C' (PI)

Type of Study: Internal

Status: New Study

Duration: 3 years

Date of Start: 1 November 2018

Scheduled date of completion: 31st October 2021

Objectives:

1. Analyze annual peak flows in the rivers of Indian subcontinent.
2. Evaluate the influence of various low-frequency atmosphere-ocean oscillations on flood magnitude and frequency.

Statement of the problem:

Floods are ranked among the largest and costliest natural disasters globally (Bryant, 2005) having the major impact on various economic sectors. In India, flooding is one of the three prominent climate extremes, other two being droughts and cyclones (Bhattacharya & Das, 2007). Majority of flooding in Indian watersheds occurs during summer monsoon months due to uneven distribution of rainfall. For example, recent devastating floods in Kerala were in response to the abnormally high rainfall received within a short period of 3 days, i.e. during 15 to 17 August 2018. However, summer monsoon rainfall being the major source of water input to the Indian subcontinent, approximately 80% of rainfall is received during summer monsoon, optimal planning and design of reliable infrastructure is very much essential.

Planning and design of water resource infrastructure requires a great depth of knowledge on the magnitude and frequency of extreme floods. Traditionally, these frequencies are derived based on the analysis of historically observed annual maximum flows assuming they are independent and identically (*i.i.d*) distributed and the system fluctuates within a fixed envelope of variability, i.e. stationarity assumption. This implies that the state of the relevant climate oscillations that are known to affect the regional hydroclimate can be ignored. However, several studies across the globe highlight the potential inadequacy of traditional flood frequency analysis (FFA) and argue that the *i.i.d.* assumption can no longer be considered valid (e.g., Kwon et al., 2008; Stedinger and Griffis, 2008; 2011; López and Francès, 2013; Barros et al., 2014; Tan and Gan, 2015; Gurrapu et al., 2016). Moreover, South Asian monsoon is influenced by several low-frequency atmosphere oscillations including Atlantic Multi decadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), El Niño-Southern Oscillation (ENSO) etc. (e.g. Roy et al., 2003; Sajani et al., 2007; Krishnamurthy & Krishnamurthy, 2013a; 2013b). For example, Krishnamurthy & Krishnamurthy (2013a) identified that the warm phase of PDO is associated with the rainfall deficit over Indian subcontinent, whereas the cool phase of PDO is associated with the rainfall excess.

In this study, we propose to analyze the annual maximum flows of the rivers of Indian subcontinent with the hypothesis that they are influenced by the low-frequency atmosphere oscillations originating in the equatorial Pacific and Indian Oceans. This study is motivated by the observation that the influence of low frequency oscillations upon flood risk is not yet a key ingredient in the planning and design of regional infrastructure. Specifically, influence of PDO, ENSO and IOD on the magnitude and frequency of floods will be analyzed. This study is the first to evaluate the impact of these low frequency oscillations, which are known to influence the monsoon rainfall in the Indian subcontinent, on the annual peak flows.

Methodology:

1. To explore whether the magnitude of annual peak flows are related to the large-sale climate oscillations, non-parametric Spearman's rank correlation coefficient provides the strength of the correlation between annual peak flows and the selected climate indices.
2. Quantile-Quantile (Q-Q) plots is a useful method to examine if the annual peak flow series from each phase of the low frequency oscillations are similarly distributed.
3. Flood frequency curves constructed based on the annual peak flow series from each phase of low-frequency oscillations helps to investigate the influence of such oscillations on return periods or frequency.
4. Flood ratio computed using the flood quantiles extracted from the flood frequency curves of each phase provide a means to evaluate the influence on flood magnitude.

Deliverables:

5. Established relations between low-frequency climate oscillations and flood magnitude and frequency in the selected watersheds of Indian subcontinent.
6. Redefined return periods or flood frequency established based on the reconstructed flood frequency curves
7. It is expected that the results from this study will be useful for optimal planning and design of infrastructure for effective water resource management.

11. PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-21

Title of the Study: Evaluation of Water Quality of Government Schools in Roorkee Block, District Haridwar

Study Group: **PI:** N. K. Bhatnagar, Scientist B
Co-PI: Dr. M. K. Sharma, Scientist D
Dr. L. N. Thakural, Scientist C
Smt Reena Rathore, Deputy Education Officer, Roorkee Block

Role of Team Members:

S. No.	Name of the person	Role
1	N. K. Bhatnagar	• Meetings with School authorities: List of Schools, fixing the schedules of schools visit for sampling, discussions about mass awareness programmes for schoolchildren and villagers etc • Preparation of study area map • Preparation of route map for sampling • Literature review including the work of NIH in district Haridwar • Pre- and Post-monsoon Groundwater Sampling • Processing of data • Organization of Mass Awareness Programme • Preparation of report
2	M. K. Sharma	• Guidance, Supervision and review of the work • Pre- and Post-monsoon Groundwater Sampling • Water quality analysis • Processing of data • Organization of Mass Awareness Programme • Preparation of report
3	L. N. Thakural	• Guidance, Supervision and review of the work • Data base preparation in GIS environment • Organization of Mass Awareness Programme • Preparation of report
4	Smt Reena Rathore Deputy Education Officer, Roorkee Block	• Providing support, supervision and help regarding Schools. • Organization of Mass Awareness Programme

Type of Study **:** Applied research

Date of start **:** October 2018

Scheduled date of completion: September 2020

Duration of the Study: 2 Years

Objectives of the Study:

i) Groundwater quality monitoring in pre-monsoon (April-May) and post-monsoon (October-November) season at identified school locations.
ii) To map degraded ground water quality zones and possible sources of pollution and identify specific parameters not conforming to drinking water quality standards.
iii) To examine the suitability of ground water quality for drinking purpose using Water Quality Index.

iv) To suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking.
v) To organize Mass Awareness Programme for school and villagers regarding Drinking Water Quality and Water Conservation.

Statement of the Problem:

Groundwater is one of the vital resources, which meets the requirements of daily livelihood especially in rural areas of India. Growing demand of water in various sectors viz; agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the groundwater resource, continuously declining groundwater levels, sea water ingress in coastal areas, and groundwater pollution in different parts of the country. There is a major possibility that School Children of Roorkee Block are bound to drink contaminated water as informed by Deputy Education officer, Roorkee Block during a talk. In view of this, a study was conceptualized to evaluate the groundwater quality status of Government Schools of Roorkee for drinking purpose.

Action Plan/Methodology:

i) Literature survey on assessment of groundwater quality and issues in the region.
ii) Meetings with School authorities: List of Schools, fixing the schedules of schools visit for sampling, discussions about mass awareness programmes for schoolchildren and villagers etc
iii) Preparation of study area map
iv) Preparation of route map for sampling
v) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.
vi) Analysis for physico-chemical parameters: pH, EC, TDS, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4,) and Toxic (Heavy) Metals: As, Cd, Cr, Pb, Cu, Ni, Fe, Zn, Mn in the collected water samples.
vii) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose.
viii) Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking.
ix) Suggesting ameliorative measures to control/ restore the groundwater quality.

Timeline:

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
2018-19	-	-	Literature Survey	Meetings with School authorities, Preparation of Maps, Interim report.
2019-20	Field visit, Sampling,	Sample Analysis and processing of the data	Field visit, Sampling,	Analysis and processing of the data, Interim Report
2020-21	Mass Awareness Programme	Preparation of Final Report	-	-

List of deliverables: Technical Report and Research Papers

Lab facilities during the study: Water Quality and Remote Sensing/GIS Laboratory of NIH

Data generated in the study: Hydro-chemical and statistical data of Roorkee block

Study Benefits/Impact: Water quality analysis of every school will be helpful to provide pure potable drinking water to schoolchildren and they wouldn't be bound to drink contaminated water that will be helpful them not to fall ill because of water born diseases. Directly the health of children will improve and, consequently, the attendance too.

Specific linkages with Institutions/beneficiaries: Villagers, Education Authority of District Haridwar and District Administration

/Difficulties: None.

Expected Budget

Sr. No.	**Sub-Head**	**I Year**	**II Year**	**Total**
1.	Travelling expenditure	1 00 000	1 00 000	**2 00 000**
2.	Infrastructure / Equipment / Consumable	1 00 000	1 00 000	**2 00 000**
3.	Experimental charges	3 50 000	3 50 000	**7 00 000**
4.	Misc. Expenditure	50 000	50 000	**1 00 000**
	Grand Total	6 00 000	6 00 000	**12 00 000**

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sanjay K Jain	Scientist G & Head
2	Dr. M K Goel	Scientist G
3	Mrs. Deepa Chalisgaonkar	Scientist F
4	Er. D S Rathore	Scientist F
5	Dr. Renoj Thayyen	Scientist D
6	Dr. Manohar Arora	Scientist D
7	Dr. P K Singh	Scientist D
8	Er. Manish Nema	Scientist C
9	Dr. P K Mishra	Scientist C
10	Dr. Vishal Singh	Scientist C
11	Sri P K Agarwal	Scientist B

WORK PROGRAMME FOR 2018-2019

SN	Title	Study Team	Duration	Funding (Rs. in Lakhs)
		Completed Sponsored/ Internal Studies		
1.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel Sharad K. Jain Deepa Chalisgaonkar P. K. Mishra	3 years (04/13-12/17) Up to 06/2018	
		Ongoing Internal Studies		
1.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Thayyen S. P. Rai Sanjay K. Jain Sudhir Kumar	3 years (04/14-03/18) Up to 09/2018	
2.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain Sanjay K. Jain Renoj J.Thayyen P. K. Mishra P. K. Agarwal	5 years (12/14-12/19)	
3	Development of window based software for hydrological data processing and Unit Hydrograph Analysis	D. Chalisgaonkar A. K. Lohani M. K. Goel	1 year (04/18-03/19)	
		Ongoing Sponsored Studies		
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen Farooq Azam P.G. Jose A.P. Dimri	3 years (03/16-02/19)	SERB (65.14)
2.	Development of a project website and hydrological database in Upper Ganga Basin (Sub-project – 1)	M. K. Goel M. Arora A. K. Lohani D. S. Rathore D. Chalisgaonkar A. R. S. Kumar Surjeet Singh P. Mani A. Sarkar M. K. Nema P. K. Mishra	5 years (01/16-12/20)	DST (52.15)
3.	Real-time snow cover information system for Upper Ganga basin (Sub-project – 2)	D. S. Rathore D. Chalisgaonkar V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
4.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region (Sub-project – 3)	Sanjay K. Jain A. K. Lohani Sudhir Kumar P. Thakur (IIRS)	5 years (01/16-12/20)	DST (36.79)
5.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios (Sub-project – 4)	Renoj J.Thayyen Sanjay K. Jain Sharad K. Jain S. P. Rai P. K. Mishra M. Arora AP Dimri (JNU)	5 years (01/16-12/20)	DST 51.43 (NIH) + 28.29 (JNU)
6.	Observation and modelling of various hydrological processes in a small	Sharad K. Jain Renoj J.Thayyen	5 years (01/16-12/20)	DST (54.07)

	watershed in Upper Ganga basin (Sub-project – 5)	Sanjay K. Jain S. P. Rai Surjeet Sing M. K. Nema P. K. Mishra P. K. Agarwal AP Dimri (JNU)		
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin (Sub-project – 11)	P. K. Mishra M. K. Nema R. J. Thayyen P. K. Sachan	5 years (01/16-12/20)	DST (90.99)
8.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya	Renoj J.Thayyen P. K. Mishra	3 years (03/17-03/19)	NMHS-MoEF (58.76 lakh)
9.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema Renoj Thayyen Sharad K. Jain Sanjay K. Jain P. K. Mishra AP Dimri (JNU)	3 years (2016-19)	MOES (Rs. 98 Lakh)
10.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)	Sanjay K. Jain (PI) Sharad K. Jain CSP Ojha (PI, IITR)	3 years (2016-2019)	MOES-NERC, Newton-Bhabha project (11.59 Lakh)
11.	Design and development of generic Decision Support System-Hydrology platform for Neeranchal Project	D. S. Rathore Deepa Chalisgaonkar Jyoti Patil	1 year (04/17-03/19)	DoLR (NNWP)
12.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore L. N. Thakural Sanjay Kumar B. Venkatesh M. K. Jose T. Chandramohan	3 years 2017-2020	PDS under NHP
13.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years 2018-2021	NIH/ DST
New Internal/ Sponsored Studies				
1.	Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework	P. K. Singh P. K. Mishra M. K. Goel Suman Gurjar	2 years 2018-2020	
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Kumar A. K. Lohani Sanjay K. Jain	2 years 2018-2020	

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2018-19/01

1. **Thrust Area:** Integrated Water Resources Development & Management
2. **Project team:**

a. Project Investigator:	Dr. M. K. Goel, Sc. "G"
b. Project Co-Investigator(s):	Dr. Sharad K. Jain, Director
	Smt. D. Chalisgaonkar, Sc. "F"
	Dr. P. K. Mishra, Sc. "C"
3. Title of the Project	NIH_Basin – A WINDOWS based model for water resource assessment in a river basin

4. Objectives

Envisaged objective of the study is to develop a WINDOWS interface (named as NIH_Basin – NIH_Basin-Simulation) of a model developed for assessment of water resources in a river basin for easy application by the user groups. It is also proposed to carry out a number of modifications in the model for analysis of water resources at basin scale.

5. Present state-of-art

A detailed spatially distributed model has been developed to assess various components of the hydrological cycle in a river basin. Focus is given to incorporate spatial variation of land-use, soil type, rainfall, evapo-transpiration, physiographic characteristics, cropping pattern, irrigation development, groundwater conditions, river network and hydraulic structures in a river basin. GIS is employed to link the spatial data with the simulation model and to project the model results in map form for easy visualization. Model computes various components of hydrologic cycle, such as actual evapo-transpiration, overland flow, groundwater recharge, and residual soil water content at monthly time step for each grid. The model brings out total water availability in the basin; water consumed by different uses; and water storage in different hydraulic structures, in soil water zone, and in groundwater aquifer in a river basin. By taking repeated runs of the model for longer time periods, sustainability of various water resources management plans can be examined. The model can be used to: a) visualize effect of land use change, cropping pattern change, climate change (in terms of rainfall and its distribution, temperature, humidity etc.), and population and industrial growth on the basin water resources, and b) analyze various management options like inter-basin transfer of water, development of new water resources projects etc.

The model is in continuous phase of development. Some of the present limitations of the model which are being addressed include: i) specification of EAC tables or corresponding relationships for various storage structures, ii) rule-curve based operation of reservoirs for analysis of different operation policies, iii) option of hydropower simulation in the basin, iv) continuous long-term simulation, and v) simplified representation of groundwater simulation. It is proposed to prepare input data files through user-interactive forms.

6. Methodology

For approximating the EAC relationships for a reservoir, the approach developed by J. Mohammadzadeh-Habili et. al (2009) has been adopted, avoiding the necessity of specifying EAC tables for various reservoirs in the river basin. The method has been programmed within the FORTRAN code of the model. Rule-curve based approach has been added for simulating operation of reservoirs as per specified policy. The option of hydropower simulation has been added. Model is planned to work in two modes: a) monthly mode (in which the simulation is carried out at daily time step for a month and then spatial recharge and discharge pattern are externally used to find revised water table in the basin with groundwater simulation model, say MODFLOW, and the revised groundwater table is used for subsequent month), and b) continuous mode (in which the simulation is carried out at daily time step for the complete period for which hydro-meteorological data are available). In the second mode, grid-wise pumping and recharge estimations are accumulated over each sub-basin and then divided by the Specific yield (S_y) of sub-basin to convert water withdrawal/recharge to corresponding change in groundwater level which can be applied to initial groundwater surface to find the revised surface in the sub-basin, thus avoiding the necessity of detailed groundwater simulation. For each sub-basin, average groundwater depth is computed from

data of a large number of observation wells (a procedure, defined by DHI, Denmark has been adopted for converting irregular observations in different wells in a sub-basin) has been programmed and is being added as a module in the software.

In WINDOWS interface of the model, various data input forms are being developed. Four important modules of the software include: a) Database preparation, b) GIS analysis, c) Model execution, and d) Analysis of results. The "Database Preparation" module is planned to include forms for the entry of attribute and temporal data of hydrological variables and model parameters. In the "GIS Analysis" module, it is planned to link the free domain GIS (ILWIS system) for creating and processing geo-spatial data. This module will also contain provisions for converting raster data to ASCII format. In the "Model Execution" module, various sub-models which are run for aggregating spatial information will be provided. In addition, the main Basin model will also be provided in this module. In "Analysis of Results" module, provision will be made to view spatial and hydrological results of the model. The study can help water resources departments and river basin authorities in the analysis of water resources at river basin scale. It can also help in assessing the impact of various natural and anthropogenic activities on various components of the hydrological cycle at basin scale.

7. Present Progress:

In addition to the envisaged modifications related to reservoirs such as specification of EAC tables, rule-curve based operation, hydropower simulation, continuous long-term simulation, and simplified representation of groundwater simulation, a number of modifications not envisaged earlier have been made in the model methodology and the source code for making it more practicable and realistic. Some of these relate to specification of GW potential factors, consideration of known population of some important cities for computing urban water supply demand, diversion of urban water supply from river segments, outlet from hydropower to join any stream segment or outside of the basin etc.

Most of these modification have been made in the computer code, which has been developed in FORTRAN language. The finalization of the WINDOWS based forms for database preparation is in progress. It is expected that the completed model would be demonstrated in the working group meeting.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2018-19/01

1. **Thrust Area** **:** Himalayan Cryosphere and Climate Change

2. **Project team** **:** Dr. R.J. Thayyen, Dr. S.P. Rai, Dr. Sanjay Jain, Dr. Sudhir Kumar

3. **Title of the project** **:** Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh.

4. **Objective**
   1. To improve the understanding of the climate forcing on cold-arid cryospheric system and hydrology.
   2. To improve the understanding of the melt water generation process and the role of permafrost.

5. **Present state of the art**

   Himalayan and trans- Himalayan regions of the country have many hydrological regimes. Role of the Himalayan cryospheric systems to the downstream river flow varies across these hydrological regimes. However, lack of data and research in these areas limit our understanding of these systems and thereby our ability to manage these system under the changing climate. Cold-arid cryospheric system of the Ladakh is unique hydrological regime of the Himalayan system. The first phase of the project entitled "Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, Ladakh Range."has revealed many unknown facets of the hydrology of the cold-arid cryospheric system such as catchment specific runoff of nival/glacier system, very high temperature lapse rate under cold-arid climate, Low contribution of glacier melt and significant contribution from ground ice melt etc. Current project focus on investigating the permafrost characteristic of the cold- arid trans-Himalayan experimental catchment.

6. **Methodology**
   a. Monitoring of weather parameters by AWS at 3500 m a.s.l., 4700 m a.s.l. and 5600 m a.s.l. for studying the orographic forcing
   b. Monitoring discharge and Electrical conductivity of discharge at 4700 m a.s.l
   c. Measuring ground temperature for permafrost studies

7. **Research Outcome from the Project:** The project is aimed at studying the permafrost characteristics and its seasonal responses. Study is expected to provide better understanding of meltwater generation during low snow conditions. Such an understanding is essential for managing the water resources of the region effectively. Understanding of the orographic processes and mountain climate at the nival/glacier systems to decipher the climate change impact on the cold-arid cryospheric system better.

8. **Cost estimate:** 48 lakhs

9. **Analysis and results**

   For evaluating the permafrost characteristics of the upper Ganglass catchment, Leh, the thermal regime was systematically analysed based on the near-surface ground temperature collected during September 2016 to August 2017 (one year) at 24 sites in the upper Ganglass catchment, Leh. The near surface ground temperature was recorded using miniature temperature data (MTD) loggers at 10cm depth below ground surface. The loggers were coupled into 12 small plots with different slope, aspect and ground cover type in order to capture the maximum spatial differentiation of the temperatures. At all the 12 plots, the plausible ranges of thermal offset, active-layer depth and mean annual ground temperature at 10m depth (MAGT10) were estimated by driving a one dimensional (1D) ground heat conduction model. The observed near surface ground temperature was imposed as a top

temperature boundary condition to the model. The model has a depth of 20 m and a zero ground heat flux condition at the lower boundary. The influence of differing soils is considered by varying the thermal conductivity of soil solids (k_solid) and the relative saturation of the pore space with water or ice. The model was run twice for all the loggers with a high diffusivity case (k_solid=4.0 W m^{-1} K^{-1} and a freezable water content of 0.03 m^3 m^{-3}) and a low diffusivity case (k_solid=2.5 W m^{-1} K^{-1} and a volumetric water content of 0.40 m^3 m^{-3}). The modelling results were then coupled for all the plots with maximum and minimum values. The mean annual ground surface temperature (MAGST) for all the plots ranges between -10.0 to 2.1 °C. The simulated MAGT10 ranges between -10.0 to 2.0 °C. The surface offset (SO) ranges from -1.1 to 5.1 °C, whereas the thermal offset (TO) ranges from 0.0 to 1.6 °C. The simulated active layer thickness (ALT) was found at all the plots above the elevation of 4900m and ranges from 0.1 to 5.4 m. These model results show that it is very unlikely not to have larger areas of permafrost in our study area. We also recognise that reversed thermal offset as reported from other high-elevation arid areas may occur but not be represented well by the heat conduction model without changing the saturation during summer.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2018-19/02

1. **Thrust Area under XII five Year Plan**: Sustainable water systems management: Adaptation of hydro-system to climate change

2. **Project Team:**
   a. Project Investigator: Manish Kumar Nema, Scientist 'C'
   b. Project Co-Investigators: Dr. Sharad K. Jain, Director,
      Dr. Sanjay K. Jain, Scientist 'G', Head, WRSD
      Dr. Renoj J. Thayyen, Scientist 'D' and
      Dr. P. K. Mishra, Scientist 'C'
3. **Title of the Project:** Hydrological Processes and Characterization of Lesser Himalayan Catchments

4. **Objectives:**
   a. To establish an instrumentation and experimental setup to measure various hydrological and meteorological variables in a watershed in the upper Ganga basin within the state of Uttarakhand for better understanding of their behavior and to study the dynamic linkages between the two.
   b. Analysis and comparison of estimated Evapotranspiration (ET) by different methods like RS/SEBAL, FAO56 method and actual field measurements
   c. To study the various water balance components in the watershed

5. **Present state-of-art**

Watershed is supposed to be the basic unit at which the hydrologic processes are studied and is central to most of the concepts in hydrology. Managing agricultural or forested watersheds for water quality and quantity improvement and productivity requires a detailed understanding of functional linkages between eco-hydrological processes and management practices. Various watershed studies are being conducted to understand the fundamental hydrologic and biogeochemical processes and their linkages with soils, vegetation, topography, climate, and management practices worldwide. These studies mainly involve modelling the natural processes but the vibrancy of experimental hydrology broadly across the areas of subsurface and surface hydrology and hydrometeorology still have a unique place of importance and no alternative.

In view of the state of affairs of existing models and studies addressing the problems of watershed hydrology, the major limitations might be characterized as mainly twofold. First, study basin designs have been limited by the black box concept and many misconceptions (e.g., the linearity, non-heterogeneity, additivity of hydrologic systems etc.). Second, operation has been substantially bounded by the hydraulic conception of these watersheds as isolated hydrological systems (Wei-Zu et al. 2013). Most of the watershed studies monitor only total runoff at the stream-outlet and the subsurface responses of the watershed are only estimated by hydrograph separation, etc. These characteristics undermine the formulation of a unified theory of watershed hydrology (Sivapalan et al. 2005) and the development of watershed models (Kirchner, 2006; Mcdonnell et al., 2007). There is a clear need to move beyond the status quo and expand from this narrow hydrological perspective to generate hypotheses governing general behavior across places and scales, with the ultimate aim to advance the science of hydrology.

6. **Methodology**

(A) Study Area:

A small Himalayan hilly watershed Hinval up to Jijli in the upper Ganga basin in the state of Uttarakhand is proposed for the study. This study area is a paired watershed of two kinds. One of them is a forested catchment (undisturbed) and other one is an agricultural watershed with anthropogenic interventions including an urban habitat at Chamba (Uttarakhand). The

geographical extent of the study area is from $30^0$17'N–$30^0$26'N latitude and $78^0$16'E–$78^0$25'E longitude. This area is a typical representative of a combination of lesser Himalayan hilly temperate climatic conditions with average annual rainfall range of 1200-1800 mm. The Himalayan subtropical forests yield to a belt of temperate broad leaf and mixed forest mainly comprises of pine forest. The total area under study is of 100 km^2 approximately (20 km^2 forested catchment and 80 km^2 the other one) with an elevation range of 999-2676 m. The location map of the watershed and their digital elevation model from SRTM is given in the figure 1.0 for reference. The stream in the forested sub-catchment is the source of drinking water for 87 nearby villages. This stream is being pumped 24x7 by the state authorities at its outlet at Dev Nagar. A study of the topography and land use of the proposed watershed shows that the watershed is representative of the surrounding areas.

