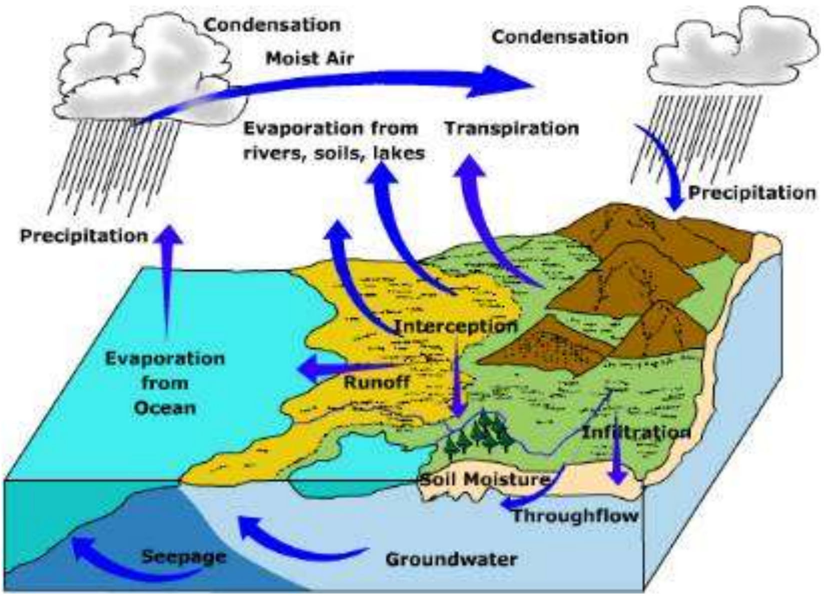
AGENDA AND AGENDA NOTES FOR THE 52nd MEETING OF THE WORKING GROUP OF NIH

12 – 13 APRIL, 2022
AT 1100 HRS



आपो हि ष्टा मयोभुव:

NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 52nd MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

ITEM NO. 52.1 Opening Remarks by the Chairman

ITEM NO. 52.2 Confirmation of the minutes of 51st meeting of the Working Group

The 51st meeting of the Working Group was held during 14-15 June, 2021 in VC mode. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/WG/NIH-10 dated 26 July, 2021.** No comments were received on the circulated minutes. A copy of the minutes of the 50th Working Group is given in **Annexure-A (Page # 4).**

The Working Group may please confirm the minutes.

ITEM NO. 52.3 Action taken on the decisions/recommendations of the previous Working Group meeting

During the 51st 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. 52.4 Presentation and discussion on the status and progress of the work programme for the year 2021-22.

The approved Work Programme of the six Divisions of the Institute for the year 2021-22 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:

	No. of Studies/Projects During the Year 2021-22					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	-	-	4	3	**7**	**2**
Ground Water Hydrology	-	1	3	10	**14**	**5**
Hydrologic Investigation	1	-	3	9	**13**	**-**
Surface Water Hydrology	2	-	4	2	**8**	**-**
Water Resources System	-	3	3	11	**17**	**-**
Research Management & Outreach	-	-	4	2	**6**	**-**
Total	**3**	**4**	**21**	**37**	**65**	**7**

During the present meeting, Division-wise progress and status of the work programme for the year 2021-22 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2021-22.

ITEM NO. 52.5 Presentation and finalization of the work programme for the year 2022-23.

The proposed Work Programme of the six Divisions of the Institute for the year 2022-23 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:

	No. of Studies/Projects During the Year 2022-23					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	1	-	3	3	**7**	**2**
Ground Water Hydrology	3	1	1	7	**12**	**1**
Hydrologic Investigation	1	-	2	7	**10**	**-**
Surface Water Hydrology	9	-	2	1	**12**	**-**
Water Resources System	1	2	3	5	**11**	**-**
Research Management & Outreach	1	-	3	1	**5**	**-**
Total	**16**	**3**	**14**	**24**	**57**	**3**

The work programme has been categorized into three groups; (a) Internally funded studies, (b) Sponsored projects and (c) Consultancy Projects. During the present meeting, Division-wise proposed work programme for the year 2021-22 shall be presented.