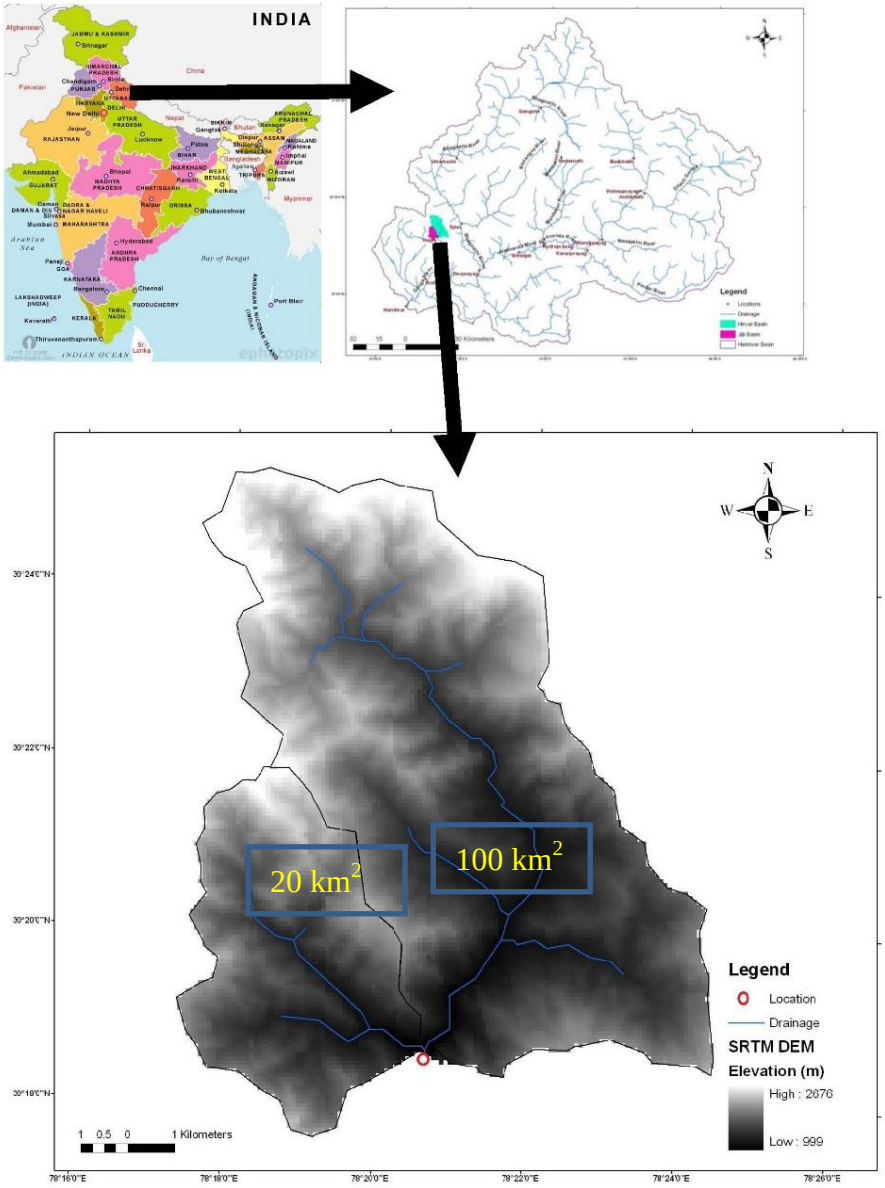


Fig. 1.0 Location of the Hinval watershed up to Jijli within India

(B) Experimental setup

Variables and parameters to be observed: organized in four categories, i.e., hydrological and ecological variables, atmospheric forcing variables, vegetation parameters, and soil parameters.

(C) Soil Heat Flux

Soil heat flux represents the amount of radiant energy absorbed or released at the soil surface during a given time period. Soil heat flux is a necessary input for many evaporation measurement and prediction techniques. One of the objectives of this study is to estimate soil heat flux using soil temperature collected at various soil depths. It is also intended to study the diurnal variation of soil heat flux in various seasons.

(D) Evapotranspiration (ET)

Accurate estimates of ET are needed for numerous agricultural and natural resource management tasks, hydrological modelling and to project changes in hydrological cycles due to potential climate change. In the present study, the estimates of ET from various sources will be compared with the actual field observations.

(E) Soil Moisture

Soil moisture in the uppermost 1–2 m of the earth's surface is recognized as a key variable in many environmental studies, including those related to meteorology, hydrology, agriculture and climate change. An understanding of the soil moisture variability is necessary to characterize the linkages between a region's hydrology, ecology and physiography (Jackson, 1993). The proposed objectives under this theme are to understand spatio-temporal variability of soil water potential and soil moisture content under different land covers in the temperate lesser Himalayan region and to evaluate differences, if any in spatial and temporal patterns of soil moisture content as influenced by nature of land cover. We propose to establish sampling points for measuring the soil moisture content under different land covers in selected watersheds, spread spatially to cover topographic highs and lows. Soil matric potential measurements are proposed using resistance-type probes. At each sampling point, probes will be installed at different depths. A roving instrument (handheld read-out unit) shall be used to record matric potential (kPa).

(F) Hydrologic Modelling

It is planned to apply distributed models such as the Soil and Water Assessment Tool (SWAT) and VIC Models.

7. Research Outcome from the project:

Development of a world class field hydrological laboratory in the lesser Himalaya. Development of better understanding of monsoon forcing on regional hydrology under changing climate for the end users/beneficiaries from the relevant Sectors. Research Papers and Reports.

8. Cost estimates:

a. Total cost of the project: Rs. 90, 55, 000. 00
b. Source of funding : NIH
c. Sub-head wise abstract of the cost :

S. No.	Sub-head	**Amount in Rs. (Lac)**
1.	Salaries/ wages	33.60
2.	Travelling Expenditure	10.00
3.	Infrastructure / Equipment / Data	39.45
4.	Experimental charges	7.50
5.	Misc. expenditure	0.00
	Grand Total:	90.55

d. **Justification for sub-head wise abstract of the cost**: due to lots of instrumentation involve in the project the non-recurring cost is the major component followed by the salary of the project staff.

9. Quarterly Break up of cost estimate for Year: 2017-18

SN	Sub-head	Amount (in Rupees)			
		AMJ (Q1)	OND (Q2)	JAS (Q3)	JFM (Q4)
1.	Salary	168000.00	168000.00	168000.00	168000.00
2.	Travelling expenditure	50000.00	50000.00	50000.00	50000.00
3.	Infrastructure/Equipment	320000.00	320000.00	320000.00	320000.00
4.	Experimental charges	0.00	0.00	0.00	0.00
5.	Misc. expenditure	37500.00	37500.00	37500.00	37500.00
	Sub- Total:	575500.00	575500.00	575500.00	575500.00
	Grand Total:				2302000.00

10. Work Schedule:

a. Date of commencement of the project: 01.01.2015
b. Duration of the project: 5 years
c. Stages of work and milestones:

SNo.	Description of Activity	2015				2016				2017				2018				2019			
		J	**A**	**J**	**O**	**J**	**A**	**J**	**O**	**J**	**A**	**J**	**O**	**J**	**A**	**J**	**O**	**J**	**A**	**J**	**O**
1.	Development of Procedure for scientific work																				
2.	Recruitment and deployment of Project Personnel																				
3.	Purchase of instruments and experimental setup																				
4.	Data generation and acquisition																				
5.	Data analysis and modellin																				
6.	Final Reporting																				

10. Progress till date:

An attempt is being made towards establishing a classical hydro-meteorological field observatory in the Lesser Himalayan environment under this field-oriented project. This NIH project is acting as a main stream and connecting to many other projects with different source of funding for attaining the common goal.

Instrumentation Progress:

SN	Name of Instrument	Parameters being monitored	Place of Installation	Date of commissioning
1.	AWS with soil parameters monitoring station	Air Temp. & Humidity sensors, four component Radiometer, Tipping Bucket Rain gauge, Heat Flux Plate, Soil Moisture & Temp. sensor at different depths, wind speed & direction sensor at different heights,	Nagani, Chamba	23.03.2016
2.	AWS with soil	-do-	Kanatal, Tehri-	04.01.2018

	parameters monitoring station		Garhwal	
3.	AWS with soil parameters monitoring station	-do-	Kumargaon, Chamba	06.01.2018
4.	AWLR-Radar Type	Water Levels at 10min intervals	Devnagar Pumping Station	01.02.2016
5.	Eddy Covariance Flux Tower	High frequency Water Vapour and Carbon Di-Oxide fluxes	Nagani, Chamba	04.01.2018
6.	COSMOS Sensor	Spatially averaged Soil Moisture	Nagani, Chamba	20.06.2017
7.	Soil Monitoring Stations	Soil Moisture, Soil Temperature, Air Temperature, Relative Humidity and Rainfall	Tipralgaon Dewari_Malli Silogi Birkot Bagi	17.06.2018

We have now two year of meteorological data of various variables and few preliminary plotting and inter annual and diurnal variability have been analyzed for air temperature, wind velocity, solar radiation, soil temperature, soil moisture and rainfall.

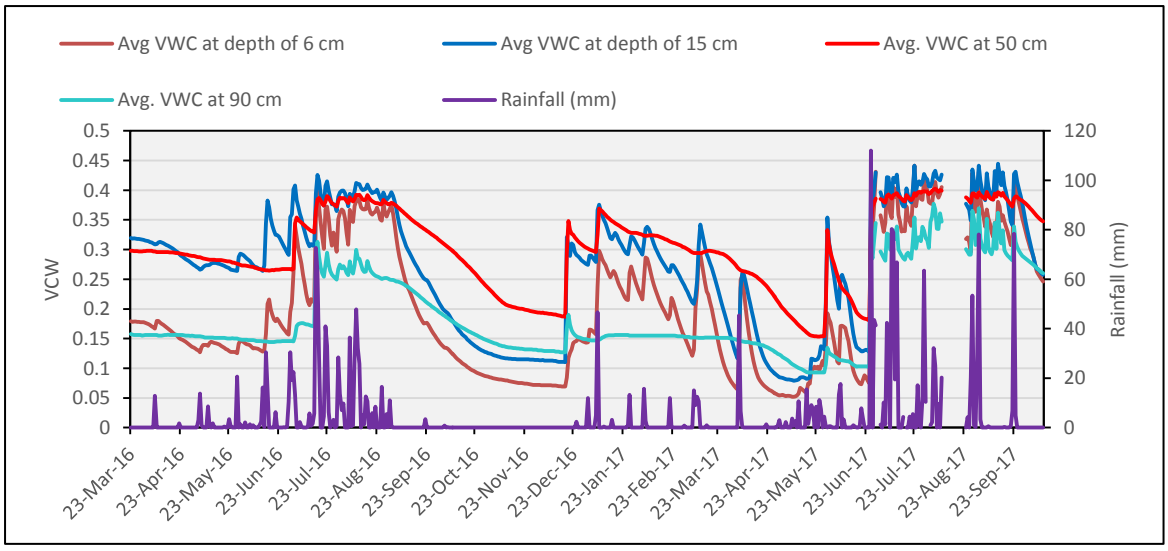


Fig.1 Inter-annual variability of Rainfall Vs Soil Moisture at different depths from March-2016 to Oct-2017

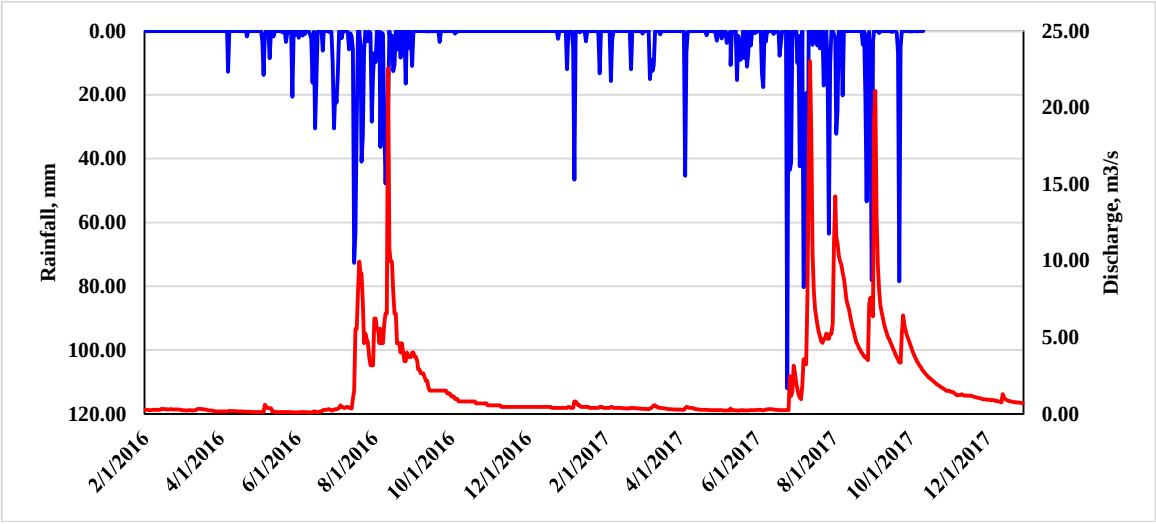


Fig.2 Daily Rainfall and Streamflow variation at Henval Valley (from Feb-2016- Nov-2017)

The daily reference evapotranspiration for the period Mar to Oct, 2016 estimated using temperature-based (Hargreaves-Samani & Blaney-Criddle) and radiation-based (Priestley-Taylor & Makkink) methods have been compared with renowned Penman-Monteith (PM) method (FAO-56). Using the statistical indices like R^2 & RMSE it has been observed that the radiation-based methods performs comparatively well than temperature-based methods.

Remote sensing based evapotranspiration estimation method Surface Energy Balance Algorithm for Land (SEBAL) is being tested for the experimental catchment. SEBAL model estimates actual ET by solving the terms of the surface energy balance derived from the visible, near-IR, and thermal-IR bands of the electromagnetic spectrum. LANDSAT 8 data used in determining land surface temperature (LST) and normalized difference vegetative index (NDVI).

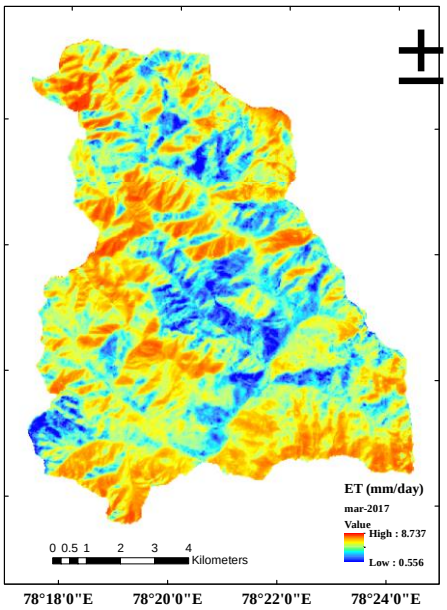


Fig.3 ET_0 map of the study area by SEBAL for the Month of March-2017

Preliminary analysis of very high frequency data of Eddy Covariance fluxes has also been started for carbon-di-oxide and water vapors. The following figure shows a diurnal fluctuations in the concentrations of these two.

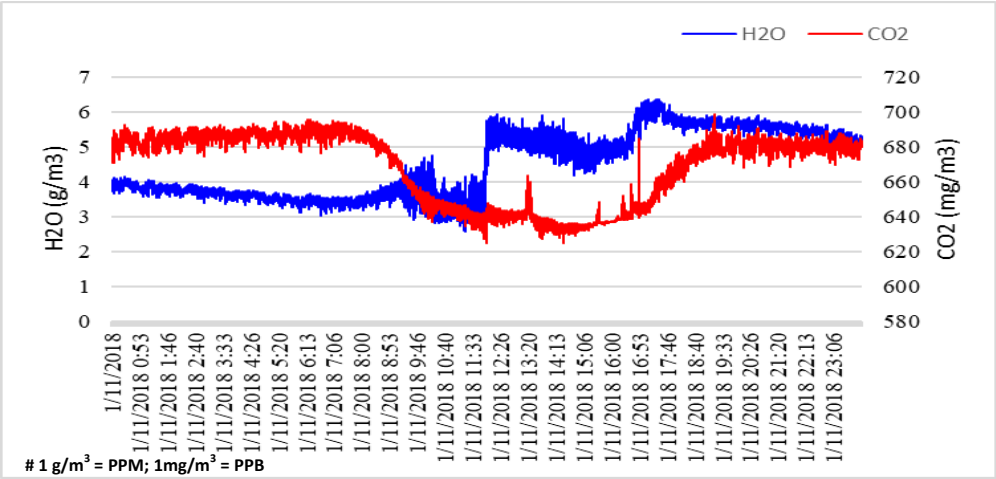


Fig.4 Diurnal variation in the CO_2 and H_2O Fluxes

SWAT model for simulating the discharge of Henval at Devnagar gauging site has been setup and preliminary results have been acquired although the model has to be calibrated yet. Since the project is about experimental hydrology, so only once we have some long-term data in hand then some conclusive inferences can be drawn. In between, the project team also has visited the site many a times for various objectives.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2018-19/03

1. **Title :** Development of window based software for hydrological data processing and Unit Hydrograph Analysis

2. **Study Group :** Deepa Chaligaonkar, Sc 'F'
   Dr A K Lohani, Sc 'G'
   Dr M K Goel, Sc 'G'

3. **Duration:** April 1, 2018 to March 31, 2019 (One Year)

4. Statement of The Problem:

Flood estimation is one of the most important components of water resources project planning, design and operation. Unit hydrograph approach is a simple, versatile and popular technique, which is being widely used for the estimation of floods for design of hydraulic structures, drainage system, small bridges, culverts etc. Right from the inception of NIH, a number of softwares/computer program have been developed at NIH for these analyses. However, they were written in FORTRAN/Pascal/Basica languages which did not provide user-friendly environment to the field users. In view of this, it is proposed to develop a WINDOWS based software to carry out hydrological data processing and unit hydrograph analysis for the estimation of flood for gauged as well as ungauged catchments of small and medium size.

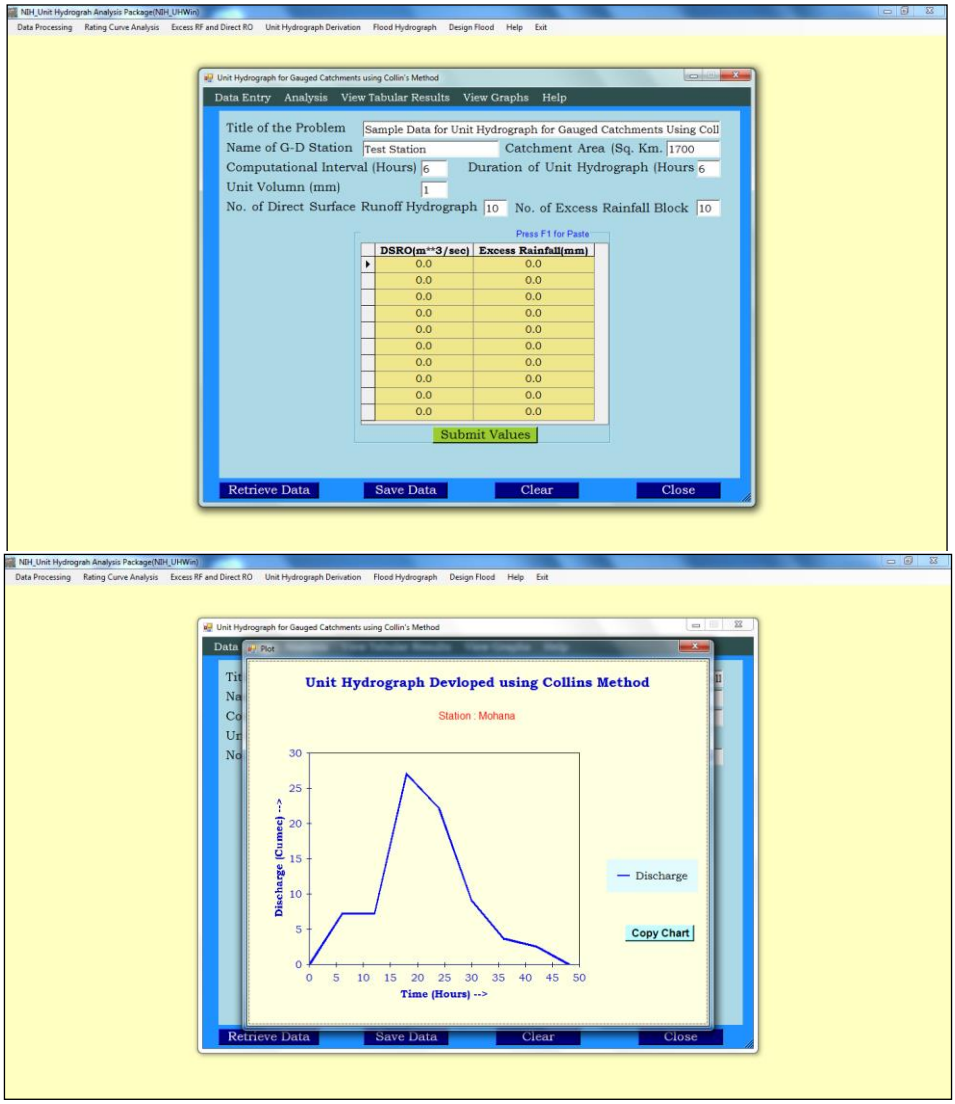
5. Methodology:

The software will have a user friendly environment for carrying out the various computations involved in the hydrological data processing unit hydrograph analysis. The software will include following main components:

- **Data Processing**
  Filling up of Missing Data, Consistency Check Using Mass Curve, Computation of Areal Average Rainfall, Computation of Variation of Depth with Area, Distribution of Daily to Hourly Rainfall
- **Rating Curve Analysis**
  Discharge from Velocity, Development of Rating Curve & Discharge Computation, Discharge from Stages
- **Excess Rainfall (ERH) & Direct Surface Runoff (DRH)**
  Base flow Separation & Computation of ERH Volume, Separation of Base flow using Straight Line Tech.
- **Unit Hydrograph Derivation,**
  Unit Hydrograph for Gauged Catchments(Collins Method, Clark Method), Unit Hydrograph for Ungauged Catchments, S Hydrograph Computation, UH of Changed Duration using Superimposition Method, UH of Changed Duration using S-Curve Method, Development of Dimensionless Hydrograph, Development of UH form a Dimensionless Hydrograph
- **Flood Hydrograph**
  Computation of Direct Surface Runoff (DRH), Computation of DRH & Error Functions
- **Design Flood**
  The help will be provided at each stage of running the package and the results will be presented in tabular as well as graphical form.

6. Status:

The software is being prepared in vb.net platform. Descriptive data formats are being prepared for easy preparation of data files. The unlined modules shown in section 5.0 have been completed. Some of the screenshots are shown below:



6. Research Outcome of the Project:

A WINDOWS based Software package for hydrological data processing and Unit Hydrograph analysis will be developed. It is expected that the field engineers will find this package useful.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/01

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

2. **Project Team:**
   Project Investigator **:** Dr. R.J. Thayyen, Sci-D
   Project Co-Investigators : Dr. Farooq Azam, Inspire Faculty-NIH (Now IIT Indore)
   Dr. P.G. Jose, Sci-D, WHRC, Jammu
   Prof. A.P. Dimri, SES, JNU

3. **Title of the Project:** Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range

4. **Objectives:**
   1. Winter and Summer Mass Balance studies of Phuche and Khardung glaciers for building a long term mass balance data series.
   2. Energy balance studies for understanding the reasons of contrasting mass balance response of Phuche and Khardung glaciers.
   3. Improving regional climate downscaling for Ladakh region using ground observations and study of glacier –climate linkages.

5. **Present state-of-the-art**

Headwater runoff is sustaining life and livelihood in the cold-arid regions of Ladakh. Due to this reason mass balance response of the small glaciers in the Ladakh range raises considerable interest. Lack of mass balance studies across diverse glacio-hydrological regimes of the Himalaya limited our understanding of climate – glacier linkages across the Himalayan region. Considering these aspects, a long-term mass balance research programme was funded by SERB on Phuche glacier in the year 2010. Since then winter and summer mass balance data is being generated over the Phuche glacier. 5 years of mass balance studies have shown that the Phuche glacier have cumulatively lost about 900 mm w.e. during these period. A nearby glacier named Khardung glacier is also studied additionally for winter and summer balance during these period. This glacier is part of the six glaciers of Khardung glacier complex and separated from Phuche glacier by around 2.5 km. Both these glaciers have NE aspect and under similar climatological setup. Khardung glacier is in the Nubra side of the Ladakh range while Phuche glacier feed into River Indus. Even though these glaciers are under seemingly experiencing similar weather, mass balance study of Khardung glacier showed enormous mass loss of this glacier with a cumulative loss up to 2300mm w.e during these five years. Reasons for such a contrasting mass balance response need thorough investigation. All the instrumentation in the region is focused on the Phuche glacier catchment and prevailing weather condition or energy balance of Khardung glacier is unknown. Present project is formulated to undertake detailed study of these two glaciers to understand the contrasting mass balance behavior.

6. **Methodology**
   1. Mass balance studies will be carried out by glaciological method including winter and summer balance with an aim to build up long-term mass balance series.
   2. Monitoring of climate parameters of AWS installed at Phuche glacier near ELA (5600 m a.m.l). The energy balance study was carried out of the Phuche glacier.
   3. Regional climate downscaling and parameterization

Use of regional climate model (RCM) outputs "without tuning" to evaluate hydrological and glacier responses to climate change in the Himalayan high mountains is still elusive (Yasunari et al., 2012). And thus it is imperative to assess the sensitivity of RCMs for hydrological and glaciological studies at basin level. Also, during winter, having an understanding of the liquid–solid precipitation ratio within the model framework is important for various hydrological and glaciological purposes. In present project statistical downscaling approach modifying dynamically downscaled outputs using Statistical Downscaling and Bias Correction (SDBC) method will be employed.

7. Research Outcome from the project:

Winter and summer mass balance of two glaciers, SEB data on two glaciers. Research papers with better understanding of climate forcing and factors controlling the glacier mass balance in the cold-arid system.

8. Cost Estimate : 65.14 lacs

Total cost of the project: Rs. 65.14 lakhs

b. Source of funding: SERB-DST

9. Work schedule

k	Year 1				Year 2				Year 3			
Acquisition of Equipment & logistics material	←	→										
Appointment of project staff	←	→										
Mass balance measurements	←	→	→	→	→	→	→	→	→	→	→	→
Meteorological monitoring by three existing AWS	←	→	→	→	→	→	→	→	→	→	→	→
SEB monitoring			←	→	→	→	→	→	→	→	→	→
Data Interpretation &Analysis						←	→	→	→	→	→	→
Report writing										←	→	→

10. Analysis and results

Point-scale surface energy balance (SEB) analysis was carried out using in situ meteorological data from the ablation zone of Phuche Glacier, Ladakh range from 1 October 2016 to 14 September 2017 (one hydrological year). The annual mean temperature over the surface of glacier was recorded to be –9.8 °C during the study period. The coldest month of the period was recorded in January with a mean of -20.7 °C and warmest month was observed in July with mean of 2.4 °C. The RH demonstrated a very high variability during the whole study period with a mean monthly minimum of 33.6% in October and maximum of 69.5% in June with a mean value of 58.2%. On the other hand, the daily mean incoming shortwave radiation varies from 43.7 to 539.2 Wm^{-2} with a mean value of 303.0 Wm^{-2} and outgoing shortwave radiation varies from 13.4 to 361.7 Wm^{-2} with a mean value of 160.5 Wm^{-2}. The mean monthly minimum and maximum wind speed observed in July (3.5 ms^{-1}) and February (5.2 ms^{-1}) respectively with a mean value of 4.5 ms^{-1}. The dominant wind direction is mostly coming from North-East (NE) and South-East (SE) direction. The mean daily values of the energy balance components are 30.8, 11.6, −30.7 and 11.7 Wm^{-2} for the net all-wave radiation, sensible heat flux, latent heat flux and surface energy flux respectively from summer-time period (1 May 2017 to 14 September 2017). The latent heat flux during the study period was mostly negative with a mean of -30.7 Wm^{-2}. Therefore, the surface mass loss throughout the sublimation process was found to have a mean value of −0.91 $mm\,w.e.day^{-1}$. Mass balance studies continued during the reporting period and data of AWS installed over the two glaciers were collected in October -2018 and the analysis is in progress.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/02
NMSHE STUDIES

1. Title - Development of a project website and hydrological database in Upper Ganga basin

2. Study team

1. Dr. M. K. Goel, Scientist 'G', NIH, Roorkee - PI
2. Dr. M. Arora, Scientist 'D', NIH, Roorkee – Co-PI
3. Dr. A. K. Lohani, Scientist 'G', NIH, Roorkee
4. Mr. D. S. Rathore, Scientist 'F', NIH, Roorkee
5. Mrs. D. Chalisgaonkar, Scientist 'F', NIH, Roorkee
6. Dr. A. R. S. Kumar, Scientist 'E', NIH, Roorkee
7. Dr. Surjeet Singh, Scientist 'E', NIH, Roorkee
8. Mr. P. Mani, Scientist 'D', NIH, CFMS, Patna
9. Dr. A. Sarkar, Scientist 'D', NIH, Roorkee
10. Mr. M. K. Nema, Scientist 'C', NIH, Roorkee
11. Smt. Suman Gurjar, Scientist 'C', NIH, Roorkee
12. Dr. P. K. Mishra, Scientist 'C', NIH, Roorkee

3. Objectives

The objectives of the project are:

a) Development of a coherent hydrological and hydro-meteorological database in Upper Ganga basin.
b) Processing and analysis of hydro-meteorological data in study area.
c) Assessment of adequacy of hydro-meteorological network in study area.
d) Investigation and referencing of available spatial database from various sources for use in water resources management.
e) Capacity building for use of hydrological data entry and processing software for maintaining hydrological database.
f) Development of interactive project web site for NIH projects under NMSHE including a web-based hydrological information system.

4. Sponsored by DST, New Delhi

5. Project Cost Rs.113.22 Lakh

6. Brief Background

The first important task in hydrological analysis for a river basin is the collection of true, accurate and regular hydrological and hydro-meteorological data. In our country, a number of organizations are involved in collection of hydrologic and meteorological data. However, it is also important to integrate the data related to different hydrological variables (say, rainfall, snowfall, temperature, humidity, wind speed, sunshine, river flow, groundwater observations etc.) in a database so that comprehensive analysis and processing of hydrologic variables in a river basin can be made. In addition to the point observations, a number of satellite platforms (such as Resourcesat, Cartosat, MODIS, TRMM, APHRODITE etc.) are now providing spatial information in various observation windows (or bands), some of which are on-line in public domain. This information can be referenced at a single platform for use in hydrological analysis for various purposes.

Data collected on hydrologic variables are generally raw which may not be used directly in most hydrologic analysis work. Processing of hydrological data has two major objectives: one to evaluate the data for its accuracy and the other to prepare the data in a form valuable to the users. The rapid advance in computer technology, in speed of operation and data storage capacity as well as the capability of hydrological software has greatly simplified the management of large quantities of hydrological data. All hydrological datasets can be maintained in well-defined computerized databases using standard database management system. Surface Water Data Entry System (SWDES), developed under Hydrology Project – I, and HYMOS software can be used for entry and processing of hydrological data in standardized format. This is essential for the long-term sustainability of the datasets in proper form and their dissemination to the end users. Both, raw and processed data sets are

to be properly stored and archived to specified standards so that there is no loss of information. NIH has trained manpower on SWDES and HYMOS software which can be used entry and process the hydrological database for the Upper Ganga basin up to Rishikesh and to build capacity in other organizations dealing with hydrological data for their effective utilization.

For mountainous areas, significant variation in altitude, slope, aspect, soil, and land use characteristics over short distances requires high density of hydrometric networks for reliable assessment of hydrological variables. However, due to various operational problems such as approachability, low temperatures, snowfall, high velocity flows with boulders and sediments etc., hydro-meteorological information available in the mountainous regions is quite limited due to lack of proper observation network. There is an urgent need to properly design and upgrade automated hydro-meteorological networks suitable for the prevailing climate in the region for long-term monitoring and database development. It is envisaged to analyze the existing hydro-meteorological network in the study area and analyze its adequacy using different techniques.

There has been widespread concern over the global change in climate and its impact on various hydrological variables. This impact is not uniform globally and mountainous regions are considered to be more susceptible to climate change. It is envisaged to carry out trend analysis of long-term data of hydrological variables to assess the possible impact of climate change on various hydrological processes. These findings can be used to analyze various scenarios of water availability and demand to develop strategies for proper management of water resources in future. Finally, it is envisaged to develop the web-site of the project for online information about various studies and sub-projects being carried out and the intermediate dissemination of results. It is also planned to link the web-based hydrological information system with the site to show the summary/gist of processed data at various observation sites in the study area.

Present Progress

Recently, the restricted flow data of CWC at 15 locations in the study area have been collected. The IMD data at monthly time step (rainfall, number of rainy days, and weather related data) of 365 stations in the Pan Himalayas and more than 50 stations at daily time step in/around the upper Ganga Basin (rainfall) has been obtained. The data analysis is in progress with regard to the data processing using SWDES and HYMOS. In addition, trend analysis of some meteorological variables is also under progress.

In addition, the digitization of the contours of study area have been completed for obtaining the digital terrain model. A comparison of the same is also planned with DEMS obtained from SRTM, ASTER and Japanese satellite.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/03
NMSHE STUDIES

1. Title - Real-time snow cover information system for Upper Ganga basin

2. Study team

a) Project Investigator:	D. S. Rathore, Sc. "F"
b) Project Co- investigators:	Deepa Chalisgaonkar, Sc. "F"
	V.S. Jeyakanthan, Sc. "E"
	L.N. Thakural, Sc. "C"
c) Project Staff (JRF)	Asish Bhandari, JRF
	Shravani Singha, JRF

3. Objectives

The objectives of the project are:

a) Development of methodology for snow cover delineation in study basin using multispectral remotely sensed data.
b) Development of web-GIS application for real-time snow cover information in study basin.

4. Sponsored by DST, New Delhi

5. Project Cost Rs.77.992 Lakh

Date of commencement of project: January, 2016
Duration of the project: 5 years

6. Statement of Problem

To study long-term snow cover extent variations, long-term and high temporal resolution snow cover maps are needed. MODIS data repository spans over nearly 17 years and highly suitable for hydrological studies. However, high temporal resolution data have coarser spatial resolution and introduces error due to mixed pixels. The data may be compared to better spatial resolution satellite data to assess its accuracy. The information generated may be further disseminated to stakeholders through web technology.

7. Present state-of-art

MODIS snow products, namely snow extent, snow fraction and grain size are available in public domain. Snow grain size has been utilized in modifying cloud mask and thus in post processing of the snow extent. Post processing algorithms also utilize filters and altitude masks. An web application developed by ICIMOD disseminates monthly snow statistics for basins in Hindu- Kush Himalaya.

8. Methodology

Satellite remote sensing imagery will be used for the extraction of snow extent and snow cover. Various techniques e.g. NDVI-NDSI regions for snow underneath forests, comparing multi spatial-resolution images for fraction snow cover determination etc. will be employed. Snow extent and its statistics will be published using Web GIS software such as Geoserver, Open layers, GeoExt etc. In addition, the available web services of spatial data e.g. Open Street Maps, Google maps etc. will also be utilized.

9. Location map/ study area

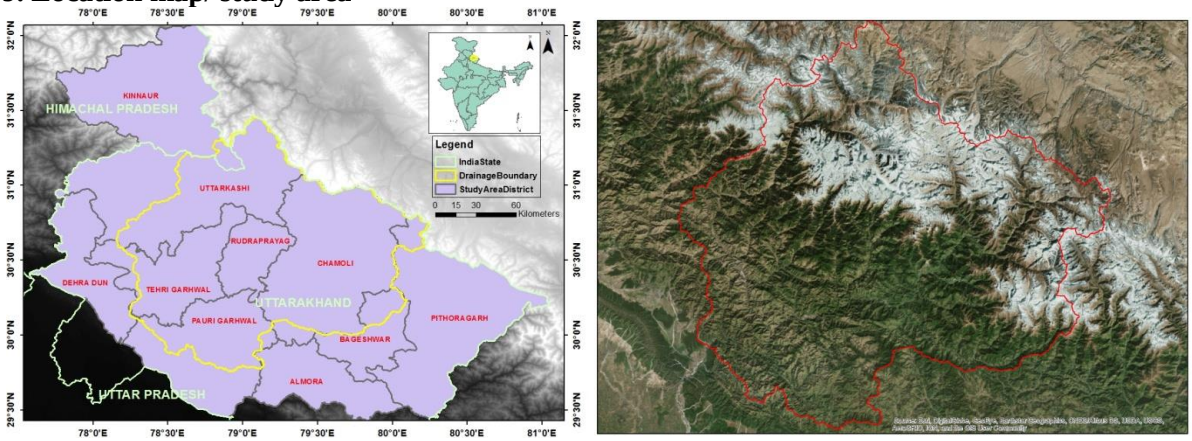


Fig. 1: Upper Ganga basin up to Trivenighat (Left), Satellite imagery for the basin (Right).

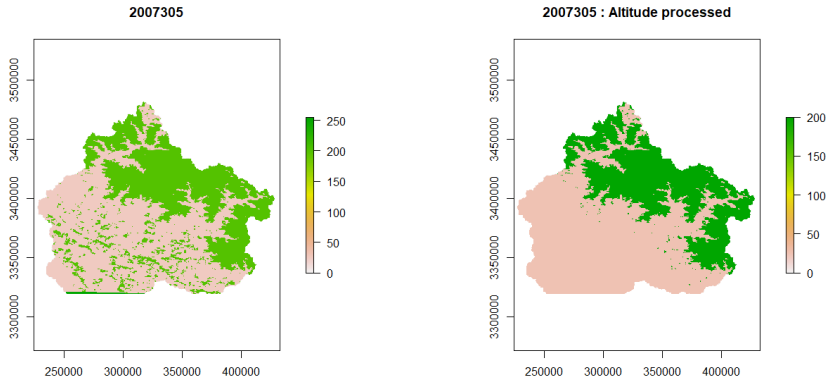
9. Approved action plan and time line

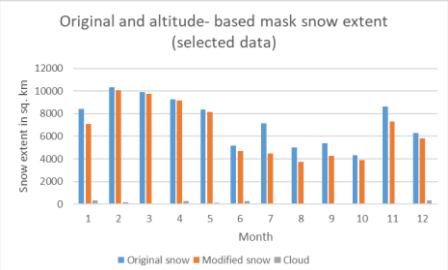
Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Processing of satellite data and GIS layers for delineation of snow	←	—	—	—	—	—	—	—	—	→
Development of web GIS application for snow	←	—	—	—	—	—	—	—	—	→
Field visit for ground truth and observations	←	—	—	—	—	—	—	—	—	→
Preparation of interim/ final reports		↔		↔		↔		↔		↔

10. Recommendations/ suggestions in previous WG

None.

11. Achievements

Year	Objectives	Achievements
2018-19	Snow extent methodology (Post processing)	Semi- automated procedure for altitude- based masking of NSIDC MODIS Snow extent maps (version 6) was developed and implemented in R software. The methodology requires SRTM DEM, polygon vector data for area without misclassification or cloud cover and snow extent maps. The processing was done for historic data (in Fig. 2 snow is seen in green color with value 200). For selected data, snow area modification was more than 20% for July- September months and for other months, it varied in ranges 1-2 and 7- 15%. Percent cloud in post processed maps was less than 6% (Fig. 3).  Fig. 2 Original and altitude- based masked snow extent for November 1, 2007

		 Fig. 3 Area for original and altitude- based mask snow extent and cloud (selected data)
2018-19	Web GIS application	The web GIS application developed for maximum, minimum and monthly snow extent in being updated from NSIDC MOD10A2 version 5 to version 6 data product.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/04
NMSHE STUDIES

1. Title - Glacial Lakes and Glacial Lake Outburst Flood (GLOF) in Western Himalayan region

2. Study team

1. Dr. Sanjay K. Jain, Scientist 'G', NIH, Roorkee - PI
2. Dr. A. K. Lohani, Scientist 'G', NIH, Roorkee – Co-PI
3. Dr. Sudhir Kumar, Scientist 'G', NIH, Roorkee
4. Dr. P. Thakur, Scientist 'D', IIRS, Dehradun

Project Staff (JRF) Mr. Amit Shukla, JRF

3. Objectives

The objectives of the project are:

1. To generate data base with regard to glaciers and glacial lakes in basins located in Western Himalayan region.
2. To define conditions of glacial lakes, moraine dams associated with mother glaciers attributing those with topographic features around lakes/moraine dams.
3. Analysis of the data to identify the potentially dangerous and vulnerable glacial lakes susceptible to out burst.
4. To define geometrical parameters (spread area, depth and volume of water etc.) of the vulnerable lakes and their further examination.
5. GLOF modeling using the hydro-dynamic mathematical modeling.
6. To disseminate the results and outputs among relevant oragnisations in the region that could make use of this information for GLOF hazard prevention and mitigation planning.

4. Sponsored by DST, New Delhi

5. Project Cost Rs. 41.796 Lakh

6. Brief Background

The climatic change/variability in recent decades has made considerable impacts on the glacier lifecycle in the Himalayan region. Warmer climates of the past have resulted in glacier retreat and the formation of glacial lakes in many mountain ranges. As the glaciers area retreating, some glacial lakes are formed behind the new exposed terminal moranins. Rapid accumulation of water in those lakes particularly in those adjacent to receding glaciers, can lead to a sudden breaching of the unstable dam behind which they have formed. The sudden discharge of large volumes of water with debris from these lakes potentially causes Glacial Lake Outburst Floods (GLOFs) in valleys downstream.

In order to assess the possible hazards from such lakes it is therefore essential to have a systematic inventory of all such lakes formed at the high altitudes. To identify the individual glaciers and glacial lakes, different image enhancement techniques are useful. Besides making a temporal inventory, a regular monitoring of these lakes is also required to assess the change in their nature and aerial extent. The criteria for identifying potentially dangerous glacial lakes are based on field observations, processes and records of past events, geo-morphological and geo-technical characteristics of the lake and surroundings, and other physical conditions. Once the vulnerable lake is identified, Mathematical modeling of dam breach floods can be carried out by either one dimensional analysis or two dimensional analyses.

7. Methodology

The studies for outlined focused area would involve following work items:

(i) Collation of literature & reference documents, procurement Remote Sensing Data from appropriate agencies-national and though on line sources.

(ii) Formulation of data on Glacial Inventory of the Basins defining snow line, different glaciers, their attributes and classification.

(iii) Establishing Glacial Lake and Moraine Dam Inventory in the Basins and defining geometric parameters of lakes, possibility of their inter-connectivity, and geomorphic classification to work out their vulnerability status.

(iv) Analysis of Glacial Lake database to identify the vulnerable lakes and their possibility of out burst under different causative modes. Defining breach parameters to estimate the scale of hazard on incidence of the GLOF.

(v) Defining slope attributes of the river from vulnerable lake/lakes to project sites and cross sections of the river-valley which would carry the flood on incidence of GLOF; the parameters would be defined based on remote sensing data.

(vi) Hydrological studies on GLOF/ Moraine Dam Break Simulation and consequent lake breach flood using the hydro-dynamic mathematical modeling.

(vii) Recommendation for the establishment of a system for monitoring potential risk lakes.

(viii) Information to be given to relevant institutions regarding the results and potential risks, thereby increasing the capability to plan for and prevent or mitigate the risks.

8. Present progress

In this project four study basins: Sutlej, Beas, Chenab and Ganga have been selected.

For the basins, Landsat data has been downloaded for the years 1990, 2000, 2004 & 2014.

Lake inventory have been prepared using all the data sets for four basins. Type of lakes have been defined. Area of all lakes have been computed.

Vulnerable lakes have been identified for all the basins.

Preparation of data base like cross sections etc. are under progress for hydro dynamic modelling. Cross section using HEC GeoRAS has been completed for Beas basin and for other basin in final stage.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/05
NMSHE STUDIES

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

2. **Project Team:**
    1. Dr. R. J. Thayyen, Scientist 'D', NIH, Roorkee - PI
    2. Dr. Sanjay K. Jain, Scientist 'G', NIH, Roorkee – Co-PI
    3. Dr. Sharad K. Jain, Director, NIH, Roorkee
    4. Dr. S. P. Rai, Scientist 'E', NIH, Roorkee
    5. Dr. P. K. Mishra, Scientist 'C', NIH, Roorkee
    6. Dr. M. Arora, Scientist 'D', NIH, Roorkee
    7. ***Collaborator: Dr. A. P. Dimri, Assoc. Professor, SES, JNU, New Delhi***

3. **Title of the Project:** Assessment of downstream impact of Gangotri glacier system at Maneri and Future runoff variations under climate change scenarios

4. **Objectives:**

    1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri
    2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri
    3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling.
    4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change.

5. Present state-of-art

River Ganga originates from the Gangotri glacier and fed by around 238 glaciers in the Bhagirathi catchment and 407 glaciers in the Alaknanda catchment covering around 1959 km^2 of the catchment area above Deoprayag. Discharge in these headwater tributaries of the Ganga is influenced by snow, rain and glacier melt. Melting glaciers of this region have raised serious concerns over the future trajectory of water availability in this crucial river system. There are conflicting viewpoints exists on the impact of glacier melt in the downstream flow regimes. IPCC 2007 report and many other studies in the Alpine systems suggested increased river flows during the early stages of glacier melt. However, Thayyen and Gergan (2010) distinguished between Alpine and Himalayan systems on the basis of annual precipitation distribution and flow regimes and pointed out that the runoff variations in the precipitation (Monsoon and winter snow) dominant systems such as Bhagirathi and Alaknanada basins are not dominated by the glacier discharge. Here precipitation variability plays the key role in runoff fluctuations with glacier melt helps to reduce the inter-annual runoff variability. Hence assessment of future runoff variation in this headwater streams required some robust future projections on precipitation and temperature. The impact of glacier melt dividend is found to be maximum for a basin with 20-30% glacier cover under the Alpine conditions. However, such assessment is non-existent in the Himalaya barring Dingad catchment, Garhwal Himalaya. As Gangotri is the largest glacier in the Ganga headwaters, extent and nature of its impact on downstream flow is critical issue for glacier resource management. The proposed project aims to understand this critical knowledge gap in the headwater regions of the Bhagirathi River at Maneri with 14.19% glacier cover. This catchment has 4205 km^2 area and 232 glaciers covering 596 km^2 (14.19%) The understanding of climate forcing on river flow under a data free regime is challenging. Key knowledge gap are precipitation and temperature gradients in the higher altitude regions. This knowledge gap will be addressed with collaborations with Jawaharlal Nehru University on atmospheric process modeling. Future runoff will be modelled using the future climate projections from this sub project.

6. Methodology

A) Discharge data of Maneri will be collected from the state agencies and inter-annual variations and long-term trends will be assessed.

B) Weather monitoring near Harsil: Weather data at the high altitude Himalayan region is very sparse. Hence orographic processes of the Himalayan slopes are poorly understood. Recent studies have shown that the orography is a key factor controlling the weather variables in the Himalaya. A full-fledged automatic weather station with four component radiometer, precipitation gauge and soil heat flux sensors will be installed near Harsil. Data from this weather station will be used for runoff modelling and climate downscaling.

C) Runoff modelling by SNOWMOD: Runoff modelling will be carried out by the established in-house model SNOWMOD. SNOWMOD is capable of providing snow, glacier, rainfall and base flow components separately. The glacier melt component in the discharge will be derived through modelling exercise. Glacier change in the Bhagirathi catchment during the past three decades will be estimated and correlations will be established between temperature/precipitation variations in the catchment with that of glacier change with the help of reanalysis data. Future glacier area change will be determined by using the inputs from the climate downscaling exercise and future runoff and glacier component will be modelled.

D) Climate downscaling and future predictions: Climate of the region is dominated by Indian winter monsoon and Indian summer Monsoon. Keeping such broad scale flow in mind climate downscaling will be done in conjuncture with the study of interaction of large scale monsoonal flow with existing variable topography and to study land surface processes in association with hydrological balance over the region of study with existing CORDEX simulation (from IITM, Pune), downscaling over the catchment region and modelling experiments. As it is understood that the region of study is of complex topography and hence such topography will not be truly represented within the model domain and hence dynamical downscaling will be used to established the atmospheric-topographic interaction in defining primarily precipitation forming processes. Statistical downscaling methods will be used to overcome the coarser horizontal model resolution problem and establish moisture-temperature interplay processes.

7. Research Outcome from the project:

Understanding of the downstream impact of Gangotri glacier system with glacier, snow & rainfall component and its probable future variability.

8. Cost Estimate:

a. Total cost of the project:	Rs. 153.716 lakhs
NIH	Rs. 80.42
JNU	Rs.73.296
b. Source of funding:	NMSHE-DST

9. Progress of the project

After assessing the elevation zone wise snow cover variation using an improved cloud removal protocol using MODIS data, Snow cover duration and it's variability is studied. Declining trend in snow cover duration is observed between 2000-2500 m a.s.l. elevation band followed by 2500-3000 m a.s.l. elevation band. Hower above 4000 m a.s.l. no significant change in SCD is observed. The snow cover changes during the past 16 years has been studied in terms of discharge response. Runoff modeling using SPHY and WIN SRM has been initiated and the database is being prepared. The bias corrected climate data is being generated by the collaborating institute (JNU) and the runoff model will use this data for runoff simulating.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/06
NMSHE STUDIES

1. Thrust Area: Himalayan Hydrology

2. Project Team

Project Investigator	**:**	Dr. Sharad K. Jain, Director
Co-Project Investigator	**:**	Dr. R. J. Thayyen, Scientist 'D' & TL
Project Co-Investigators	**:**	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. S. P. Rai, Scientist 'F'
	:	Dr. Surjeet Singh, Scientist 'E'
	:	Mr. M. K. Nema, Scientist 'C'
	:	Dr. P. K. Singh, Scientist 'C'
	:	Dr. P. K. Mishra, Scientist 'C'
	:	Mr. P. K. Agarwal, Scientist 'B'
	:	Dr. A. P. Dimri, Professor, JNU

3. Title of the Project: Observation and Modelling of Various Hydrological Processes in a Small Watershed in Upper Ganga Basin

4. Objectives:

1. To establish relationship between climatic and hydrologic variables and their seasonal variations in Himalayan environment.
2. To study the atmospheric dynamics including seasonal variations in atmospheric water budget, land-surface flux, orographic interactions during Indian summer and winter monsoon.
3. To develop the understanding of the hydrological processes in the watershed though isotope geochemistry.
4. To study the ground water dynamics in a lesser Himalayan watershed.
5. To study the soil erosion characteristics and sediment routing of the watershed.
6. To model various water balance components for a small watershed.