ITEM NO. 52.6: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 51st MEETING OF WORKING GROUP

APPROVED MINUTES OF THE
51ST MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING 14-15JUNE 2021

The meeting was held in VC mode under the Chairmanship of Dr. J V Tyagi, Director, NIH. The list of participants of the meeting is given in Annexure-I.

ITEM NO. 51.1: OPENING REMARKS BY THE CHAIRMAN

The Chairman, WG, welcomed the WG members and the Scientists of NIH. TheChairman then requested the WG 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. Manoj P.Samuel	▪ Suggested use of modern tools like AI, IOT ▪ Address water related issues with changes in landuse and water use ▪ Also address equity and economics aspects of water security
2.	Dr. Pawan Labhasetwar	▪ Use of IOT sensors and systems
3.	Dr. Man Singh	▪ Bring out a vision paper on hydrology in future ▪ Impact of rural toilets on groundwater system and health of human beings
4.	Dr. Varun Joshi	▪ Align spring studies demonstrating impacts to beneficiaries ▪ Urban flood modelling for some cities in India
5.	Prof. A K Saraf	▪ Emphasized on effective presentation during meetings
6.	Dr. Bhishm Kumar	▪ Address real-life water related problems faced by India ▪ Start with problems in Roorkee
7.	Dr.Kaushal K Garg	▪ Attempt holistic solution through integrated approach
8.	Dr. Sadhana Malhotra	▪ Document success stories ▪ Plan follow up studies for impact assessment ▪ Due attention should be given to the preparation and delivery of the presentation ▪ Carefully worded shorter titles with important keywords are easier to locate in a keyword search ▪ Objectives for the project can be stated as SMART objectives ▪ Wider dissemination of short and informative films,such as made by RMOD, to reach as many people as possible can go a long way in generating interest and desirable action in hydrology
9.	Sh. Sudhindra Mohan Sharma	▪ More studies/projects dealing with drinking water security
10.	Director, NIH & Chair	▪ PIs to complete pending studies ▪ Before proposing a new study, explore data availability, consent of local user departments and collaborators ▪ Find out how studies are utilized by user organizations/stakeholders

Next, the Chairman asked the Member-Secretary to take up the agenda.

ITEM No. 51.2: CONFIRMATION OF MINUTES OF 50th MEETING OF WORKING GROUP

The 50th meeting of the Working group was held during 20-21 August, 2020 in VC mode. The minutes of the meeting were circulated to all the members and invitees vide letter No. **RMOD/WG/NIH-10 dated 7 Sept., 2020**. The members confirmed the minutes of the 50thWorking Group meeting.

ITEM No. 51.3: 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 50th working group meeting.

ITEM Nos. 51.4& 51.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2020-21 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2021-22

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2020-21 and also to present the proposed studies for F.Y. 2021-22. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2021-22, were 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

The overview of the technical activities of Environmental Hydrology Division (EHD) was presented by Dr R.P. Pandey, Scientist 'G' & Head. The Working Group was appraised about the scientific manpower, status of completed and ongoing studies, consultancy projects, publications, technology transfer activities etc. Subsequently, the scientists of the Division were invited to present the completed studies, progress of ongoing internal studies and proposed new studies. The Comments/suggestions of Working Group members are summarized below.

Work Program for 2020-21

S. No.	Study	Suggestions/Comments
	Sponsored Projects	
1.	Title: Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin **Study Group:** M. K. Sharma (PI), Manohar Arora, Pradeep Kumar, Rajesh Singh & D. S. Malik (GKU) **Duration:** 5 Years (04/16 –3/21) **Sponsored by:** DST (NMSHE) Status: Draft Report submitted	Dr. M. K. Sharma Sc E presented the findings of the study. Dr. Pawan Labhasetwar, NEERI appreciated the study and suggested to compare the results of other studies carried out by other workers in the region. Dr. Saraf, IITR suggested to include geological map in the report to correlate with hydro-chemistry. The suggeston was noted for compliance.
2.	Title: Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures **Study Group:** M. K. Sharma (PI), Surjeet Singh, Pradeep Kumar; Partner: WRD, Raipur & CGWB, Raipur	There was no specific comments from the members.

	Duration: 3½ Years (09/17 –3/21) **Sponsored by:** NHP-PDS Status: Project Report submitted	
3.	Title: Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures **Study Group**:Rajesh Singh (PI), Pradeep Kumar, M. K. Sharma, Sumant Kumar Partner: Irrigation Deptt., Punjab **Duration:** 3½ Years (09/17 –8/21) **Sponsored by:** NHP-PDS Status: In-progress	**Not presented.**
4.	Title: Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures **Study Group:** Anjali (PI), Sudhir Kumar, J. V. Tyagi, M. K. Sharma Partner: CGWB (Delhi unit) **Duration:** 3 Years (11/2019 –05/23) **Sponsored by:** NHP-PDS Status: In-progress	**Not presented.**
5.	Title: Water Efficient Irrigation by Using SCADA System for Medium Irrigation Project (Mip) Shahnehar **Study Group:** R.P. Pandey, (PI), Jagdeesh Patra, Rajesh Singh, N. K. Bhatnagar **Duration:** 3 Years (12/17 –06/22) Status: In-progress	**Not presented**
	Internal Studies	
6.	**Title:** Water quality assessment for Haridwar District **Study Group:** R.K. Nema (PI), Rajesh Singh, J. V. Tyagi, R. P. Pandey & Pradeep Kumar **Duration:** 2.0 years (05/19-06/21) **Status:** Ongoing	Dr. Rajesh Singh presented the progress of the study. Dr. Bhism Kumar appreciated the study and its outcomes. He suggested that the study has very significant contributions in determining the deterioration in water quality at different areas in the Haridwar district and he suggested for further investigation to find out the causes of deterioration in next study. He also suggested that the outcomes of the study should be presented before the district administration for suitable dissemination of results of this study for the benefit of the mass. Dr. Sudhindhra Mohan Sharma suggested to incorporate layer of drainage map with the maps of water quality parameters. He also suggested publicizing the outcomes of the study.
7.	**Title:** Simulation of Non-Point Source Pollution Processes in Song River **Study Group:** Pradeep Kumar (PI), J. V. Tyagi, M. K. Sharma & Rajesh Singh **Duration:**4 years (11/19-10/23) **Status:** Ongoing	**Not presented.**
8.	**Title:** Identification of Causes for deterioration of	Dr. M. K. Sharma presented the progress of the

	River Hindon and suggestive rejuvenation plan **Study Group:** M. K. Sharma (PI), Dr. Sudhir Kumar (Project Coordinator), R. P. Panday, Anupma Sharma, Anjali, Vishal Singh, Pradeep Kuamr, Nitesh Patidar, Surjeet Singh, Rajesh Singh. **Duration:**3 years (07/20 to 06/23)	study in brief. There was no specific comments from experts.
9.	**Title:** Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar **Study Team:** Rajesh Singh (PI), J. V. Tyagi, R. P. Pandey, R. K. Nema, Pradeep Kumar, M. K. Sharma **Duration:** 2 Years (06/20 – 05/22)	**Not presented.**