5. Present State-of-the-Art

Climate – Hydrology interaction in the mountain areas is complex due to closer and dynamic land-atmospheric exchange on account of orographic updraft and drainage winds. Indian Summer Monsoon (ISM) and Indian Winter Monsoon (IWM) is a major factor controlling climate of the Himalaya (Thayyen and Dimri, 2014). Hence, understanding the atmospheric, land surface and hydrological processes and its linkages is key to our understanding of climate change forcing on the Himalayan hydrological system. We did not succeed in attributing the regional climate change to the anthropogenic forcing till date. There is a clear need to move beyond the status quo and expand from this narrow hydrological perspective to generate hypotheses governing general behaviour across places and scales, with the ultimate aim to advance our understanding of the mountain hydrological processes. The project is envisaged to cover major components and processes of the water cycle; starting from the seasonal atmospheric water budgeting, atmosphere-land surface interaction and feedback, surface water balance, soil moisutre-soil temperature-sediment and water quality responses, groundwater dynamics and hydrological process studies and atmospheric moisture source assessment by stable isotope measurement.

6. Methodology

Study Area: The small Himalayan watersheds (Henval & Jijali) in the upper Ganga basin in Tehri Garhwal district of the state of Uttarakhand are proposed for the study.

i. Analysis of factors influencing local weather, land surface flux including soil temperature and diurnal & seasonal forcing at AWS site.

ii. Application of updated Regional Climate Model-RegCM4 (Giorgi et al. 2012) for atmospheric modelling along with CORDEX and subgrid land surface parameterization using mosaic-type scheme of the RegCM 3 (Giorgi et al. 2003).

iii. Water and sediment sampling for water quality investigations and modelling with advance use of isotopes.

iv. Develop understanding of the groundwater dynamics or interactions and recharge through installation of piezometer's longitudinally along the river, modeling and isotopic analysis.

v. Water balance modelling using field experiment based input data to understand the components of the hydrological cycle.

vi. Quantitative assessment of soil erosion and spatial distribution using USLE, RUSLE and MMF, RSSYM, WERM, SWAT Models with GIS and Remote Sensing in order to plan soil conservation measures.

7. Research Outcome from the Project: Enhanced understanding of the Lesser Himalayan hydrology-atmospheric interactions and climate change forcing aiding water resources management.

8. Cost Estimate: 134.32 lakhs

Total cost of the project : Rs. 134.32 lakhs
Source of funding : NMSHE-DST

9. Work schedule:

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Development of procedure for scientific work										
Recruitment and deployment of Project Personnel										
Purchase of instruments and experimental setup										
Data generation and acquisition										
Data analysis and modelling (Isotopic analysis / Sediment Modelling)										
Atmospheric Dynamics (water budgeting / Land Surface Flux)										
Watershed water balance and budgeting										
Ground Water Dynamics										
Final Reporting										

10. Progress of Work:

i. AWS Setup: After continuous efforts, permission for installation of an AWS has been obtained from the Uttarakhand Forest Department. It has been installed recently in the Jijali catchment near the ridge through NMSHE-5 funds, will aid in studying lapse rate. TDR sensors, heat flux plates, tipping bucket rain gauge were also placed around AWS.

ii. Other Instrumentation: Ordinary rain gauges have been installed at 10 different sites for monitoring rainfall distribution across elevations. A pan evaporimeter is installed at NIH-AWS site. The local peoples have been trained and engaged for monitoring rainfall and evaporation. The locations for installation of piezometer were identified in Henval valley.

iii. Apparent Thermal Diffusivity at Lesser Himalayan Henval Experimental Station:

Duration	**Pre-Monsoon M-A-M**	**Monsoon J-J-A-S**	**Early-Winter O-N-D**	**Core-Winter J-F-M-A**	**For all 4 Seasons**
Thermal diffusivity D_h (m^2/hr)					
average:	0.0021	0.0022	0.0019	0.0019	**<u>0.0020</u>**
minimum:	0.0013	0.0015	0.0014	0.0013	0.0013
maximum:	0.0026	0.0038	0.0025	0.0029	0.0038
Damping depth = 2 D_h / w (m)					
average:	0.13	0.13	0.12	0.12	**<u>0.12</u>**
minimum:	0.10	0.11	0.10	0.10	0.10
maximum:	0.14	0.17	0.14	0.15	0.17

Adopting the diffusivity based damping depths the temperature profiles at any depth (within selected soil reach < 30 cm) and time can be derived. The average efficiency of temperature prediction for the 4 subsoil depths (2, 6, 15 & 30 cm) is 96.29%. The diffusivities can also be applicable to identical soil types (Silt Loam). The values aids in filling soil temperature data gaps during sensors malfunction.

iv. **Sine-exponential Modeling of Diurnal Air & Skin Temperature:** During stable nighttime air temperature, decreases continually up to sunrise. Sinusoidal component: (sunrise — sunset) reproducing the temporal influence of solar heating. Exponential component: (sunset — next sunrise) reproducing Newton's law of cooling for a heated surface. Inputs: Daily max. & min. temperature, day & night length, sunset temp., time of sunrise and sunset. The R^2 between obs. & modeled air as well as skin temperature for the period 24th March, 2016 to 11th April, 2017 is 0.97 and 0.95, respectively.

v. **Mountain Wind Statistic:** Wind frequencies w.r.t. 16 directions & 6 wind speed classes have been estimated from April-16 to March-17 over the NW-SE aspect of Henval valley. The average air temperature as well as wind speed have also been analysed w.r.t. wind directions. This analysis further revised on daytime & night time basis. Overall anabatic winds dominance at the site is restricted for monsoon months of July and August. Rest of the months katabatic wind dominance is observed.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/07
NMSHE STUDIES

1. Title - Water Census and Hotspot analysis in selected villages in Upper Ganga basin

2. Study team

1. Dr. P. K. Mishra, Scientist 'C', NIH, Roorkee - PI
2. Dr. R. J. Thayyen, Scientist 'D', NIH, Roorkee
3. Er. M. K. Nema, Scientist 'C', NIH, Roorkee
4. Dr. P. K. Sachan, Scientist 'C', NIH, Roorkee
5. Swagatam Das (JRF)
6. Sanjay Kumar (PA)
7. Pankaj Kumar (PA)
8. Vishal (PA)

3. Objectives

The objectives of the project are:

a) To map water use pattern and livelihood linkages.
b) To map potential water hazard zones in the catchment.
c) To identify hotspot matrix components, hotspots analysis and adaptation strategies.

4. Sponsored by DST, New Delhi

5. Project Cost Rs. 90.99 Lakh

6. Brief Background

Himalaya is called the water tower of Asia. Himalayan rivers gather melt water from glaciers, snow and rainfall and deliver it to the millions living in the nearby plains across the Shivaliks. But the paradox lies in the fact this pristine water flowing in the Himalayan gorges have little use for the mountain people living on its slopes. Their livelihood is solely sustained by the springs and small rivulets as well as the rain and snowfall. The issues of the mountain people is often neglected in the Himalayan climate change discourse. This project is framed with the strong conviction that the sustainable Himalayan ecosystem is a mirage without addressing burning issues of the mountain people. Flash floods and landslides triggered by the frequent extreme events is becoming a regular feature for the mountain people. Reducing winter snowfall/extent/duration in consonant with the increase in winter temperature has already impacted the mountain hydrological regime as evident in the changing spring flow characteristics. The prime objective of the water census is to identify the water sources of the mountain villages and habitat, their issues and concerns, their habits and water use pattern. This fundamental understanding is necessary for evaluating the climate change impact on the mountain habitat and structuring and implementing adaptive strategies for sustaining the Himalayan ecosystem.

Water accounting, otherwise known as 'water census' is as important as other census activities for population, livestock, etc. carried out by the Government every decade. The Water Census is an emerging concept vital for creating Decision Support Capacity for water management agencies and policy makers. This provide a detailed accounting of water availability and use in a region. The main aim of the Water Census is to integrate diverse research on water availability and use as well as enhancing the understanding of relationship between water quality and water availability. Further, water census can be an umbrella platform in the hands of the stakeholders working in the field of water resources with information on water availability, water uses, potential water hazards, and most importantly the livelihood linkages. Livelihood- water linkage is core to sustaining the Himalayan ecosystem for the mountain people. Water disasters are increasingly become a threat to the mountain habitat and economic development under changing climate. Identification and management of potential water disaster zones are also key to sustaining Himalayan eco-system.

Considering these issues, this project is aimed to map and develop the water census (preliminary) for the Upper Ganga basin with information at micro (village) level on water availability, water use pattern and livelihood linkage, potential water threat, water structures not only for the major streams but also for tributary streams and rivulets close to habitat. It is also envisaged to identify the hot spot matrix components and its analysis to identify the most vulnerable sites (villages). This can only be accomplished by extensive survey at micro-level (village). The project could become a platform to integrate input from all other studies and information aiding policy formulation and strategic planning. Methodology developed and refined through this project can be replicated across the Himalayan region in subsequent stages of this mission.
An inter-linked approach to water resources management is envisaged in this project with following key components of water governance.

- Consider all water resources
- Address water demand as well as water supply
- Address wastewater management as well as water supply
- Involve all sectors and civil society stakeholders
- Promote access and gender equality
- Recognize the economic (livelihood), social, and environmental value of water.
- Recognize the water related threat and hazards for preventive measures (adaptation and mitigation strategies)

7. Methodology
The project will be executed as per the following roadmap:

Sampling
The study requires extensive survey work of two distinct nature, one is to develop water census of at least 100 selected villages distributed across the altitudes of the upper Ganga basin and another is of engineering survey of selected water structures/ sites. The engineering survey will capture L-section, X-section and other design flood parameters of selected bridges and culverts in the area.
The upper Ganga is divided into two major zones comprising of Alaknanda basin and Bhagirathi basin. Each of this major zones will be sub-divided into five sub-zones based on the elevation (altitude), climate etc. At least 10 villages will be screened from each sub-zones through scientific assessment and field visit as well as with discussion with other stakeholders.

Water census will be carried out by developing an elaborative matrix to capture various WRM components. A structured questionnaire and field mapping will be done to gather the information. An engineering survey will include mapping of the water structures, bridges, culverts etc. Landslide and earth quake hazard zonation maps will be integrated in the engineering survey.

Road map/ work components:
1. Preparation of GIS layers and Base line data collection
2. Selection of villages
3. Training of Resource Persons
4. Launch workshop
5. Stage I survey
    a. Attributes for water census
6. Mid-term Workshop
7. Diagnostics report
8. Stage II survey
9. Finalisation of Hotspot analysis
10. Development of adaptive strategies
11. Concluding workshop
12. Report preparation and submission

Activity chart (5 years)

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Selection of project personnel	■									
Preparation of GIS layers and Base line data collection	■	■								
Selection of villages		■	■							
Training of Resource Persons				■	■					
Stage I survey				■	■					
Mid-term workshop						■				
Diagnostics report					■	■	■			
Stage II survey							■	■		
Finalization of Hotspot Analysis								■	■	
Development of adaptive strategies									■	■
Concluding workshop										■
Report preparation and submission										■

9. Present progress

- A pilot surveyed using the developed questionnaire has been carried out in Neergaon village (Rishikesh) has been carried out on 27th October, 2017. Short-comings in the questionnaire during survey has been identified and corrections incorporated.
- First village level survey was carried out for 27 villages in the Henvel valley during 26-30 December, 2017 to gather different water-related information.
- Second field level survey was conducted during 02-07 January, 2018 in the stretch between Uttarkashi to Harsil. During the survey 22 villages were visited and primary information on water were collected.
- Third field level survey was conducted during 13-22 April, 2018 in the Joshimath Block (Chamoli). During the survey 39 villages were visited and primary water related information were collected.
- Fourth field level survey was conducted during 07- 13 July, 2018 in the Pauri Garhwal district. During the survey 42 villages were surveyed.
- Fifth field level survey was conducted during 013- 15 August, 2018 in the Tehri Garhwal district. During the survey Five (5) villages were visited and primary information on water were collected. Earlier 27 villages from the same districts were already covered.
- Presentation on the brief findings from the surveys will be made before the Working Group members.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/08
NMHS STUDY

1. Title - Dynamics of Himalayan Ecosystem and its impact under changing climate scenario- Western Himalaya

2. Project team

National Team

Lead : Prof. A. P. Dimri, SES, Jawaharlal Nehru University, New Delhi, India
Co-Lead: Dr. R. Thayyen, National Institute of Hydrology, Roorkee, Uttarakhand, India
Institutional PI's
Dr. Subimal Ghosh (Indian Institute of Technology, Mumbai, Maharashtra, India)
Dr. Renoj Thayyen (National Institute of Hydrology, Roorkee, Uttarakhand, India)
Dr. P. K. Mishra (National Institute of Hydrology, Roorkee, Uttarakhand, India)
Dr. Sarat Kar (National Center for Medium Range Weather Forecasting, Noida, UP, India)
Dr. Soumya Prasad (Jawaharlal Nehru University, New Delhi, India)
Dr. Sumanta Bagchi (Indian Institute of Science, Bangalore, India)
Dr. Raman Kumar (Nature Conservation Foundation, Mysore, Karnataka, India)
Prof. A. P. Dimri (Jawaharlal Nehru University, New Delhi, India)

3. Objectives

The proposed project will address the following objectives, in particular for the Ganges and Indus within the western Himalayan Region, spanning select states:

1. *Develop database for climate* and ecological processes across the elevation gradients
2. Regional climate modeling with sub-grid orographic forcing, extreme hydrological events, biodiversity dynamics for the present (1970-2010)
3. Regional climate model simulations for climate change scenarios (upto ~ 2100)
4. Identify ecological restoration strategies to adapt to future climatic scenarios
5. Communicate findings to stakeholders

4. Present state-of-art

Developing a clear understanding of climate change impacts on Himalayan snow cover, glaciers, water storage and associated rivers, forest and ecosystems are key scientific questions which need to be assessed as these affect large a proportion of the Indian population living along the southern rim of the Himalayas. To address these issues we need a comprehensive understanding of climatic and ecological process for the Himalayan region. Due to limitations imposed by availability of climatic and ecological data layers, we have a limited understanding of impacts of future climates on ecological, hydrological and climate regimes in the Indian Himalayan Region.

The Himalayan region consists of diverse ecosystems, and encompasses a global biodiversity hotspot, and several Important Bird Areas. They span alpine, temperate, tropical non-monsoonal and monsoonal forest habitats, with heterogeneous topographic and landuse characteristics. As the world warms, several species and communities in mountain ecosystems have been documented to be moving to higher altitudes to keep track of suitable habitats. Faced with changing climates, species can (a) evolve adaptations to new climatic conditions, (b) adapt to new climatic conditions if they have pre-existing adaptations, (c) migrate to suitable habitats which have climatic conditions that match the species requirements or (d) go extinct if the species cannot evolve, adapt or migrate in response to changing climates (Corlett 2009). Anthropogenic climate change has already influenced biodiversity and ecological processes, and this is certain to increase in the coming decades. Changes in the distribution of species has been well documented in the temperate regions in the recent decades (Walther et al. 2002; Parmesan and Yohe 2003). There is limited baseline data to document such range shifts for the Himalayan region, and it has been forecast that a vast majority of species will display changes in distributions along rainfall and temperature gradients (Colwell et al. 2008; XU et al. 2009; Joshi et al. 2012))

5. Methodology (NIH)

Objective 1: NIH component of the project to install 50 AT/RH stations and 10 rainfall stations in the western Himalaya and develop data.

Objective 2: Climate data will be upended with IMD station data and mathematical formulations for temperature and precipitation gradients will be derived. This will provide better insights on the orographic processes controlling these variables. Climate envelope – biodiversity distribution relationships will be examined using niche models, including Maxium Entrophy models.

6. Research Outcome from the project

Deliverables (NIH): Fine resolution temperature data from 50 AT/RH stations and 10 precipitation stations for at least 3years. Regional slope environmental lapse rate of temperature and precipitation gradients.

7. Cost Estimate:

Total cost of the project:	Rs. 2.1 Crore
a. NIH	Rs. 58.76 Lakh
b. Source of funding:	NMHS-MoEF

8. Progress of the project

One of the key work packages in the project is to procure and install 50 air temperature/ Humidty (AT/RH) and 10 precipitation gugaes in the region. Focus during the reporting period was to install the AT/RH stations. 43 stations were installed along five profiles such as 1) Dak Pathar – Rohru 2) Dak Pathar- Kharsali 3) Roorke- Jhala 4) Kotdwara – Phata 5) Kathgodam- Joshimath. Apart from these sections, 13 stand alone stations were installed in the western Himalaya including Ladakh and Kashmir. Temperature and relative humidity data of these stations during June-September 2018 period is being collected and preliminary analysis of Slope Environrmntal Lapse rate (SELR) is being carried out during the reporting period. Station specific Liquis Condensqation Level (LCL) variations arew also studied for the 03 summer period of 2018.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/11

1. Title - Design and development of DSS (H) platform for Neeranchal National Watershed Project

2. Project team

a) Principal Investigator: Mr D.S. Rathore, Sc F
b) Project Co- investigators: Mrs Deepa Chalisgaonkar, Sc F
Dr. Jyoti Patil, Sc C
Dr. V C Goyal, Sc G
Dr. S.M. Pingale, Sc C

Approved budget

Source of funding: Neeranchal National Hydrology Project (NNWP), DoLR, GOI, WB
Date of commencement of sub project : April, 2016
Duration of sub project : 2 years

3. Objectives

To develop a web-based Decision Support System platform for deriving hydrological information required in preparation of DPRs for watershed development.

4. Statement of the Problem

The project is a component of the PMKSY scheme of GoI. The Sub-component 2.2 of the Project (*Decision Support System and Data Bases for Hydrology and Watershed Management*) would develop and pilot a new decision-support system (DSS) to support DoLR and nine project states to implement IWMP in a more comprehensive and scientific manner, particularly around hydrology.

5. Present State-of-Art

Various existing DSS at national and international level are reviewed. These are ICAR-IISWC DSS for Farm Pond 1.0 and Drop Structure 1.0, ICAR-CRIDA Jal-DSS Watershed Development Monitoring and Evaluation Tool (WDMET), 2016, software developed by ICAR-Central Institute of Agricultural Engineering (Bhopal) for design and data analysis, Fujian Normal University (China) DSS-WMRJ Watershed Management, Purdue University L-THIA etc.

6. Methodology

DSS-H is being developed at NIH as a web based system with thin client with capabilities of processing raster as well as vector data and uses open source tools and technologies. The applications provide tools for processing the data to create specific output relevant to users. DSS-H shall be enabled to act as data repository for hydrometeorological, satellite remote sensing and GIS data. Two districts in each state and 4-5 watersheds in each district have been selected.

7. Location map/ study area

DSS will be developed for nine states. Two district in each state and six watershed in each district are selected. DSS will operate at scale of basin, sub-basin and watershed.

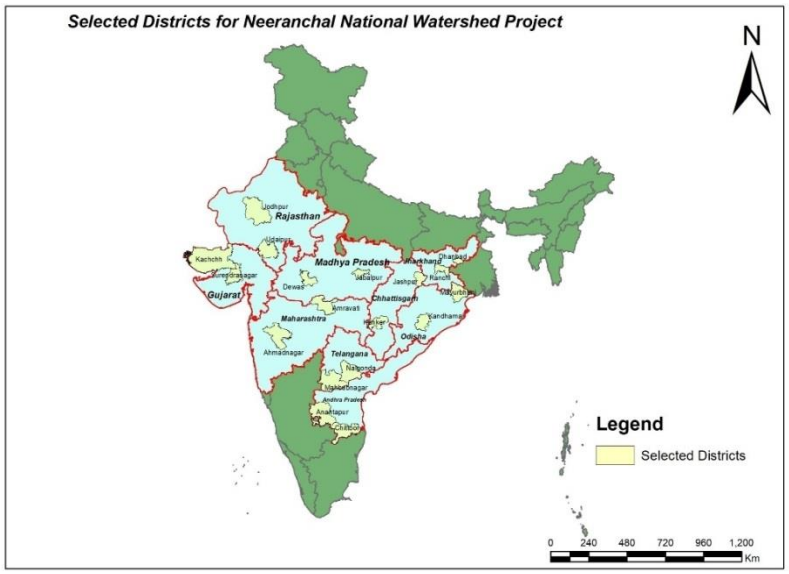


Fig.1 Neeranchal States and Districts

8. Approved action plan and time line

S N	Work Element	2017-18				2018-19			
		I	II	III	IV	I	II	III	IV
1	DSS model conceptualization								
2	Design of protocol of database generation								
3	Generic DSS development								
4	Design of GUI for DSS								
5	DSS customization as per user needs								
6	DSS testing and refinement								

9. Recommendations / suggestions in previous WG

None

10. Achievements

Year: 2018-19

Objectives: Generic DSS development

Achievements: Main technologies/ software used in DSS development are PHP, OpenLayers, GeoServer, PostgreSQL, Python and PostGIS. Libraries such as Plotly for plotting and exporting of graphs, Bootstrap framework for responsive web layout and various Python libraries have been used. DSS-H has been divided into five modules viz., Data visualization, Planning, Sites and Structures, Impact assessment and DPR. . The tools that are developed under each of these modules are given here. Apart from core module functions, other functionality e.g. print, measure tool, multi-lingual are also integrated.

Data Visualization:

- Layer viewing options

Planning:

- Evapotranspiration calculations using Penman Monteith Method
- Runoff calculation using SCS Curve Number method
- Ground Water Recharge tool using rainfall infiltration method
- Water Demand using domestic, agriculture and livestock

Sites and Structures:

- Identification of suitable areas for various rain water harvesting structures

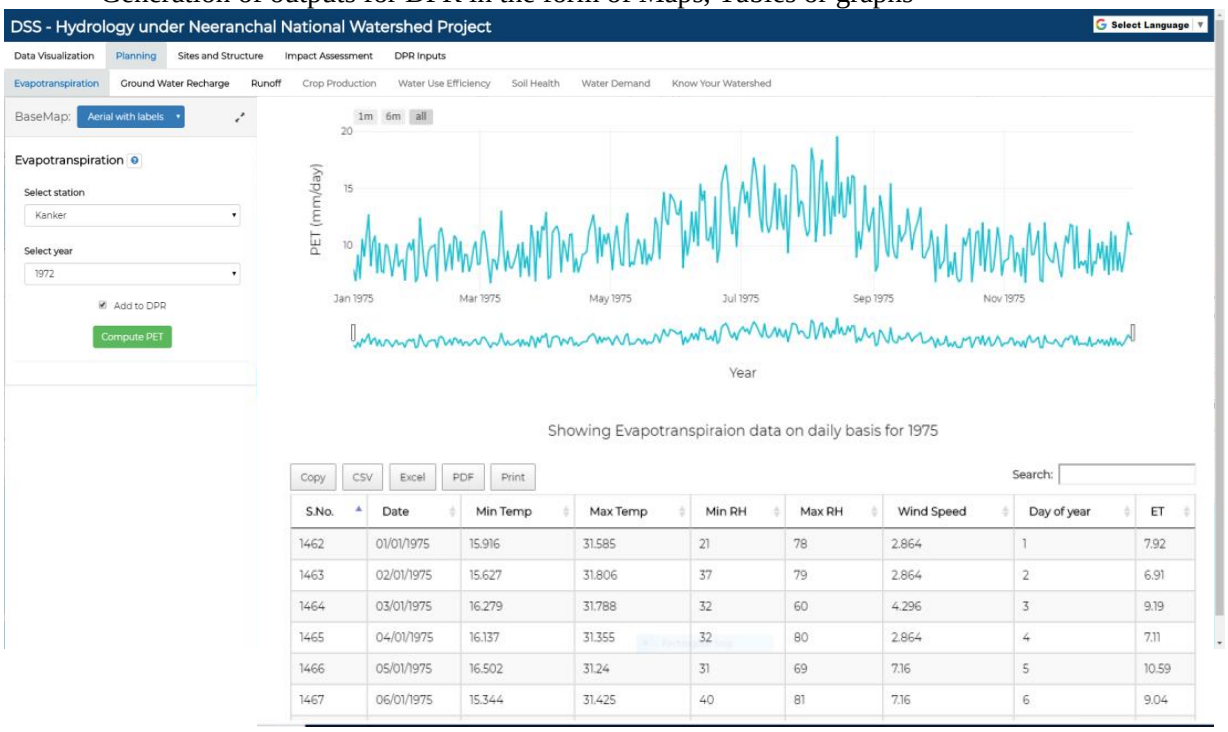
- Peak runoff calculation

Impact Assessment:

- Ground Water Level tool
- Ground Water Quality assessment for drinking and agriculture
- Livelihood Vulnerability Index
- Normalized Differential Vegetative Index (NDVI)
- Normalized Differential Water Index (NDWI)
- Soil Loss Estimation
- Soil Moisture Estimation

DPR generation:

- Generation of outputs for DPR in the form of Maps, Tables or graphs



ET is calculated using the Penman Monteith Equation

Fig. 2: Evapotranspiration tool

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/12

1. Title of Project: Investigating water stress using hydro-meteorological and remote sensing data, Purpose Driven Study (PDS), National Hydrology Project (NHP)

2. Project team:

c) Principal Investigator: Mr D.S. Rathore, Sc F

d) Project Co- investigators: Dr. L.N. Thakural, Sc C
Dr. Sanjay Kumar, Sc E
Mr. R. K. Jaiswal, Sc D
Dr. B. Venkatesh, Sc F
Dr. M.K. Jose, Sc D
Dr. T. Chandramohan, Sc D

1. Statement of the Problem

Large part of states such as Maharashtra, Karnataka and Andhra Pradesh in Peninsular India are affected by drought condition frequently. Due to availability of surface irrigation, large areas in Andhra Pradesh and some areas in Maharashtra and Karnataka, the drought conditions are mitigated. Droughts and water stress conditions have socio- economic and environmental effects, necessitating scientific investigation of the conditions and mitigating it. Drought mitigation measures are moisture conservation, reduction in water demand and increase in supply.