Recommended Work Program for the Year 2021-22

SN	Study	Study Team	Duration/Status
	Sponsored Projects (Ongoing)		
1.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) Pradeep Kumar, M. K. Sharma, Sumant Kumar **Partner:** Irrigation Department, Punjab	3 Years (09/17-08/21) **Sponsored by**: NHP-PDS **Status:** In-progress
2.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma **Partner:** CGWB (Delhi unit)	3 Years (11/2019 – 5/2023) **Sponsored by**: NHP-PDS **Status:** In-progress
3.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (Mip) Shahnehar	R.P. Pandey, (PI). Jagdeesh Patra, Rajesh Singh, N. K. Bhatnagar, Shekhar Saini	**3-years (12/17-06/22)** **Status:** In-progress
	Sponsored Projects (New)		
4.	Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanashi and surrounding area	Rajesh Singh (PI) R. P. Pandey BHU, Varanashi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	**3 years 07/ 2021-07/24** **(proposed collaborative study)**
	Internal Study (Ongoing)		
5.	Water quality assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh, J. V. Tyagi, Pradeep Kumar	2 years (05/19-06/21) **Status:** completed
6.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi, M. K. Sharma, Rajesh Singh, R. K. Nema	4 years (11/19-10/23) **Status:** In-progress
7.	Development of rejuvenation plan for Hindon river system	M. K. Sharma (PI) Sudhir Kumar, R. P. Pandey, Anupma Sharma, Anjali, Vishal Singh, Pradeep Kumar, NiteshPatidar, Surjeet Singh, Rajesh Singh	3 Years (07/20-06/23) **Status:**In-progress
8.	Influence of Anthropogenic Factors on River Ganga in the stretch from	Rajesh Singh (PI) J. V. Tyagi, R. P. Pandey,	2 Years (06/20-05/22) **Status:** In-progress

	Rishikesh to Haridwar	R.K. Nema, Pradeep Kumar, M. K. Sharma	
Internal Studies (New Study)			
9.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI) R. K. Nema, Sumant Kumar, Pradeep Kumar, M. K. Sharma	3 Years (July 2021 – June 2024) **Status:** Proposed Dr. Bhism Kumar appreciated the proposed study and suggested that this is the right time to take up this study, for the benefit of society, before the problem exaggerates.

GROUND WATER HYDROLOGY DIVISION

Dr. M. K. Goel, Scientist 'G' presented a brief overview, status of studies and activities carried out by the division since the 50th Working Group meeting held in August, 2020. He gave an account of scientific personnel available in the division; internal, sponsored and consultancy projects - ongoing and completed; and also future activities planned by the division for the year 2021-22. Dr. Goel informed that four in-house R&D studies and ten sponsored studies were approved for the year 2020-21.

In addition to the above studies, scientists of the division have a major role in activities of the National Hydrology Project (NHP), DSS (Planning and Management) in selected states, development of groundwater module for "*Spatial Hydrologic Model (SHM)*" with IIT Kharagpur, Computer Centre, External Project Management Cell and procurement related activities. The number of research papers published in various journals, lectures delivered in various training courses and number of M.Tech./Ph.D. students guided/under guidanceduring the period were also reported. The progress of following studies was presented by the respective Principal Investigator:

Work Program for the year 2020-21

SN	Title of Project/Study	Study Team	Duration	Status & Comments/ Suggestions	Funding
Internal Studies					
1. NIH/GWH/NIH/19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh, C. P. Kumar, P. K. Singh	May 2019-Apr 2021	Completed **Presented** It was informed that Mrs. Suman Gurjar is leaving NIH and joining IMD by middle of July, 2021 and will submit the report before her relieving.	Internal

2. NIH/GWH/NIH/19-20	The Regional Hydrological Impact of Agricultural Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	Aug 2019-Mar 2021	**Completed** Presented Dr. Arun K. Saraf asked about the existence of relationship between geological formation and groundwater level and PI clarified the same. WG members appreciated the work completed in the scoping study and suggested to provide the outcomes of the study to user agency.	Internal
3. NIH/GWH/DoWR/20-20	Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi	Gopal Krishan (PI), B. Venkatesh, Nitesh Patidar	July 2020-May 2021	**Completed** Presented	Internal
4. NIH/GWH/NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan, Suman Gurjar	Aug 2020-Jul 2022	**On-going** Presented	Internal
Sponsored Projects					
5. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	Dec 2017-Nov 2021	On-going **Not presented**	Sponsored by BGS, UK
6. NIH/GWH/NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C.P. Kumar, R.J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	Jan 2016-Mar 2021	Completed **Presented**	Sponsored by DST under NMSHE