4. Objectives

- Characterizing water stress using hydro meteorological, remotely sensed data and vadose zone modeling
- Analysis changes in water stress conditions due to drought response and mitigation measures
- Field level measurements of vadose zone moisture
- Forecasting and regionalizing drought indices
- Devising reservoir operating policy

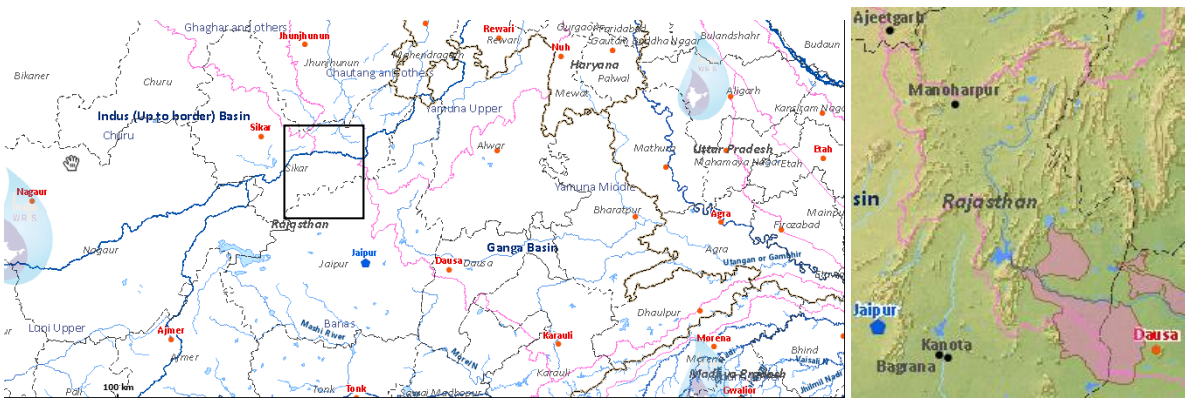
5. Present State-of-Art

Drought indices e.g. SPI, SODI, ADI, NADI utilize hydrometeorological and NDVI, NDWI, VCI, TCI, SMADI, VTCI, VAI etc. utilize remotely sensed data. PCA, clustering and DIT techniques were used for regionalization of indices. Forecasting of the indices was done using ANN, SARIMA and ARMA techniques.

6. Methodology

Drought indices will be estimated using hydrometeorological and remote sensing data. Field experiment will be done to study soil moisture profile and relate this information with drought indices. Water movement will be simulated in vadoze zone. Soil moisture condition will be simulated with varying cropping pattern. Regionalization and forecasting of the indices will be carried out.

7. Location map/ study area



Ram Garh reservoir and its command was selected as study area. The dam is located on Banganga river. The study area falls in Jaipur and Dausa districts of Rajasthan. Catchment area of the dam is located in Arawali ranges. Area is located in East Rajasthan meteorological sub- division. Nearest IMD stations are Jaipur and Dausa. Main aquifer system consists of alluvium. Quartzite, gneiss, schist and granite have localised occurrances. Catchment area is nearly 700 sq. km. The dam was built in 1903. The reservoir is dry since 2006. Mean annual rainfall is 492 mm with 36% COV. Normal annual rainy days are 110.

8. Approved action plan and time line

Activity	1st yr				2nd yr				3rd yr			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Data collection												
Satellite data procurement												
Field observation												
Data pre processing												
Computation of drought indices												
Regionalization of drought indices												
Forecasting												
Drought identification												
Unsaturated zone modeling												
Reservoir operation												
Scenario analysis												

9. Recommendations / suggestions in previous WG

None

10. Achievements

Year	Objectives	Achievements
2018-19	Characterizing of water stress	Satellite data collection is in progress.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2018-19/13

1. Title of the Study: Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

2. Study Group **:** Dr Manohar Arora, Sc 'D'
Dr Sanjay Kumar Jain, Sc 'G'

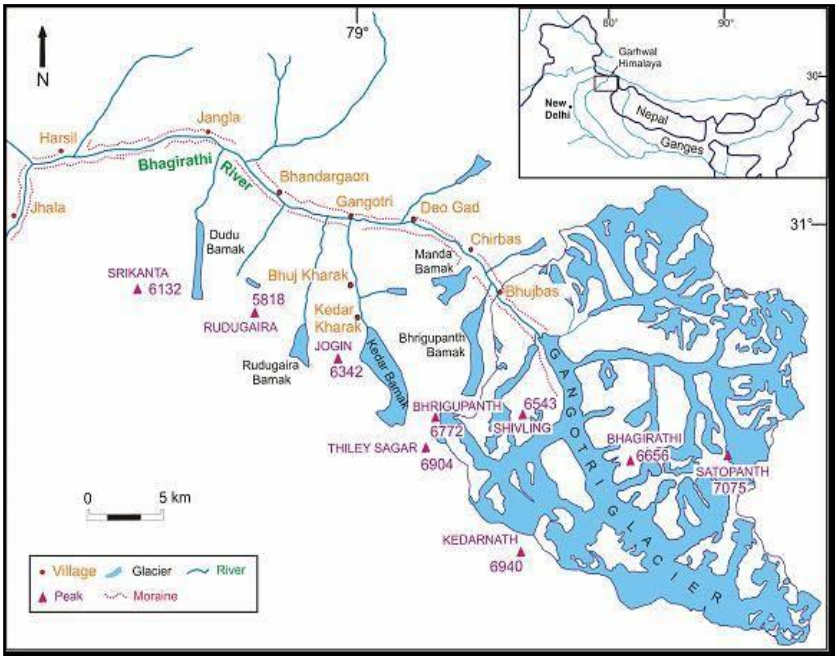
3. Role of Team Members:

Dr Manohar Arora, Sc-D&PI: Conduction field investigations, analyzing data/information, report preparation and overall responsible for the study completion.
Dr Sanjay Kumar Jain, Sc-G&Co-PI: Guidance in development of methodology, modelling and structuring of report.

4. Type of Study **:** Internal. Project will be submitted to DST for funding.

Date of start **:** 01.04.2018
Scheduled date of completion: 31.03.2021.

5. Location Map:



6. Objectives: The objective of this study includes:

- Continuous observations of meteorological, hydrological and suspended sediment data for the melt season to determine monthly and seasonal specific water and sediment yield from the study glacier.
- Seasonal characterization of the glacier melt.
- Estimation of suspended sediment yield from the Glacier.
- Modeling the catchment runoff variation under different climatic scenarios.

1. **Statement of the problem**
   The study involves collection and analysis of hydro-meteorological and discharge data of the glacier site. The second step is to use a snow melt model for streamflow generation and identification of different runoff components. The third step is to simulate catchment runoff variation under different scenarios.

7. Action Plan

Year	May to October	November to April	Remark
All Years	Field investigations & Data Collection	Data analysis	Report preparation after three years

8. Objectives vis-à-vis Achivements:

Objectives	Achèvements
Continuous monitoring of meteorological and hydrological data for monthly and seasonal specific water yield and its variability from the year to year	The data collection and field investigations for the year 2018 commenced in the month of May 2018 and were carried out till October 2018.
To improve the hydrological model for simulating daily streamflow	The simulation of flow will be carried out after collection of three years of data.

9. Adopters of the results of the study and their feedback

The study is a sponsored study and the results will be disseminated by DST.

10. Lab facilities during the study

Analysis of suspended sediment samples will be carried out in Soil Lab.

11. Data generated in the study

Meteorological and hydrological data for the Gangotri Glacier.

12. Study Benefits/Impact

The meteorological and discharge data would be utilised in studying the characteristics of the Gangotri glacier under changing climate.

13. Specific linkages with Institutions/beneficiaries

The data collected is also being shared with the authorities of Gangotri National Park. The details of sediment concentration are being communicated to the downstream Dam authorities.

14. Shortcomings/Difficulties

The study involves four months of extensive field work and maintenance of construction site etc. Without the support of project staff it is difficult to manage data collection.

14. Future Plan

The study will be conducted for long term. The Himalayan glaciers are poorly monitored. There is very little or sparse data of Himalayan Glaciers The collected data will be used for climate change studies.

NEW STUDIES
RESEARCH PROJECT: NIH/WRS/2018-19/01

1. Thrust Area under XII five year Plan
Food security and the sustainable management and use of water resources

2. Project team:

a. Project Investigator:	Dr. P K Singh, Scientist 'D', WRS
b. Co-PI Project Co-Investigator(s):	Dr. P K Mishra, Scientist 'C', WRS
	Dr. M K Goel, Scientist 'G', WRS
	Er. Suman Gurjar, Scientist 'C', GWH

3. Title of the Project– Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework

4. Objectives-The major objective of this study is to apply newly developed WA+ framework for Subarnarekha river basin in India. The objectives of this study includes assessment of:

1. Agricultural water consumptions using green water and blue water concept
2. Total water withdrawals and their partitioning in to surface and groundwater withdrawls
3. Land productivity and water productivity for food security
4. Consumed and non-consumed water along with beneficial and non-beneficial consumptions
5. Water scarcity and develop water allocation plans from water demand and water supply statistics
6. Available, exploitable, utilized and utilizable water resources

5. Present state-of-art

Water accounting (WA) has emerged in recent years as a key approach to understanding water scarcity and identifying gaps and in-efficiencies in water resources management. Various efforts have been made by United Nations (UN), Food and Agricultural Organisation (FAO), International Water Management Institute (IWMI) and the Australian government to develop standard water accounting (WA) frameworks.

FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, and has the advantage of consistency and standard terminology. However, AQUASTAT falls short of giving enough detail about the interaction between land use and water use. One major point pertinent to water scarce basins is that AQUASTAT focuses on water withdrawals, and does not distinguish between consumptive use and non-consumptive use.

The United Nations Statistics Division has proposed a WA framework called System of Environmental Economic Accounting for Water (SEEA-WATER). However, its applicability for water stock accounting is in question mainly because key required data are unlikely to be available (Perry, 2012). The essential difference in green and blue water resources (Falkenmark and Rockstr¨om, 2006; Rockstr¨om andGordon, 2001) is not recognised in the SEEAW framework.

The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) as part of the National Water Initiative (NWI) is based on several aspects of the SEEAW. The framework accounts for water withdrawals rather than consumptive use.The AWAS considers irrigated agriculture, industrial and domestic users and does not provide any information on rainfed systems and natural evapotranspiration (ET) processes.

The International Water Management Institute (IWMI) developed a WA procedure (Molden, 1997) with the aim of tracking water depletion rather than withdrawals to avoid errors when neglecting recycling, and to account for ET. The IWMI WA framework has been applied by IWMI in many irrigation system studies (e.g., Bhakra system inIndia (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and atthe national scale (e.g., India: Amarasinghe et al., 2007; SriLanka: Bastiaanssen and Chandrapala, 2003). However, only a few countries have adopted these WA mechanisms usually due to the lack of data needed to implement these approaches.

6. Methodology

The Water Accounting Plus system (WA+) is based on open access remote sensing data -in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be understoodby people with technical and non-technical backgrounds alike.

The WA+ framework is developed by IHE-Delft in partnership with IWMI, FAO, and the World Water Assessment Program (WWAP). WA+ is based on a mass water balance approach (at the pixel level) and uses Budyko theory (Budyko, 1974) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certainarea of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies landuse lancover (LULC) in to 80 classes. These 80 LULC classes are further grouped under four main Water Management Classes (WMC), i.e., Protected Land Use (PLU), Utilized Land Use (ULU), Modified Land Use (MLU), and Managed Water Use (MWU). WA+ framework uses the Budyko theory (Budyko, 1974) for measurable ET separation in to ETgreen and ETblue. The Budyko theory is based on the coupling of (a) Water Balance approach and (b) Energy Balance approach. The water balance is performed individually for green and blue pixels, respectively. Following this, WA+ procedure develops eight fact sheets and spatial maps. The eight fact sheets are listed here:

1. Resource Base
2. Evapotranspiration
3. Agricultural Services
4. Utilized Flow
5. Surface Water
6. Groundwater
7. Ecosystem Services
8. Sustainability

In the present study, all the data will be generated for the study basin using open source data. Then WA+ Framework will be applied to achieve the desired objectives.

7. Research outcome from the project

There are eight fact sheets, which will yield many outputs (spatial and temporal estimates) at the pixel level. Estimates of the following will be achieved through this study:

- Exploitable, reserved, utilized, utilizable and non-utilizable flows at river basin scale
- Consumed, non-consumed and recoverable & non-recoverable flows
- Land productivity and water productivity
- Man-made and natural water withdrawls in the basin
- Water supply and demand scenarios and allocation plans
- Surface water availability and surface water storage in the basin
- Groundwater recharge in the basin

8. Work schedule

a. Probable date of commencement of the project:

b. Duration of the project: 02 Years

c. Stages of work and milestone: Shown below

Project Year	**Jan 2019-Dec 2019**				**Jan 2020-Dec 2020**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. Data downloading, processing, and generation of data base	←	—	→					
b. Basic data analysis in WA+ framework, Ground truthing surveys for LULC and data collection from CWC, and state govt. departments		←	—	→				
c. WA+ framework application and testing			←	—	→			
d. Calibration and validation of the WA+ framework					←	—	→	
e. Sensitivity analysis of the WA+ models, finalization of results and writing research papers					←	—	→	
f. Final report writing and research paper publications							←	— →

NEW STUDIES
RESEARCH PROJECT: NIH/WRS/2018-19/02

1. Thrust Area under XII five-year Plan
Flood modeling and inundation mapping

2. Project team:
Dr. Vishal Singh, Scientist C
Dr. A K Lohani, Scientist G
Dr. Sanjay K Jain, Scientist G

3. Title of the Project -
Real time flood modelling using HEC-RTS modelling framework

4. Objectives-
The present study will be undertaken in Periyar basin in Kerala state with the following objectives:

- To investigate the rainfall extremity over the selected river basin after pre-processing of the rainfall data sets.
- Construction of the hydrological model (i.e. HEC-HMS) to generate stream flows at different sections of the river channels.
- Construction of the 2D Flood model by the coupling of hydrological model (i.e. HEC- HMS) and hydrodynamic model (i.e. HEC-RAS) named as HEC-RTS framework.
- Generation of flood discharges at different sections of rivers and the development of flood inundation maps in a stochastic manner including return periods.
-

5. Present state-of-art

Flood related risks are mostly affect social, economic, and human lives. There have been significant advances in flood inundation modelling made over the past decade. The understanding of the processes controlling runoff and flood wave propagation, in simulation techniques, in uncertainty handling, and in the provision of new data sources are required to perform flood modeling.

HEC-RTS is designed to integrate various HEC software including HMS, ResSim, RAS, and FIA with a flexible API (Application Programming Interface) that allows for scripting-based retrieval of observed and forecasted precipitation data and real-time production of different forecasting products. In this study the real time and forecasted rainfall and discharge will be utilized to generate the real time and stochastic scenarios of flood discharge in the selected river basin.

6. Methodology

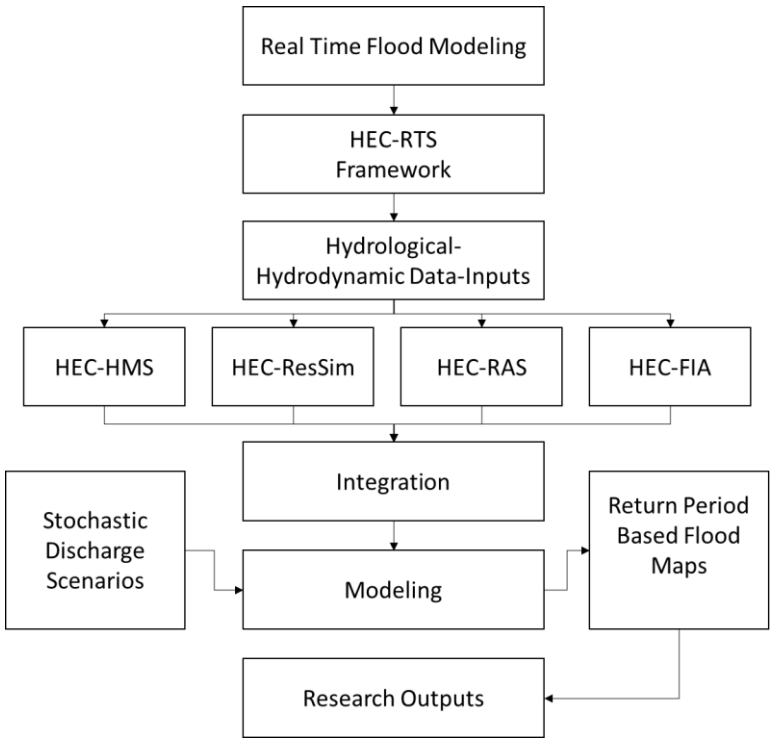
HEC-RTS integrates real-time data acquisition and database storage, and performs flood forecasting at different river sections, decision support system, inundated area determination, water levels and velocity computations. In this study, a 2D model (i.e. HEC-RTS) has been proposed to conduct a flood modeling and inundation study in Southern river basin. HEC-RTS is able to do real time flood mapping. It has ability to estimate flood damages and potential risk to life.

For the proposed study, Periyar basin in Kerela state has been selected. The real time time-series rainfall datasets with high spatial resolution along with other meteorological variables (e.g. temperature, humidity, radiation, wind etc.) will be utilized from different sources such as Indian Meteorological Department, APHRODITE, TRMM etc. The high resolution digital elevation model (DEM) and other thematic layers such as landuse/landcover (LULC), Soil map will also be utilized.

The rainfall series will be utilized to define the extreme rainfall events and further to generate stochastic flood discharge and their return periods such as 10y, 50yr, 100yr, 500yr, 1000yr etc. These return periods based flood flows will be utilized to generate the stochastic return period flood maps. These stochastic flood maps will be useful to analyze the extent and

depth of extreme flood events in the selected river basin. The proposed methodology framework has been given below :

7.



Research outcome from the project

The main outcomes of the research project are:

- Total water-balance components and parameter values of the selected river basin
- Streamflow discharge at the watershed(s) outlet(s) (Hydrographs)
- Flood discharge at different sections of the river network
- Water depth, stage-discharge (rating curve), water velocities, and river profile
- Real-time flood forecasting and simulated scenarios
- Stochastic flood and return period maps under extreme conditions
- Event based flood maps and discharge scenario
-

8. Work schedule

a. Probable date of commencement of the project: December, 2018
b. Duration of the project: Two years
c. Stages of work and milestone: Shown below

Project Year	**Jan. 19-Dec 2020**				**Jan 2021-Dec 2022**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. Concept Building and understanding of study basin								
b. Data gathering, Preparation & Synthesis								
c. Modelling : Hydrological Model Development								
d. Model Application and Testing								
e. Incorporation of Hydrodynamic Model Parameters: Hydrodynamic Model Development								
f. Model Application and Testing								
g. Flood simulation								
h. Model Application and Testing								
i. Inundation Mapping								
j. Final Report Preparation								

RESEARCH MANAGEMENT AND OUTREACH DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. V C Goyal	Scientist G & Head
2	Er. Omkar Singh	Scientist F
3	Dr. A R Senthil Kumar	Scientist E
4	Er. Digamber Singh	Scientist C
5	Dr. (Mrs.) Jyoti Patil	Scientist C (LCU)
6	Dr. Santosh M. Pingale	Scientist C
7	Sri Subhash Kichlu	PRA
8	Sri Rajesh Agrawal	SRA
9	Sri N R Allaka	RA

WORK PROGRAMME 2018-19

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar (PI) J V Tyagi, S D Khobragade , Manohar Arora	Apr 2015-Sep 2018	NIH
2	Effect of climate change on evaporation at point scale	NIH	Digamber Singh (PI) A R Senthil Kumar, Manohar Arora	Jun 2014-Jun 2018	NIH
3	Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of water management plan	NIH	Digamber Singh (PI) Omkar Singh Rajesh K.Nema Hukam Singh Subhash Kichlu N R Allaka	Apr 2018-Mar 2020	NIH
4	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH,CEH (UK) & IITR	**NIH**: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digamber Singh, Subhash Kichlu, Rajesh Agrawal, NR Allaka **IITR**: Himanshu Joshi **CEH**: Laurence Carvalho, Mike Clarke	Apr 2018-Mar 2020	NIH, CEH (UK) & IITR
	Sponsored Projects				
1	Vulnerability assessment of identified watersheds in Neeranchal Project States	NNWP	Jyoti P Patil (PI) + RCs	Jul 2017-Jun 2019	DoLR (under NNWP)
2	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	NMSHE	A R Senthil kumar (PI) J. V. Tyagi, M. K. Goel S. D. Khobragade P. C. Nayak, Manohar Arora	Mar 2016-Mar 2021	DST (under NMSHE)
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts	MoWR-funded project	V C Goyal (PI) Omkar Singh, Digamber Singh, Rajesh Singh, Subhash Kichlu, Rajesh Agrawal, NR Allaka, Rakesh Goel	Apr 2017-Mar 2020	MoWR, RD & GR
4	Development of water allocation plan for a Neeranchal watershed in Chhattisgarh	NNWP	A R Senthil kumar (PI) T R Nayak, Jyoti P Patil, Santosh Pingale, Rajesh Agrawal	Apr 2018-Mar 2020	DoLR (under NNWP)
New Sponsored Project					
1	Rejuvenation of village ponds in identified villages of Baghpat, Ghazibad and Meerut districts of Uttar Pradesh	MoWR-funded project	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digamber Singh, Subhash Kichlu, Rajesh Agrawal, NR Allaka & Project Staff	Apr 2017-Mar 2020	MoWR, RD & GR

1. Title of the study:

Study on effect of climate change on sediment yield to Pong reservoir

2. Study Group:

Dr. A. R. Senthil kumar Sc E, SWHD
Dr. J. V. Tyagi, Sc "G", SWHD
Dr. Suhas Khobragade, Sc "F", HID
Dr Manohar Arora, Sc "D", SWHD

3. Date of start: 1 April 2015

4. Duration of the study: 3 Years

5. Whether externally funded or not: No

6. Objectives of the study:

a. To model sediment yield at Pong dam.
b. To investigate the impact of likely future changes in climate on sediment yield up to Pong dam using future climatic scenarios.
c. To assess the life of the reservoir for the likely sediment yield under the projected different climatic scenarios.

7. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Pong reservoir.

8. Brief methodology:

Sediment yield model

The sediment yield up to Pong reservoir is modeled by Soil and Water Assessment Tool (SWAT) with the information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed.

Climate Scenarios

The different scenarios of climatic conditions such as RCP2.6, 4.5, 6 and RCP8.5 are obtained from CMIP5 models available from different institutes.

Computation of sediment yield under different scenarios

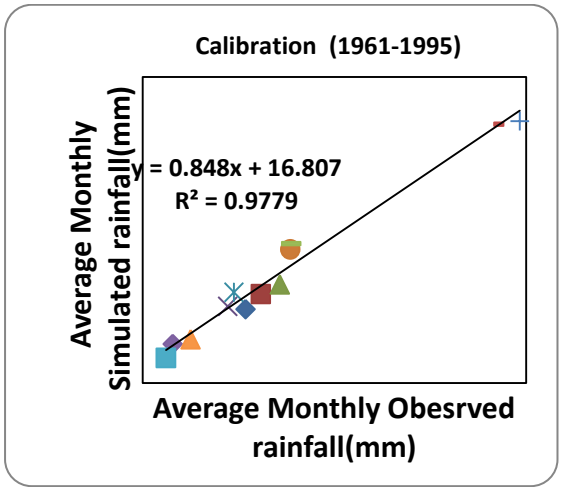
The parameters of the SWAT are calibrated using the historical hydro-meteorological data. The future sediment yield is simulated using SWAT with the data of different climatic scenarios. The impact of likely future changes in climate on stream sediment yield up to Pong is analyzed by the output of SWAT for future climate scenarios.

Revision of elevation-area-capacity table

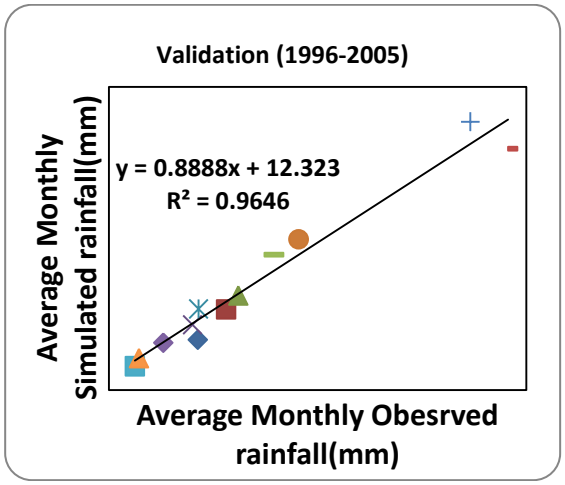
The projected sediment volume for future periods is distributed in the reservoir by empirical-area reduction method to find out the revised elevation-area-capacity table.