7. NIH/GWH/PDS/17-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI),Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary, Ram Chander **Partner Organization:** MWRD, Bihar **Collaborator:** Brijesh Yadav, IIT Roorkee; N.S. Maurya, NIT Patna	Dec 2017-Jul 2021	Completed **Presented** Dr. Bhishm Kumar suggested PI to carry out dating to know the age of GW and a relation may be established with arsenic concentration.	Sponsored by NHP under PDS
8. NIH/GWH/PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	Dec 2017-Jul 2022	On-going **Not presented**	Sponsored by NHP under PDS
9. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), M. K. Goel, Sudhir Kumar, Suman Gurjar, Gopal Krishan	Dec 2017-Jul 2022	On-going **Not presented**	Sponsored by NHP under PDS
10. NIH/GWH/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	Jan 2018-Dec 2021	On-going **Not presented**	DST-Newton Bhabha – NERC - India - UK Water Quality Research Programme

11. NIH/GWH/DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants	Anupma Sharma (India Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Other Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* Cranfield University *Project Partners:* Water Harvest, Excellent Development (UK based NGOs)	Jan 2018-Dec 2021	On-going **Presented** On a query regarding collection of baseline data to study the impact of rainwater harvesting structures, it was informed that historical records are available for the study area and in addition, lysimeter experiments mimicking the field conditions are also being carried out to generate data.	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
12. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi	Anupma Sharma (PI), Sanjay K. Jain, Archana Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Suman Gurjar, Vishal Singh, Nitesh Patidar *Partner Organizations:* Irrigation & WRD Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, New Delhi	Apr 2018-Mar 2022	On-going **Not presented**	Special Project under “Centre of Excellence” (NHP)
13. NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (Lead NIH), C. P. Kumar, Suman Gurjar, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur)	Mar 2019-Feb 2024	On-going **Not presented**	Sponsored by DST
14. NIH/WRS/NMSHE/16-20	Development of a project website and hydrological database in Upper Ganga basin (SP-1)	M. K. Goel (PI), M. Arora, A. K. Lohani, D. S. Rathore, D. Chalisgaonkar, A. R. S. Kumar, Surjeet Singh, P. Mani, A. Sarkar, M. K. Nema, Suman Gurjar, P. K. Mishra	Jan 2016-Sep 2021	On-going **Not presented**	Sponsored by DST under **NMSHE** SP-1,

15. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	Jul 2020-Jun 2023 ***Status: Approval is under consideration of MEA***	On-going **Not presented**	Sponsored by Federal Ministry of Education & Research, Germany

Training Courses Organized	
1	Online training course on "**Groundwater Modelling using Visual MODFLOW"** under National Hydrology Project (NHP) during 06-10 Jul, 2020.
2	Online training course on "**Groundwater Modelling using Visual MODFLOW"** under National Hydrology Project (NHP) during 18-22 Jan, 2021.
3	Online training course on "**Groundwater Salinity, Issues and Management Solutions"** under National Hydrology Project (NHP) during 17-19 Feb, 2021.
4	Online training course on "**Principles of Groundwater Hydrology"** under National Hydrology Project (NHP) during 24-26 Feb, 2021.
5	Online training course on "**Groundwater Management & Modelling"** under National Hydrology Project (NHP) during 08-12 Mar, 2021.
Research Publications	
1	International Journal **- 7**
2	National Journal **- 1**
3	International Conferences **- 17**

Recommended Work Program for the year 2021-22

SN	**Title of Project/Study**	**Study Team**	**Duration**	**Status & Comments/ Suggestions**	**Funding**
		Internal Studies			
1. NIH/GWH/NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan, Suman Gurjar	Aug 2020-Jul 2022	On-going	Internal
		Sponsored Projects			
2. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	Dec 2017-Nov 2021	On-going	Sponsored by BGS, UK