9. Results achieved with progress/present status

The SWAT model is setup with the required input data to simulate the sediment yield from Beas Catchment up to Nadaun bridge (Pong reservoir). The input data such as DEM, LULC and soil type are generated from different sources such as NASA, National Bureau of Soil Survey and Land Use Planning (NBSSLUP) and NRSC. Grid based meteorological data such as daily rainfall, minimum and maximum temperatures are obtained from Indian Meteorological Department (IMD) and rainfall, minimum temperature, maximum temperature, solar radiation, wind velocity, relative humidity are obtained from European Centre for Medium-Range Weather Forecasts (ECMWF) (ERA Interim data). The parameters for the simulation of discharge and sediment yield have been calibrated manually by trial and error method by considering the data from 1993 to 1996 for calibration and 1999 to 2002 for validation. The coefficient of determination for simulation of sediment yield during calibration and validation are 0.95 and 0.92 respectively. Significant predictors of rainfall have been determined using the averaged IMD gridded data of rainfall and the rainfall from NCEP-NCAR reanalysis data for the period from 1961-2005 by SDSM tool. The significant predictors are mean sea level pressure (pa), total precipitation (mm), surface airflow strength (m/s), specific humidity at 500 hpa (%), surface specific humidity (%). The calibration and validation of significant predictors of NCEP-NCAR data have been carried out by SDSM with averaged IMD gridded data. The averaged IMD gridded data for the period from 1961 to 1995 and from 1996 to 2005 have been considered for calibration and validation of significant predictors of rainfall respectively. The coefficient of determination for the calibration and validation of significant predictors are 0.98 and 0.96 respectively and are given in the following figures.

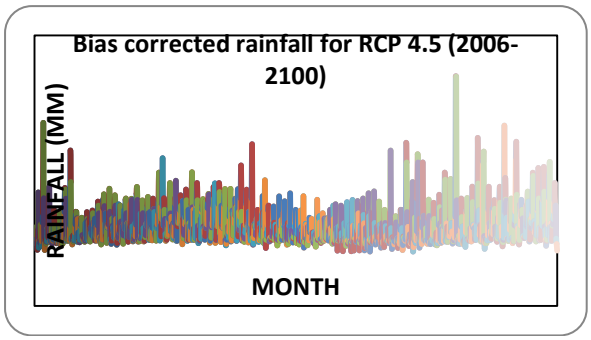


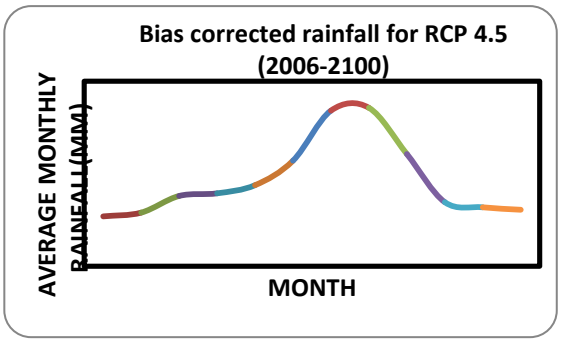
Calibration (1961-1995)



Validation (1996-05)

The rainfall values for the scenario of RCP2.6, 4.5 and 8.5 for the period from 2006 -2100 have been downscaled from CanESM2 predictors from the regression equation developed for NCEP/NCAR significant preditctors. The downscaled values of the rainfall for the scenarios of RCP2.6, 4.5 and 8.5 have been bias corrected by probality of exceedence method. The bias corrected values of rainfall for the scenario of RCP 4.5 from 2006 to 2100 is given as follows:





The downscaling of minimum and maximum temperature is being carried out from the predictors of CanESM2 for the scenarios of RCP 2.6, 4.5 and 8.5.

10. Expected date of completion: **30 September 2018 (Actual date of completion: 31 March 2018)**

11. Revised timeline

Sl. No.	Work Element	2015-16		2016-17		2017-18		2018-19	
		H1	H2	H1	H2	H1	H2	H1	H2
1	Literature Review								
2	Collection and processing of Hydrometeorological data and purchase of satellite imagery and soil maps								
3	Data preparation for SWAT								
4	Simulation of Sediment yield by SWAT								
5	Downscaling of data from GCM Models								
6	Simulation of sediment yield with the data from future climatic scenarios								
7	Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield								
8	Preparation of interim report								
9	Preparation of final report								

1. Title of the study:

Effect of climate change on evaporation at point scale

2. Study Group:

Sh. Digambar Singh, Sc C, SWHD
Dr. A. R. Senthil kumar Sc E, SWHD
Dr. Manohar Arora, Sc D, SWHD

3. Date of start: 1 June 2014

4. Duration of the study: 3 Years

5. Whether externally funded or not: No

6. Objectives of the study:

a. To develop evaporation model by empirical and soft computing techniques
b. To downscale the data of temperature, rainfall and humidity from GCM model
c. To determine the effect of climate variables on evaporation by using the downscaled data

7. State of the problem

Crop water requirement is the depth of water needed to meet the water loss through evapotranspiration. Computation of crop water requirement is very important in planning, design and operation of irrigation projects. Evapotranspiration comprises of both evaporation and transpiration from the crops/plants and surface of the land. Computation of evaporation and evapotranspiration requires climatic factors such as minimum and maximum temperature, relative humidity, radiation, solar radiation and wind speed, etc. Variability of evaporation and evapotranspiration depends on the local condition of climatic factors. IPPC predicts increase in mean temperature till 2100 due to the anthropogenic activities. So the Prediction of evaporation and evapotranspiration is very much important under this condition to plan the cropping pattern in future.

8. Brief methodology:

Evaporation model

Empirical models such as Penman Method, Meyer Model, Multiple Linear regression (MLR) and soft computing techniques are applied to model the evaporation with rainfall, temperature and humidity as input vectors.

Development of climate scenarios

The rainfall, minimum and maximum temperature and humidity for future can be generated by GCM models. The different scenarios of climatic conditions such as RCP2.6 4.5, 6 and 8.5 are obtained from CMIP5 models available from different institutes. The historical data used for the downscaling and the bias correction are maximum and minimum temperature, rainfall, wind speed and solar radiation computed from extra terrestrial radiation. The empirical and the best model developed by soft computing techniques are applied to simulate the evaporation from the downscaled values of rainfall, maximum and minimum temperature and humidity for different climatic scenarios as mentioned above.

9. Results achieved with progress/present status

The evaporation for the period from 1987 to 2013 has been computed with the available data by different methods such as Penman method, Meyer method and other empirical equations based on saturated vapour pressure and the results are compared by statistical parameters such as coefficient

of correlation and root mean squared error. The empirical equation for the condition of air and water surface temperature different is the best method among all. The evapotranspiration for the period from 1987 to 2013 has been computed with the available data by different methods such as Turc method, Hargreaves method and Thornthwaite method and the estimates by Hargreaves method is best among all. The ANN model for simulating the evaporation has been developed with the input data derived from the statistical parameters such as ACF, PACF of evaporation and CCF of evaporation with rainfall, minimum temperature, maximum temperature and relative humidity and performance of the ANN models analysed statistical parameters such as coefficient of correlation, root mean squared error and Nash-Sutcliffe model efficiency. A Multiple Linear Regression (MLR) model has been developed using the inputs considered in the development of ANN model for the simulation of Evaporation. The inputs considered in the modelling are the observed data from NIH observatory from 1987 to 2013. A comparison between the MLR and ANN models is carried out by performance indices such as coefficient of correlation, root mean squared error, Nash-Sutcliffe Model efficiency. It is found that ANN model has performed better than MLR during calibration and validation.

The trend analysis of rainfall, max temperature, min temperature, wind speed and pan evaporation have been done by Mann-Kendall, Kendall Rank Correlation test and Spearman's Rho test. The trend analysis for season wise series of rainfall, max temperature, min temperature, wind speed and pan evaporation have also been carried. The results of trend analysis by different method rainfall and wind speed at 5 significant level are given as follows:

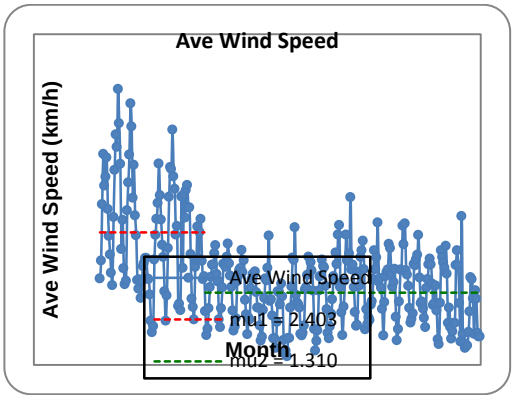
Results of trend analysis for rainfall at 5 % significant level

Sl No	Varaible	Mann-Kendall	Kendall Rank Correlation	Spearman's Rho Test
1	Monthly Rainfall	No trend	No trend	No trend
2	Winter rainfall	No trend	No trend	Rising trend
3	Pre monsoon rainfall	No trend	No trend	No trend
4	Monsoon rainfall	No trend	No trend	No trend
5	Post Monsoon Rainfall	No trend	No trend	No trend
6	Average Annual rainfall	No trend	No trend	Rising trend

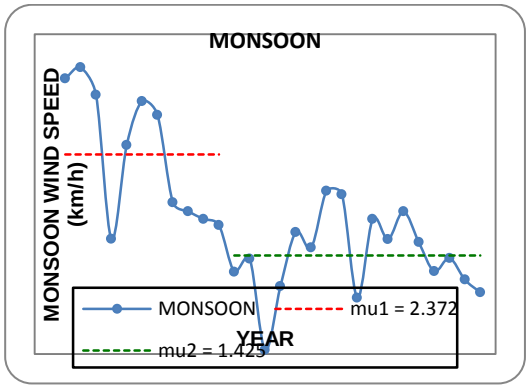
Results of trend analysis for wind speed at 5 % significant level

Sl No	Varaible	Mann-Kendall	Kendall Rank Correlation	Spearman's Rho Test
1	Monthly wind speed	Falling trend	Falling trend	Rising trend
2	Winter wind speed	Falling trend	Falling trend	Rising trend
3	Pre monsoon wind speed	Falling trend	Falling trend	Rising trend
4	Monsoon wind speed	Falling trend	Falling trend	Rising trend
5	Post Monsoon wind speed	Falling trend	Falling trend	Rising trend
6	Average Annual wind speed	Falling trend	Falling trend	Rising trend

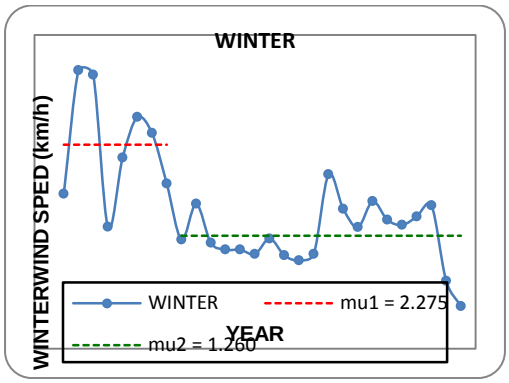
The homogeneity test by Pettitt's method have been carried for the monthly, winter, pre monsoon, post monsoon, monsoon and average annual wind speed data of at 5% significant level and the results clearly show a shift in the data around 1999 and the corresponding plots are given as follows:.



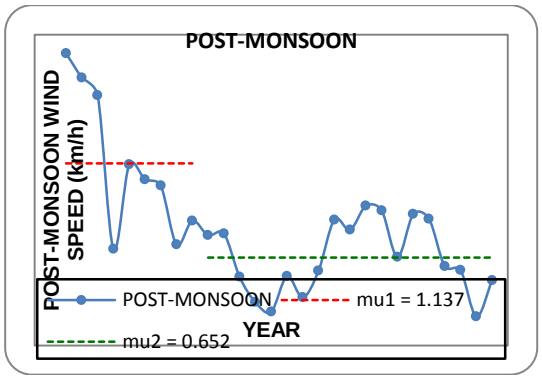
Result of homogeneity test for Monthly data



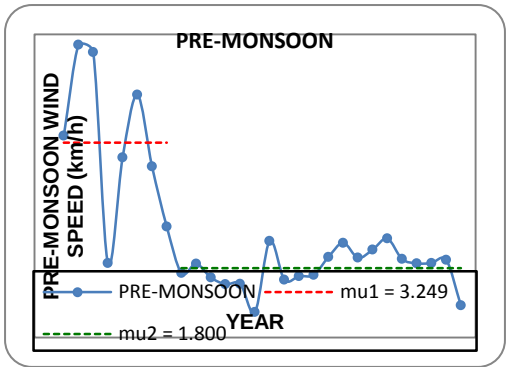
Result of homogeneity test for Monsoon data



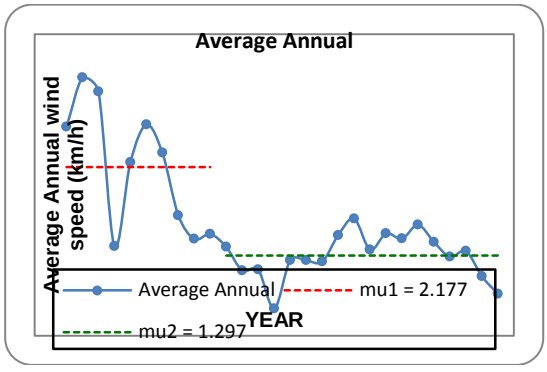
Result of homogeneity test for Winter data



Result of homogeneity test for Post monsoon data



Result of homogeneity test for Pre monsoon data



Result of homogeneity test for Average annual data

10. Date of completion:

The study was completed by June 2018.

11. Timeline

Sl. No.	Work Element	2014-15		2015-16		2016-17		2017-18		2018-19	
		H1	H2	H1	H1	H1	H2	H1	H2	H1	H2
1	Literature Review										
2	Data collection, compilation and processing										
3	Development of model for evaporation by empirical and soft computing techniques										
4	Development of model for evaporation by multiple linear regression models										
5	Downscaling of data from COordinated Regional Downscaling Experiment (CORDEX) (IITM Pune) and CanESM2 (GCM Model)										
6	Simulation of evaporation by considering the climate scenarios										
7	Preparation of interim report										
8	Preparation of final report										

1. Title of the study:

Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of watershed management plan.

2. Study Group:

Digambar Singh Sc C, RMOD, Er. Omkar Singh Sc F, RMOD
Shri Subhash Kichlu PRA, RMOD, Rajesh K.Nema, PRA, SWHD, Hukam Singh, PRA, SWHD, Shri N R Allaka RA, RMOD

3. Date of start: 1, April 2018

4. Duration of the study: 2 Years

5. Whether externally funded or not: No

6. Objectives of the Study:

a. Bathymetric survey of identified ponds and estimation of water storage capacity of ponds.
b. Assessment of water quality of ponds for irrigation and fisheries etc.

7. Statement of the problem

Assessment of availability of water from surface water bodies (Ponds) in the Bundelkhand region is very important to sustain irrigation, fisheries and other water needs as well as to provide security to farmers. This study aims to estimate the quantity and quality of available water in the selected water bodies to know the present status and plan a strategy for the future by carrying out bathymetric survey and water quality investigations.

8. Brief methodology:

(a) **Remote/Pedal boat (using sonding weight) will be used for bathymetric survey**.

The Echo Boat is a hand portable remote controlled catamaran platform developed for bathymetric survey applications. The light weight, wide profile and water tight connection provide stability, ruggedness and portability. Work environment include mines, STP, contaminated lakes/ponds and rivers etc.

(b) Assessment of water quality

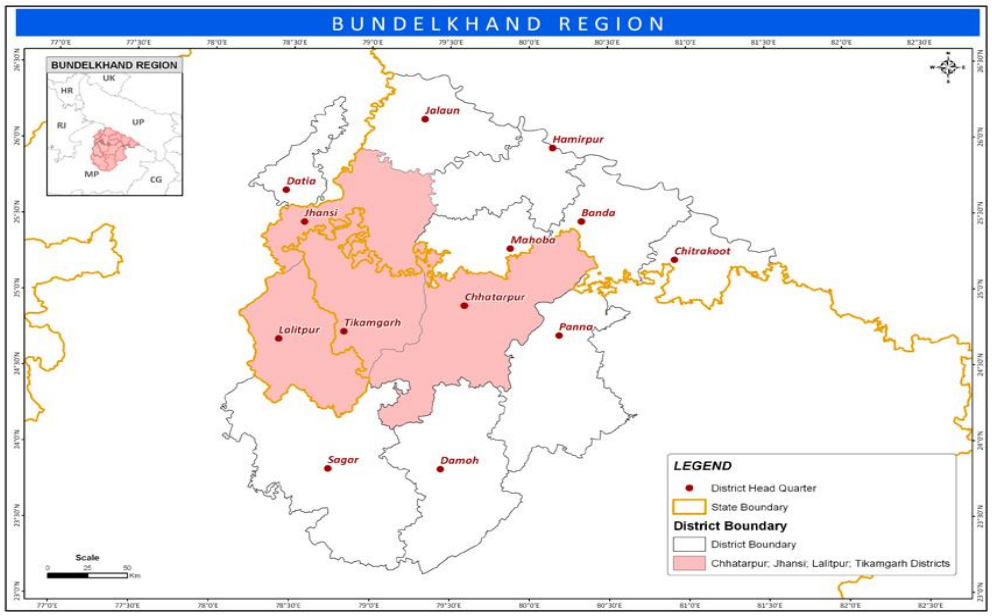
The water quality parameters, viz. temp., pH, electrical conductivity, total dissolved solids, dissolved oxygen, turbidity, chlorophyll and blue green algae are to be monitored using multi-parameter Sonde (YSI, 2014) The water quality of different ponds is to be assessed based on above mentioned limited water quality parameters as monitored in field for fishery (Bhatnagar & Devi, 2013), irrigation (CPCB, 1978/2007-8), and drinking (IS: 10500, 2012), respectively and the apparatus available at water quality laboratory at NIH, Roorkee.

(c) Determining the Water quality index

Water Quality Index (WQI) is a standard index created and designed by The National Sanitation Foundation (NSF). The WQI is one of the most widely used tools of all existing water quality procedures. The overall results of nine separate tests can be used to determine WQ index of any water body. Water quality index is a 100 point scale that summarizes results from a total of nine parameters given below. Temperature, pH, Dissolved Oxygen, Turbidity, Fecal Coliform, Biochemical Oxygen demand, Total Phosphates, Nitrates, Total Suspended Solids.

9. Study area

The study area covers Jhansi (U.P.), Lalitpur (U.P.), Tikamgarh (M.P.), Chhatarpur (M.P.) districts. Map of the area is given below:



10. Action plan and timeline

Sl. No.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Literature review	■	■						
2	Collection of water sample and measurement of water quality parameters by SONDE			■	■				
3	Bathymetric Survey of the ponds			■	■				
4	Water Quality Analysis			■	■				
5	Computation of the volume of the ponds				■	■	■		
6	Analysis of the suitability of water for irrigation and fisheries					■	■	■	
7	Report writing							■	■

11. Data requirements

Dissolved oxygen, Ph, EC, TDS, Chlorophyll, Temperature, Depth, Conductivity, Salinity, ORP, BGA, FDIM, Phosphate etc.

12. Results achieved with progress/present status

Bathymetric survey by eco boat and water quality of the pond water by Sonde will be carried during October/November 2018.

12. Deliverables:

i) Bathymetric map
ii) Water quality status and evaluation report for irrigation
iii) Research papers

13. Adopters of the results of the study and their feedback: **Agriculture and fisheries department of the concerned region**

1. Title of the Study: Conservation of ponds in Ibrahimpur-Masahi village and performance evaluation of natural treatment system.

2. Study Group:

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigators Dr. V. C. Goyal, Scientist G & Head (RMOD) Dr. Rajesh Singh, Scientist C, EHD Er. Digambar Singh, Scientist C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N.R. Allaka, RA
Partner Organization	Dr. Laurence Carvalho & Team, Centre for Ecology & Hydrology, Edinburgh, United Kingdom

3. Type of Study: Internally Funded (CEH-UK will cover the expenses towards DO sensors and biota analysis)

4.

4. Nature of Study: Applied

5. Date of start: April 2018

6. Scheduled date of completion: March 2020

7. Duration of the Study: 02 Years

8. Study Objectives:

i) Water quality investigations of ponds, wastewater and groundwater.
ii) Performance evaluation of CW based Natural Treatment System.
iii) Assessment of health of water body through ecological indicators.
iv) Planning for use of treated wastewater.
v) Societal impact assessment.
vi) Mass Awareness Activities.

9. Statement of the Problem:

In our country, most of the traditional sources of water (i.e. ponds) in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and face severe eutrophication mainly due to untreated input of wastewater in the ponds. In this context, the Institute has rejuvenated a pond (Village: Ibrahimpur Masahi, Tehsil-Bhagwanpur, Dist. Haridwar) by establishing CW based Natural Treatment System (NTS). The rejuvenated ponds with treated wastewater will be used for agricultural use and livelihood activities such as fishery. The performance evaluation of this system, which is an important aspect to establish its feasibility and replicability in other village ponds receiving continuously input of domestic wastewater in the ponds. Therefore, in this study it proposed to regularly monitor key water quality parameters at two ponds, namely Ibrahimpur (pond with control) and Masahi Kala (pond without control) lying under Ibrahimpur-Masahi revenue village (Tehsil-Bhagwanpur, Dist. Haridwar) in collaboration with Centre for Ecology & Hydrology (Edinburgh, United Kingdom).

10. Approved Action Plan/Methodology:

In this study, the pond, wastewater, and groundwater (hand-pumps) quality will monitored per standard procedures (APHA 2012). Along with CEH-UK team, the health of the water body and its impact on society will also be assessed. Options for the use of treated wastewater will be explored.

The water quality assessment for agriculture purposes (BIS-1987/2001; USDA 1954) and Fishery will be performed as per recommended procedures including development of WQ Indices. Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977).

11. Timeline:

S. N.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Review of literature								
2	Water quality and depth monitoring of pond, groundwater, and wastewater								
3	Data compilation & performance evaluation of NTS								
4	Assessment of health of water body								
5	Societal impact assessment								
5	Mass awareness activities								
6	Report Preparation								

12. Achievement during last twelve months:

Objectives	Achievements
Review of literature	• Under progress
Water quality and depth monitoring of pond, groundwater, and wastewater	• Samples were collected in April (06 GW+01 PW+01WW), May (04 GW + 01 PW + 01 WW) and July (01 PW). • The organoleptic, major cations and major anions were analyzed. • Trace metal analysis of the samples are under progress. • The groundwater levels of the study area were also recorded.
Data compilation & performance evaluation of NTS	• Productivity experiment conducted in the month of April & July 2018.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	-

14. Analysis & Results:

Natural treatment system i.e. constructed wetland has been establish in Ibrahimpur Masahi village. To check the efficiency of constructed wetland, water quality and ground water level monitoring has been done from time to time. Ground water level monitoring of Ibrahimpur Masahi village was carried out

in November 2017 & January 2018 and samples were collected from the ponds and ground water. The depth of GW range from 3.0 to 17.58 mbgl in April 2018. 5 GW s, 1 pond, and 1 wastewater samples were collected in April and July 2018 and analyzed for organoleptic and major cations and anions. pH, EC and ORP of collected samples were done in the field using Sensorex SMART AQUAMETER.

pH of groundwater samples ranged from 6.9 to 7.0 and conductivity ranged from 534 to 1214 µS/cm. Turbidity, hardness and alkalinity of all the samples exceeded the acceptable limit prescribed by BIS. TDS and nitrate of one sample exceeded the prescribed limit. Total coliforms were present in all the samples except one i.e. near primary school (entrance of village).

pH of pond water samples were in the range of 6.9 to 7.0 and EC was in the range of 711 to 1108 µS/cm. The dissolved oxygen was non-detectable in CW inlet, 1.8 mg/l in CW outlet, and 1.9 mg/l in pond. Fecal coliform was also detected in the pond water sample. Primary productivity experiment for the pond was conducted to assess the heath of water body for fishery production. Results indicated that sufficient production of organic matter exists to support fish life. Also, an experiment was conducted to estimate the greenhouse gases (CH_4, CO_2, N_2O) emission from the village pond.

15. **End Users / Beneficiaries of the Study:** Villagers & Stakeholders

16. **Deliverables:** Performance Evaluation Report of CW-NTS, Societal impact of rejuvenated water body, Eutrophication Trends of Ponds,

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH) / IIC (IITR)

19. **Data procured or generated during the study:** Pond and groundwater quality and groundwater level data.

20. **Study Benefits / Impacts:** The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond and also enhance the groundwater water quality of the area. This study will address the issues related to contamination of village ponds and the outcomes from the study can be utilized by the policy makers for addressing the issues in other villages.

21. **Involvement of end users/beneficiaries:** Villagers and Gram panchayats

22. **Specific linkage with Institution and /or end users / beneficiaries**: Gram panchayats

23. **Shortcoming/Difficulties:** Societal issues

24. **Future Plan:** As per approved action plan

1. Title of the Study:

Vulnerability assessment of identified watersheds in Neeranchal Project States

2. Study group:

Dr Jyoti P Patil and nodal scientists from Regional centres (Bhopal, Patna, Kakinada, Belgaum)

3. Type of Study: Sponsored- Neeranchal National Watershed Programme (NNWP)

4. Date of start: 01.07.2017

5. Scheduled date of completion: 30.06.2019

6. Duration of the Study: Two years

7. Study Objectives:

The aim of the study is to assess the vulnerability to climate change for the identified watersheds of 9 Neeranchal Project States.

8. Statement of the Problem:

Assessing vulnerabilities is the process of identifying, quantifying, and prioritising the vulnerabilities in a system. Vulnerabilities from the perspective of climate change means assessing the threats from potential hazards to population, infrastructure, development goals etc. VAs can help to improve adaptation-planning, allocation of resources and raising awareness about climate change at different levels. Vulnerabilities cannot be measured directly; it has to be inferred with the help of various variables.

9. Brief methodology

Focus of this study has been on generating Livelihood Vulnerability Index (LVI) by IPCC approach for watersheds under NNWP. The IPCC-LVI approach would facilitate the identification of areas, which are vulnerable to climate change and need special attention towards adaptation. The socio-economic, environmental, agriculture, water resource, health, climate and forest indicators of vulnerability will employed and classified into adaptive capacity (A), sensitivity (S), and exposure (E). The LIV-IPCC approach was applied on block level assessment of vulnerability to climate change in Neeranchal districts. The micro-watershed level vulnerability assessment was also done using Vulnerability Composite Index. Identification and classification of indicators for vulnerability assessment is always subjective keeping in view the importance of indicators in the spatial context, availability of quantitative/measurable data, time series availability of data and to some extent any indicator having proxy representation. They will be classified manually as it is not possible to carry out such a classification statistically. Statistics is based on numbers and do not take into account the physical nature of the indicator.

10. Timeline:

S. N.	Work Element/ Milestone	2017-18	2018-19		2019-20
		H2	H1	H2	H1
1	Select a set of indicators to assess the vulnerability of people, livelihoods and ecosystem				
2	Collection of data from secondary sources				

3	Calculate Livelihood Vulnerability Index using the IPCC approach				
4	Highlight areas that are most vulnerable and need to be protected as well as the areas that need improvement				
5	Suggest measures/ strategies to cope up with climate change events in future				

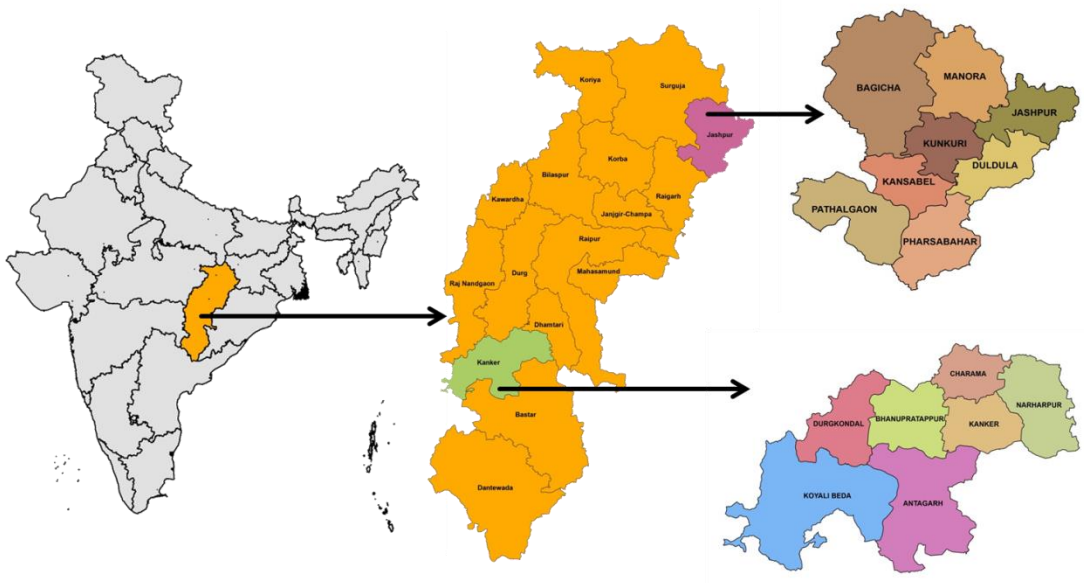
11. Achievement during last six months:

Work Element as per timeline	Achievement
Collection of data from secondary sources	Data was collected from secondary sources like DPRs, census (population/ livestock), state department sites, district statistical handbooks etc.
Calculate Livelihood Vulnerability Index using the IPCC approach	The pilot set of data is prepared for Jashpur and Kanker districts of Chhattisgarh. The LVI-IPCC methodology results made available through DSS-H.
Vulnerability was assessed for villages using Composite vulnerability approach on watershed scale	The computation was completed three micro-watersheds in Kanker district of Chhattisgarh

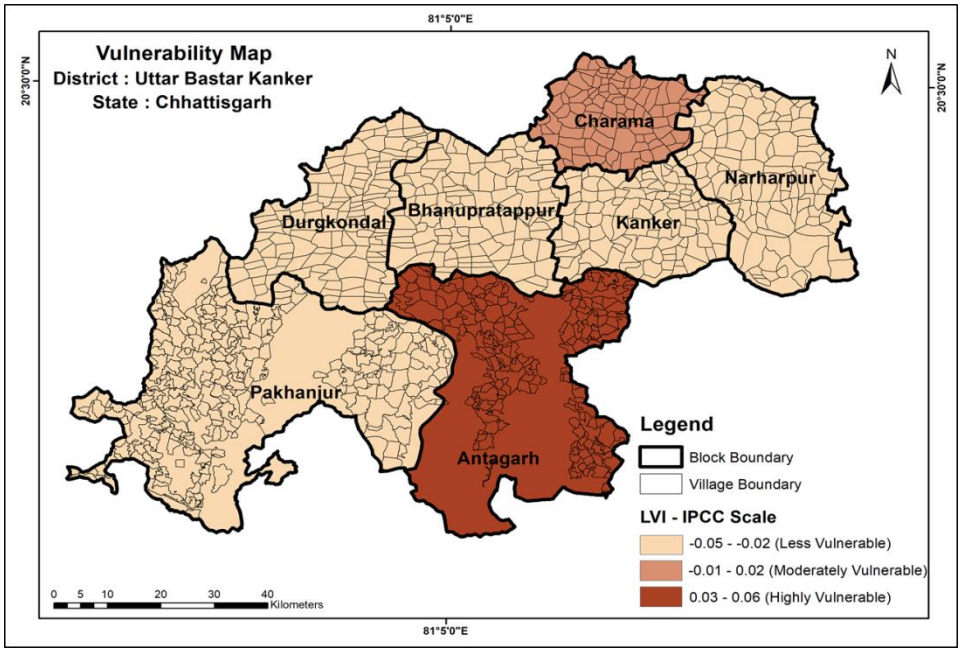
12. Recommendation / Suggestion: **NA**

13. Analysis & Results:

1. The two districts, Kanker and Jashpur, Chhattisgarh were selected on pilot basis for block level assessment using LVI-IPCC approach.

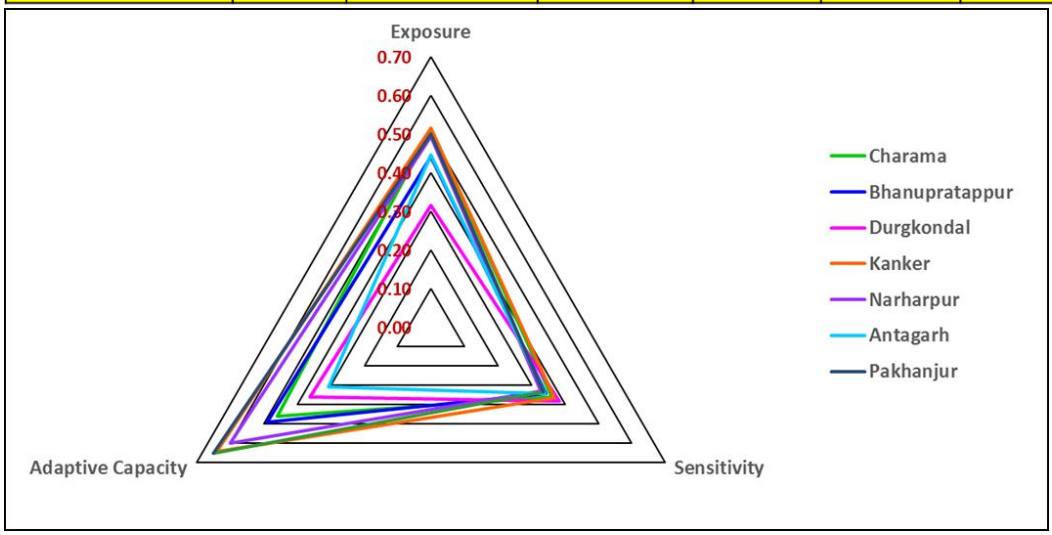


2. Vulnerability assessment on block level in Kanker district is shown in following figure.



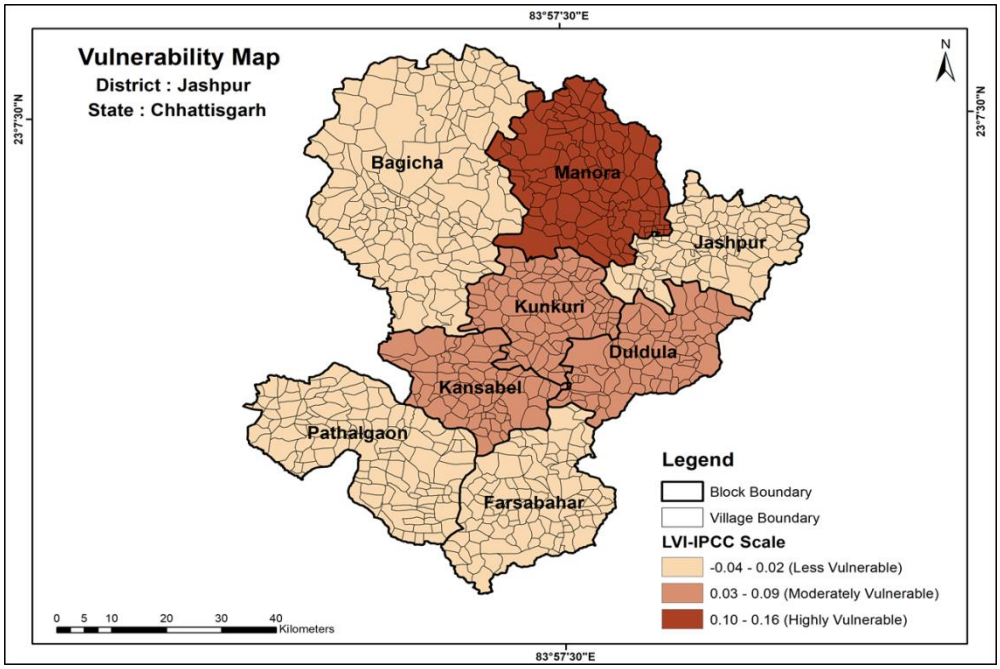
3. Kanker district- LVI-IPCC overall results are given below"

Major Components	Charama	Bhanupratappur	Durgkondal	Kanker	Narharpur	Antagarh	Pakhanjur
Exposure	0.51	0.44	0.32	0.52	0.49	0.45	0.50
Sensitivity	0.36	0.34	0.38	0.37	0.33	0.34	0.34
Adaptive Capacity	0.46	0.49	0.36	0.64	0.60	0.31	0.65
LVI - IPCC	**0.02**	**-0.02**	**-0.02**	**-0.05**	**-0.04**	**0.05**	**-0.05**

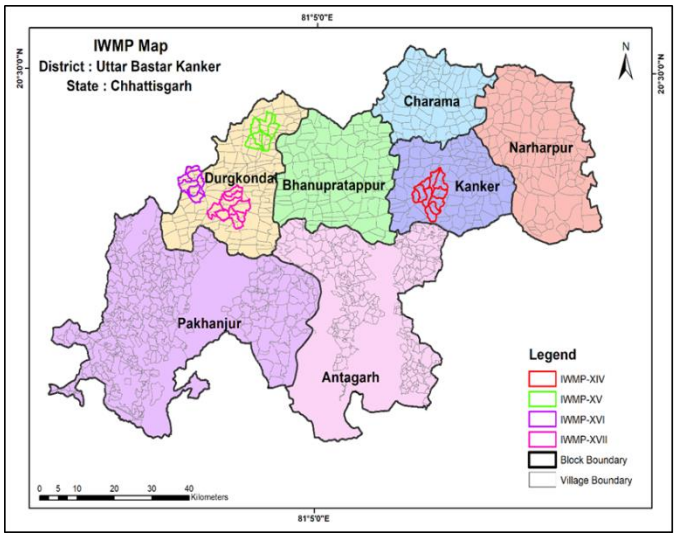


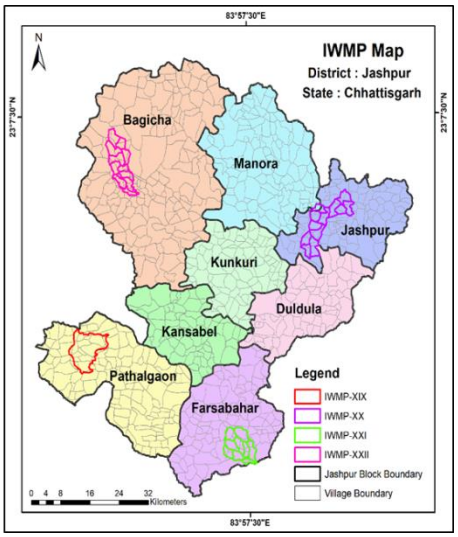
Vulnerability Order:
Antagarh > Charama > Bhanupratappur > Durgkondal > Narharpur > Kanker > Pakhanjur

4. Likewise, vulnerability assessment of Jashpur district was completed



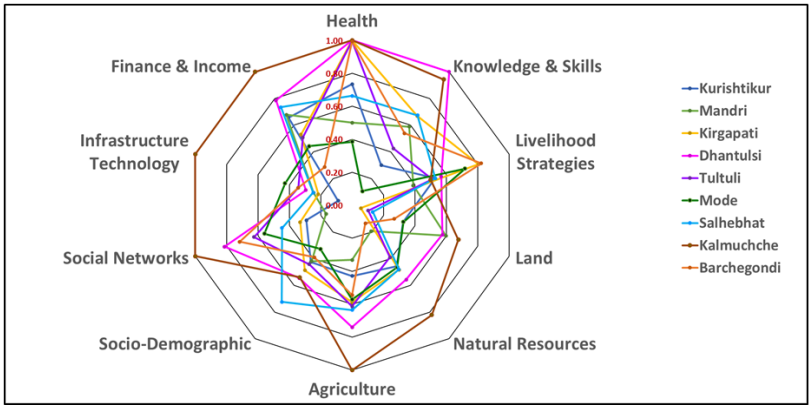
5. Assessment on micro-watershed level using Composite vulnerability approach was initiated for Kanker district. The locations of mico-watersheds in both districts are shown in following figure.





6. The results of IWMP-IVX are given below

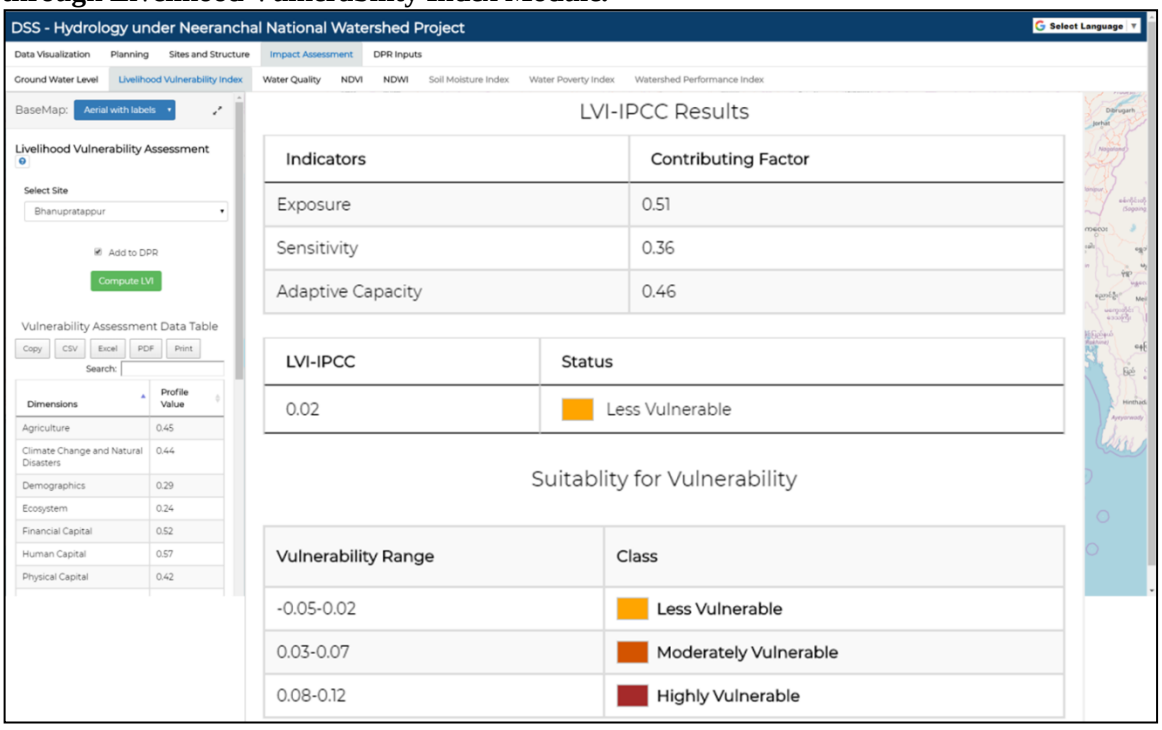
Indicators	Kurishtikur	Mandri	Kirgapati	Dhantulsi	Tultuli	Mode	Salhebhat	Kalmuchche	Barchegondi
Health	0.73	0.50	1.00	1.00	1.00	0.39	0.66	1.00	0.99
Knowledge & Skills	0.30	0.59	0.67	1.00	0.43	0.11	0.67	0.94	0.54
Livelihood Strategies	0.53	0.39	0.80	0.57	0.51	0.72	0.53	0.50	0.82
Land	0.33	0.60	0.06	0.58	0.10	0.33	0.13	0.68	0.27
Natural Resources	0.46	0.19	0.48	0.56	0.39	0.46	0.48	0.82	0.14
Agriculture	0.43	0.33	0.59	0.74	0.61	0.57	0.63	1.00	0.55
Socio-Demographic	0.43	0.42	0.49	0.55	0.44	0.33	0.72	0.54	0.39
Social Networks	0.29	0.17	0.33	0.81	0.63	0.56	0.45	1.00	0.72
Infrastructure Technology	0.09	0.25	0.22	0.30	0.34	0.43	0.25	1.00	0.34
Finance & Income	0.66	0.68	0.53	0.79	0.51	0.44	0.73	1.00	0.29
LVI Score	0.40	0.38	0.49	0.63	0.47	0.43	0.54	0.82	0.45



7. The village wise vulnerability order is as below
Kalmuchche > Dhantulsi > Salhebhat > Kirgapati > Tultuli > Barchegondi > Mode > Kurustikur > Mandri

8. The analysis of IWMP-15 and IWMP-16 in Kanker district is also completed.

9. The methodology and results of the LVI-IPCC approach are incorporated in DSS-H through Livelihood Vulnerability Index Module.



14. End Users / Beneficiaries of the study**: Integrated Watershed Management Programme**

15. Deliverables: **Areas which are most vulnerable to climate change and need further attention will be highlighted**

16. Major items of equipment procured: **Nil**

17. Lab facilities used during the study: **Nil**

18. Data procured or generated during the study: -

19. Study Benefits / Impacts: **Outputs of the study will be used in the development of DSS(Hydrology), and later on for preparation of DIP/ DPR by the respective line departments**

20. Involvement of end users/beneficiaries: **IWMP**

21. Specific linkage with Institution and /or end users/beneficiaries: **Various line departments (KVKs, Irrigation, WRD, Agriculture, Industry)**

1. Title of the study:

Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact

2. Study Group:

Dr. A. R. Senthil kumar Sc E, SWHD
Dr. J. V. Tyagi, Scientist 'G', NIH, Roorkee
Dr. M. K. Goel, Scientist 'G', NIH, Roorkee
Dr. S. D. Khobragade, Scientist 'F', NIH, Roorkee
Dr. P. C. Nayak, Scientist 'D', Deltaic Regional Centre, NIH, Kakinada
Dr. Manohar Arora, Scientist 'D', NIH, Roorkee

3. Date of start: 1 January 2016

4. Duration of the study: 5 Years

5. Whether externally funded or not: DST

6. Objectives of the study:

a. To model stream flow/snow melt runoff in Bhagirathi Basin up to Tehri dam.
b. To model sediment yield at Tehri dam.
c. To investigate the impact of likely future changes in climate on stream flow and sediment yield up to Tehri dam using future climate scenarios.
d. To assess impact of afforestation/deforestation on sediment yield in the basin.
e. To assess the operation policy of the Tehri dam in light of the climate change impact.

7. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Tehri reservoir. The study on impact of afforestation/deforestation on sediment yield in the basin is also important for effective watershed management.

8. Brief methodology:

Sediment yield model

The sediment yield up to Tehri reservoir is modeled by Soil and Water Assessment Tool (SWAT) with the information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed.

Streamflow simulation

The streamflow up to Tehri reservoir is modeled by SNOWMOD with the input data of elevation, rainfall, aspect, temperature and snow cover area. The performance of SWAT is compared with SNOWMOD in simulating the discharge.

Climate Scenarios

The different scenarios of climatic conditions such as RCP2.6, 4.5 and RCP8.5 are obtained from CMIP5 models available from different institutes.

Computation of streamflow and sediment yield under different scenarios

The parameters of the SWAT are calibrated using the historical hydro-meteorological data. The future streamflow and sediment yield are simulated using SWAT and SNOWMOD with the data of different climatic scenarios. The impact of likely future changes in climate on streamflow and sediment yield up to Tehri is analyzed by the output of SWAT and SNOWMOD for future climate scenarios.

Revision of elevation-area-capacity table

The projected sediment volume for future periods is distributed in the reservoir by empirical-area reduction method to find out the revised elevation-area-capacity table.

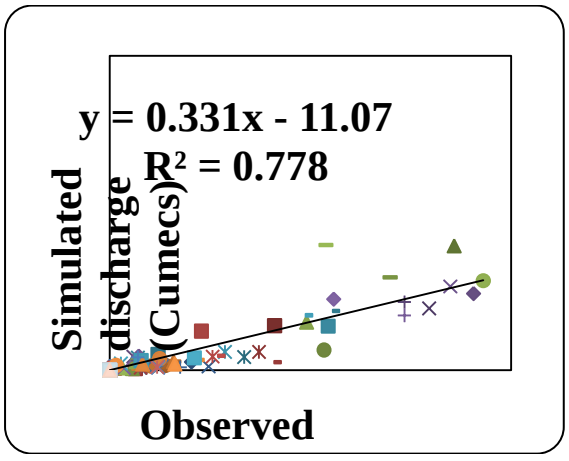
The impact of afforestation/deforestation on sediment yield is analyzed by the simulation of sediment yield using SWAT by increasing/decreasing the LULC.

The rule curves for operating the reservoir are modified by considering the revised elevation-area-capacity curve in light of increased/increased sediment yield.

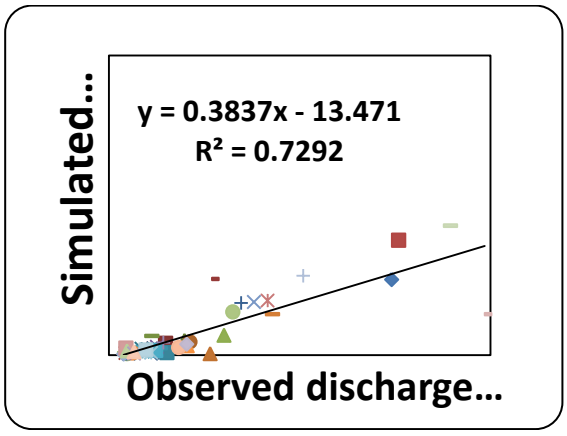
9. Results achieved with progress/present status:

The sediment yield at Tehri reservoir is modelled by Soil and Water Assessment Tool (SWAT). The inputs such as DEM, LULC and Soil map for running the ARCSWAT have been generated using different sources available in the web sites of different organisations such as NASA, National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Indian Council of Agricultural Research, Harmonized World Soil Database (HWSD) International Institute for Applied Systems Analysis **(**IIASA) and National Remote Sensing Centre (NRSC). The daily rainfall, maximum temperature, minimum temperature, Solar radiation, wind speed, relative humidity (from surface pressure, mean temperature and dew point temperature) have been obtained from **ERA INTERIM, European Centre for Medium Range Weather Forecasts (ECMWF).**The discharge and sediment yield at Tehri dam has been simulated using the gird based input data by taking the parameters randomly with SWAT .

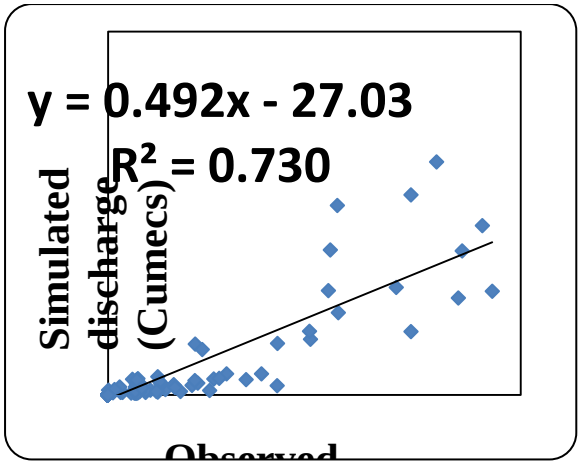
Ten daily silt data from 2002 to 2011and daily discharge from 2001 to 2013 at Tehri reservoir have been obtained. The parameters of the SWAT are calibrated by considering the discharge, rainfall from IMD and ERA INTERIM separately. The graphical comparison of the observed and simulated discharge at Tehri dam for ERA INTERIM and IMD are given as follows:



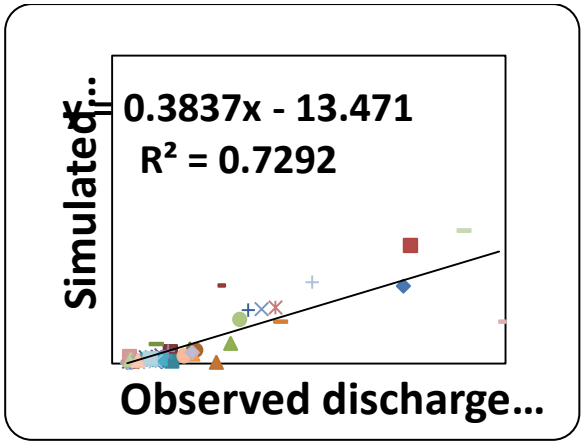
Calibration result for ERA INTERIM data from 2001 to 2006



Validation result for ERA INTERIM data from 2007 to 2010



Calibration result for IMD data from 2001 to 2006



Validation result for IMD data from 2007 to 2010

The comaprison of the results for ERA INTERIM and IMD data are given as follows:

10. Outcome of the study

The output of the study will give an idea of increased sediment yield and streamflow from the future climatic scenarios to the state department officials for managing the various demands based on the available the storage in the reservoir on priority basis. The impact of afforestation/deforestation on sediment yield will be used for planning cropping pattern to reduce the sediment yield

11. Expected date of completion: 31 January 2021

12. Timeline

Activity	2016-17		2017-18		2018-19		2019-20		2020-21	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
Collection and processing of Hydrometeorological data and purchase of satellite imagery										
Data preparation for SNOWMOD and SWAT										
Simulation of streamflow by SNOWMOD										
Simulation of Sediment yield by SWAT										
Downscaling of data from GCM Models										
Simulation of streamflow and										

Statistical Parameters	Calibration (2001-2006)		Validation(2006-2010)	
	ERA INTERIM	IMD	ERA INTERIM	IMD
R^2	0.77	0.73	0.71	0.67
NSE	0.17	0.15	0.25	0.24

sediment yield with the data from future climatic scenarios										
Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield										
Analysis of the reservoir performance with the revised elevation-area-capacity table and projected streamflow										
Writing of the final report										
Training workshop										

1. Title of the Study:

Development of water allocation plan of a Neeranchal watershed in Chhattisgarh

2. Study group:

Dr A. R. Senthil kumar, Sc "E" RMOD
Dr. T R Nayak, Sc "E", RC, Bhopal
Dr. Jyoti P Patil, Sc "C", RMOD
Dr. Santosh M. Pingale, Sc."C", RMOD
Sh. Rajesh Agarwal, SRA, RMOD

3. Date of start: April 2018

4. Duration of the study: 2 Years

5. Whether externally funded or not: NNWP

6. Objectives:

a. To model the different components of hydrological process.
b. To evolve water allocation plan for various uses by scenario analysis.

7. Statement of the problem

The demand for water from agricultural, industrial and domestic uses is continuously increasing due to the development in their respective sectors. The fixed availability and uncertainty over the occurrence of water increases the complexity of allocation of water to the competing demands from various sectors. It is imperative to evolve management plans for the allocation of water in efficient way to achieve optimum crop yield without compromising the demands for domestic and industrial uses. Allocation of limited water resources among agricultural, domestic and industrial uses requires the integration of supply, demand, water quality and ecological considerations. The Conventional supply-oriented simulation models are not always adequate for exploring the full range of management options for water allocation. Water Evaluation And Planning (WEAP) tool integrates all tools in a robust way for integrated water resources planning.

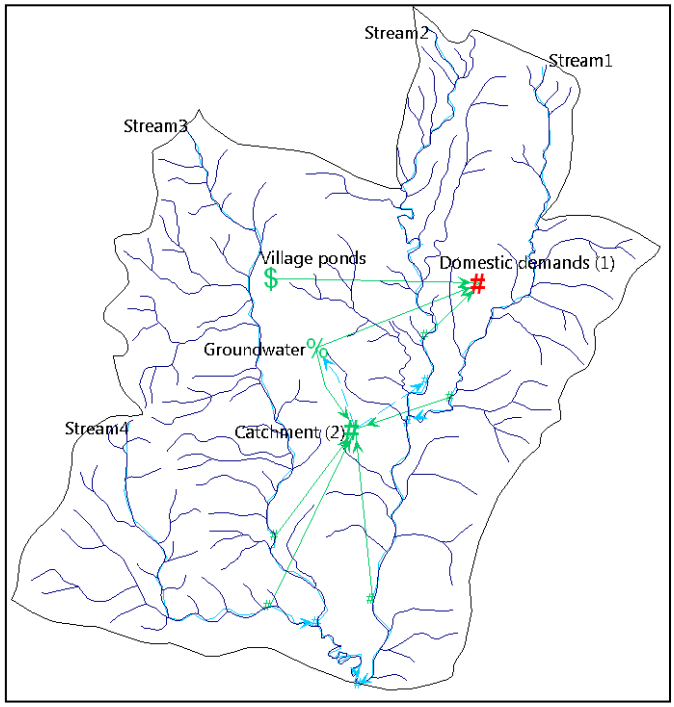
8. Methodology

The water allocation plan among different uses in a Neeranchal Watershed in Chhattisgarh is evolved by setting up of WEAP tool. The inputs to WEAP tool such as water demand from various sectors, priority of the demand, catchment details, hydrologic conditions and inflows, catchment hydrology (river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc), supply preference (operating rules/policy), return flows, minimum flow requirements, economic variables such as cost water transmission etc are prepared from the data obtained from various sources such as irrigation department, IMD, CWC, census department. The hydrological processes occurring in the catchment will be modeled and will be compared with the measured discharge time series. After the proper calibration of the model, the demand sites will be added into a model framework and different scenarios will be generated to assess the gaps in the water demand and supply and water availability at different locations and at the different period of time. The different water allocation plan will be evolved based on the scenario analysis to achieve optimum crop yield.

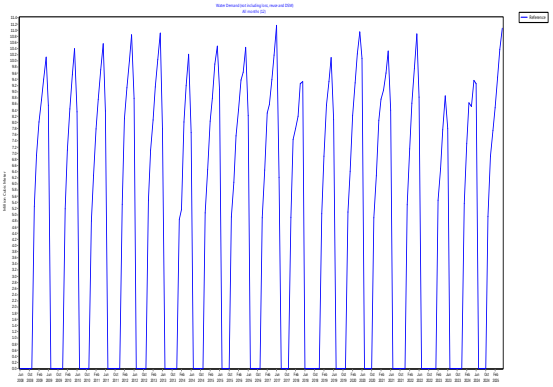
9. Results achieved with progress/present status:

The WEAP model has been setup for micro watersheds IWMP14, IWMP15 and IWMP16 using the climate data such as rainfall, temperature, wind speed obtained from NCEP/NCAR reanalysis data downloaded from WEAP site, population data and livestock details, area under

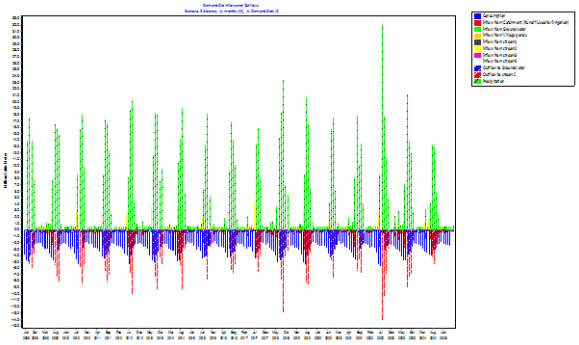
different crops, priority for supply, crop coefficient, etc. The runoff computation is done using the soil moisture model. The schematic diagram of the model setup is given as follows:



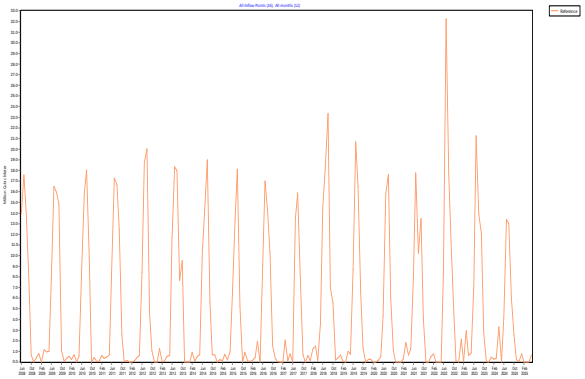
The results of initial runs for IWMP 15 are given as follows:



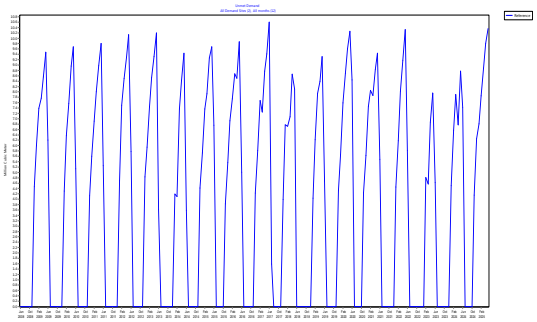
Water demand computed for the period from 2008 to 2015



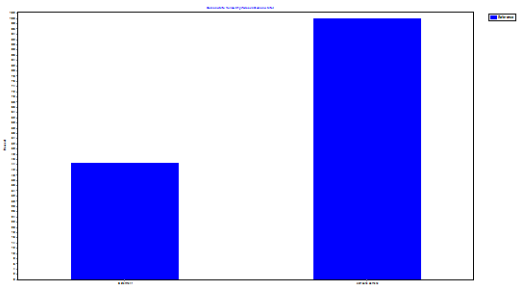
Demand site inflows and outflows for the period from 2008 to 2025



Runoff generated for the period from 2008 to 2025



Unmet demand for the period from 2008 to 2015



Reliability of demand met for the period from 2008 to 2025

The input to the WEAP model for micro watersheds will be fine tuned and rerun the model and scenario analysis will be carried.

10. Research outcome from the study

Expected date of completion**: 31 March 2020**

11. Timeline

Sl. No.	Work Element	**2018-19**				**2019-20**			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1	Literature review								
2	Collection of hydro meteorological data, satellite images, thematic maps etc.								
3	Compilation and verification of hydro-meteorological data, baseline survey data, census data and other qualitative data								
4	Preparation of input data for WEAP model								
5	Simulation of components of hydrological processes using SWAT model								
6	Water allocation plan for different uses by scenario analysis by WEAP model								
7	Report writing								

1. Title of the Study: Rejuvenation of village ponds in identified villages of Muzaffarnagar & Meerut districts of UP

2. Study Group:

Lead Organization	**Project Investigator** Dr. V. C. Goyal, Sc. G & Head, RMOD
	Co-Investigators Er. Omkar Singh, Scientist F, RMOD Dr. Rajesh Singh, Scientist C, EHD Er. Digambar Singh, Scientist C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N. R. Allaka, RA Dr. N. G. Shrivastava, Senior Expert Dr. Nihal Singh, Research Scientist Dr. Kalzang Mathus, Research Associate Sh. Sandeep Yadav, Research Associate Sh. Subhash Vyas, Project Assistant
Civil Work Execution Agency	NPCC Limited (A GoI Enterprise), Noida

3. Type of Study: INCSW (MoWR, RD & GR) Sponsored Project
Budget: Rs 8.3 Crores

4. Nature of Study: Applied Research

5. Date of start & duration: April 2017 (3 Years)

6. Scheduled date of completion: March 2020

7. Study Objectives:

a. Assessment of water situation in the identified villages and carry out water budgeting exercise with the respective Gram Panchayats.
b. Rejuvenation of identified village ponds through installation of appropriate Natural Treatment Systems.
c. Carry out awareness generation and capacity building of the local villagers.

8. Statement of the Problem:

Presently, ponds in the villages of western UP are in a very bad shape. Ponds are generally used as sink for all wastewater as well as for solid waste generated in the villages leading to the deposition of solid wastes and growth of weeds. Capacity of these ponds has been reduced drastically as removal of silt is not taken up on regular basis. Encroachment of the catchment area has added to the dismal state of such ponds in the rural and per-urban areas.

The project aims to develop a model for rejuvenation of village ponds, which will facilitate the practice of water conservation and management in the selected villages in totality for water security and sustainability, which is also expected to be a role model for the Gram Panchayats in other part of the UP/country.

9. Approved Action Plan/Methodology:

After field measurement of the dimensions of the ponds, DPRs were prepared for estimation of the civil works, etc. involved in the pond rejuvenation related works. Execution of the pond rejuvenation works will be carried out by awarding contract to an identified agency.
In the next phase, an appropriate NTS technology (Floating Wetland) will be established in the identified ponds for treatment of the wastewater entering into these ponds. In order to ensure effectiveness of NTS, Screen Chamber, Grit Chamber and Sedimentation chamber will be provided at the identified locations of Inlet of waste water to the pond. Side walls/embankments of the ponds will be strengthened and a small pathway will be made on the periphery of the ponds along with periphery drain to trap household waste water in order to regulate through treatment system.

10. Timeline:

S. N.	Work Element/ Milestone	2017-18				2018-19				2019-20			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Data collection (baseline data of village/ community) for existing ponds and identification of suitable natural treatment system												
2	Carry out water budgeting exercise with the respective Gram Panchayats												
3	Groundwater level measurement around ponds												
4	Water/wastewater sample collection and analyses												
5	Execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)												
6	Nursery development *(plant species for floating wetland)* at NIH, Roorkee												
7	Performance evaluation of Natural Treatment System & feasibility of treatment through Microbial inoculums												
8	Trophic State Analysis and Primary Production Capacity												
9	Capacity building, Mass Awareness & preparation of SOP for O&M of treatment system												
10	Submission of reports												

11. Achievement during last twelve months:

Objectives	Achievements
Rejuvenation of ponds by execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)-through NPCC/any Govt. Agency	• The ponds for the study were identified with the help of people representatives. • MoU was signed with the gram panchayats of the ponds to be undertaken for the study. • The consent from respective gram panchayats for undertaking the research work was undertaken. • MoU was signed with NPCC Ltd., Noida for execution of civil works and awarded work of 12 ponds. • Tenders were floated for 12 ponds by NPCC for awarding the work. Accordingly, the work has been awarded for rejuvenation of 10 ponds. • Rejuvenation work is in progress for the ponds.
Nursery development *(plant species for floating wetland)* at NIH, Roorkee	• The nursery for developing aquatic plant saplings has been established. • Approx. 4500 Reed Plant and 1000 Canna plant saplings has been raised and are ready for transportation to the site.
Trophic State Analysis; assessment of Water Quality Index and Primary Production Capacity	• Water quality data analyzed, compiled and the trophic status of ponds computed.

12. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	

13. Analysis & Results:

Pond water is becoming polluted mainly due to discharge of wastewater from houses and septic tanks as rural area are not having access to improved sanitation practices and also has no provision for wastewater treatment. Since, ponds are playing important role in groundwater recharge so pond water quality needs to be ascertained by strategic management of these resources. Keeping all these points in mind ground water, pond water and pond water inlets samples were collected form the study area. Groundwater monitoring was also done in the month of June 2017 to check the water level and water level ranged from 3.87 m to 38 m. Total 45 samples (17 ground water, 12 pond water and 12 pond water inlet and 4 sludge samples) collected from the 12 villages of Muzaffarnagar and Meerut districts of Western Uttar Pradesh and analysed in NIH water quality laboratory and Institute Instrumentation Centre IIT Roorkee. pH, EC & ORP was analysed in the field using digital Sensorex Smart Aquameter.

pH of groundwater samples were well within the limits as prescribed by BIS. EC of water samples ranged from 302 to 1677 µs/cm. Total dissolved solid of 62% ground water samples were above the acceptable limit (500 mg/l) prescribed by BIS, however, all the samples were within the permissible limit. Turbidity of all the samples exceeded the acceptable limit of 1 NTU, however, only 5 samples exceeded the permissible limit. Calcium content of all the water samples were within the permissible limit (200 mg/l). Fluoride concentration in 23% water samples exceeded the acceptable limit (1.0 mg/l), however, none exceeded the permissible limit. Total Hardness and Total alkalinity of all the water samples were above the acceptable limit (200 mg/l) but within the permissible limit (600 mg/l).

The ORP values of all the pond water samples indicated anaerobic/reducing condition prevailing in the ponds and unsuitability for Pisciculture. However, the pond water from all the 12 villages were found suitable for irrigation except village Roni Hazipur, Electrical conductivity (i.e., 2280 µS/cm) was high making it unsuitable. Trophic status index of 12 ponds were also calculated on the basis of Carlson's index and on basis of TSI (Chlorophyll-a). The average tendency of all the ponds is towards eutrophication.

14. End Users / Beneficiaries of the Study: Villagers and Stakeholders

15. Deliverables: Rejuvenated village ponds, Estimated potential of fish production for the Gram Panchayats, Standard Operating Procedures (SOP) for O&M of treatment system in village ponds, Technical report(s) and publications

16. Major items of equipment procured: Nil

17. Lab facilities used during the study: Water Quality Laboratory (NIH) / IIC (IITR)

18. Data procured or generated during the study: Groundwater level, Groundwater quality, Pond water Quality, Trophic Status Index, Pond productivity test and Village wastewater quality.

19. Study Benefits / Impacts:

The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond and also enhance the groundwater water quality of the area. This study will also help in replication of the technology in other village ponds of other districts of the country.

20. Involvement of end users/beneficiaries: Villagers & Gram Panchayats

21. Specific linkage with Institution and /or end users / beneficiaries: Yes

22. Shortcoming/Difficulties: NA

23. Future Plan: As per approved action plan

1. Title of the Study: Rejuvenation of Village Ponds in Identified Villages of Baghpat, Ghaziabad and Meerut Districts of Uttar Pradesh

2. Study Group:

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigator Dr. Rajesh Singh, Sc. C, EHD Dr. V. C. Goyal, Sc. G, RMOD Er. Digambar Singh, Sc. C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N. R. Allaka, RA Dr. N. G. Shrivastava, Senior Expert Dr. Nihal Singh, Research Scientist Dr. Kalzang Mathus, Research Associate Sh. Sandeep Yadav, Research Associate Sh. Subhash Vyas, Project Assistant
Civil Work Execution Agency	NPCC Limited (A GoI Enterprise), Noida

3. Type of Study: Invited study by MoWR, RD & GR,
Budget: Rs. 856.94 Lakh (Submitted for funding)

4. Nature of Study: Applied Research

5. Date of start & duration: March 2018 (3 Years)

6. Scheduled date of completion: February 2021

7. Study Objectives:

a. Rejuvenation of identified village ponds by carrying out de-weeding, de-silting and associated civil works for development of Natural Treatment System (NTS) in the ponds for their rejuvenation.
b. Establishment of appropriate phyto-remediation based Natural Treatment System (NTS) technology for treatment of wastewater entering into these ponds,
c. Performance evaluation of the NTS based rejuvenated ponds and assessment of treated wastewater for irrigation and fishery by monitoring relevant water & wastewater quality parameters, groundwater levels, etc.
d. Capacity building and Mass Awareness Activities.

8. Statement of the Problem:

With the availability of millions of village ponds and local drains, there exists a vast potential of recycling and reuse of wastewater through simple retrofitting techniques. Such decentralized treatment of these small water bodies is an emerging need for their restoration and preservation, leading to multiple benefits of disaster resiliency, groundwater recharging, environment regeneration and livelihood generation at the local watershed level. The Ministry of WR, RD & GR (GoI) directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Bagpat, Ghaziabad and Meerut.

9. Approved Action Plan/Methodology:

- Reconnaissance survey of identified village ponds for data collection along with sampling and analysis of wastewater input to the pond
- Designing and erection of suitable natural treatment system (CWT) for carbon and nutrient removal.
- Technology demonstration and performance (technical/chemical) evaluation
- Health Assessment of Water Body
- Reuse of Treated Water & Sludge
- Assessment of Methane Emission
- Hygienic and health impact assessment
  Environmental systems analysis
- Technical guidelines for design and technology application
- Training and capacity building
- Contribution to conference and publication
- Transfer of the installed treatment plants to Gram Panchayats
  Submission of final report

10. Timeline:

Sr. No.	Activities	YEAR 1				YEAR 2				YEAR 3			
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
1	Identification of study site												
2	Site survey, sampling and analysis of samples												
3	Detailed engineering design												
4	Construction of CW based treatment plants												
5	System optimization												
6	Technology demonstration and performance evaluation												
7	Assessment of methane emission												
8	Health Assessment of Water Body												
9	Reuse of Treated Water & Sludge												
10	Hygienic and health impact assessment												
11	Environmental systems analysis												
12	Guidelines for design and technology application												
13	Training & capacity building												
14	Participation of Gram Panchayat												
15	Transfer to Gram Panchayats												
16	Contribution to conference and publication												
17	Final technical report												

11. Achievement during last twelve months:

Objectives	Achievements
Identification of study site	• The ponds for the study were identified based with the help of people representatives. • MoU was signed with the gram panchayats of the ponds to be undertaken for the study.
Site survey, sampling and analysis of samples	• A field survey of the experimental sites were conducted in the month of May 2018 and 63 samples from ponds, inlet water to ponds, and groundwater were collected. • The organoleptic, major cations and major anions were analyzed. • Trace metal analysis of the samples are under progress. • The groundwater levels of the study area were also recorded.
Detailed engineering design	• The engineering design of primary treatment and Natural treatment system was completed.
Construction of CW based treatment plants	• MoU was signed with NPCC Ltd., Noida for execution of civil works and awarded work of 9 ponds. • Tenders were floated for 9 ponds by NPCC for awarding the work. Accordingly, the work has been awarded for rejuvenation of 8 ponds. • Rejuvenation work is in progress for the ponds.
Nursery development for aquatic plants at NIH, Roorkee	• The nursery for developing aquatic plant saplings has been established. • Approx. 4500 Reed Plant and 1000 Canna plant saplings have been raised and are ready for transportation to the site.

12. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	

13. Analysis & Results:

Ten ponds from Baghpat and Ghaziabad districts of Western Uttar Pradesh were selected for the rejuvenation purpose. Ground water level of village hand pumps was monitored using water level indicator. The GW level in the study area ranged from 10.2 meter to 50 meter. Total 63 samples (41 ground water, 11 ponds and 11 wastewater) were collected in the month of May 2018. All the samples were analysed for physico-chemical, microbiological and trace metal analysis. pH, EC and ORP of samples were measured using portable Sensorex SMART AQUAMETER on the spot. pH of ground water ranged from 5.9 to 7.25 and EC values were in the range of 573 to 1794 µs/cm. Total alkalinity of all the samples were higher than the BIS prescribed acceptable limit (200 mg/l) but within the permissible limit (600 mg/l), except the one sample collected from Dagarpur, which was within the acceptable limit. Chloride and sulphate were within the prescribed limit for all the ground water samples. The TDS of 68.3% samples exceeded the acceptable limit, however, all were within the permissible limit (2000 mg/l).

Fluoride concentration of 6 hand pump samples exceeded the acceptable limit (1 mg/l) and 2 samples exceeded the permissible limit (1.5 mg/l). Samples from 7 hand pumps (Saidpur, Khindora, Paldi, Pilana and Daggarpur villages) exceeded the prescribed limit (45 mg/l) by BIS.

The pH of all the pond water samples were alkaline in nature and EC was in the range of 692 to 2250 µS/cm. COD values ranged from 56 mg/l to 2240 mg/l in the pond water samples indicating the organic contamination. Dissolve oxygen in five ponds i.e. Ikari, Saidpur, Dhikana and Budhera ponds were found zero. As per Sodium Adsorption Ratio (SAR) values, water from 8 ponds is suitable for irrigation.

14. End Users / Beneficiaries of the Study: Villagers and Stakeholders

15. Deliverables: Technical reports, SOP & research publications

16. Major items of equipment procured: Nil

17. Lab facilities used during the study: Water Quality Laboratory (NIH) / IIC (IITR)

18. Data procured or generated during the study: Groundwater level, Groundwater quality, Pond water Quality, Trophic Status Index, Pond productivity test and Village wastewater quality.

19. Study Benefits / Impacts:

The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond, enhance the groundwater water quality of the area, and increase the income of Gram Panchayats through Pisciculture. This study will also help in replication of the technology in other village ponds of various districts, where there is scarcity of freshwater is found.

20. Involvement of end users/beneficiaries: Villagers & Gram Panchayats

21. Specific linkage with Institution and /or end users / beneficiaries: Yes

22. Shortcoming/Difficulties: NA

23. Future Plan: As per approved action plan

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