3. NIH/GWH/PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	Dec 2017-Jul 2022	On-going	Sponsored by NHP under PDS
4. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), M. K. Goel, Sudhir Kumar, Suman Gurjar, Gopal Krishan	Dec 2017-Jul 2022	On-going	Sponsored by NHP under PDS
5. NIH/GWH/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	Jan 2018-Dec 2021	On-going	DST-Newton Bhabha – NERC - India -UK Water Quality Research Programme
6. NIH/GWH/DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants	Anupma Sharma (India Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Other Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* Cranfield University *Project Partners:* Water Harvest, Excellent Development (UK based NGOs)	Jan 2018-Dec 2021	On-going	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme

7. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi	Anupma Sharma (PI), Sanjay K. Jain, Archana Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Suman Gurjar, Vishal Singh, Nitesh Patidar *Partner Organizations:* Irrigation & Water Resources Dept. Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, New Delhi	Apr 2018-Mar 2022	On-going	Special Project under "Centre of Excellence" (NHP)
8. NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (Lead NIH), C. P. Kumar, Suman Gurjar, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur)	Mar 2019-Feb 2024	On-going	Sponsored by DST
9. NIH/WRS/NMSHE/16-20	Development of a project website and hydrological database in Upper Ganga basin (SP-1)	M. K. Goel (PI), M. Arora, A. K. Lohani, D. S. Rathore, D. Chalisgaonkar, A. R. S. Kumar, Surjeet Singh, P. Mani, A. Sarkar, M. K. Nema, Suman Gurjar, P. K. Mishra	Jan 2016-Sep 2021	On-going	Sponsored by DST under NMSHE SP-1,
10. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	Jul 2020-Jun 2023 ***Status: Approval is under consideration of MEA***	On-going	Sponsored by Federal Ministry of Education & Research, Germany

Training Courses Proposed

1	Four Training courses shall be organized by the Division during 2021-22 under the National Hydrology Project (NHP).

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr Sudhir Kumar, Scientist-G and Head of the H. I. Division presented the brief details of the Division including the scientific staff strength and infrastructure. He briefly introduced about the scientific work of the Division and the various studies being carried by the Division, along with details about the publications by the Division and analytical work carried out at the Nuclear Hydrology Laboratory. He also informed about the technology transfer activities organized/proposed by the Division during 2020-21.

Table 1: Details of training Courses/Workshops organised and Proposed by HI Division during April 2020-March, 2021

S. N.	Title of Training Course/Workshop	Duration	Venue	No. of Participants
1.	Stakeholder Workshop on "Web-GIS based Spring Information System"	02 Dec., 2020	NIH, Roorkee (Virtual mode)	91
2.	Advanced Tools & Techniques for Hydrological Investigations	22-26 Feb., 2021	NIH, Roorkee (Virtual mode)	49

Table 2: Details of Research Publications by HI Division during April 2020-March, 2021

	Published	Accepted	Communicated
Books/Book Chapter	01	-	-
International Journals	09	-	08
National Journals	1	01	01
International Conferences	02		-
National Conferences	-	-	-

The progress of each individual study for the year 2020-21 and the proposal for a new study was presented by the respective P.I. of the study. The comments/actions suggested by the working group for various studies are as follows:

Work Programme for the year 2020-21

SN	Project	Study Team	Duration	Status & Comments/ Suggestions	Funding
INTERNAL STUDIES					
1.	Hydrological Investigations of Selected Springs in Tehri-Garhwal District of Uttarakhand	S M Pingale (PI), Sudhir Kumar Suhas Khobragade S. S. Rawat Rajeev Gupta	Apr 2019 – Mar 2022	***Continuing Study*** Dr. Bhishm Kumar suggested to contact Uttarakhand Government and get funding for this study. Director, NIH suggested to take this study outcome to the logical end and show utility of this study to the end users.	
2.	Assessment of Impact of Land Use and Land Cover Change on Groundwater Recharge in Parts of	M S Rao (PI), Sudhir Kumar, Hukum Singh, V. K. Agarwal, Vishal	Apr 2021 – Mar 2023	***Revised New Study*** Dr. Bhishm Kumar advised to use tritium tagging technique only at places where	

SN	Project	Study Team	Duration	Status & Comments/ Suggestions	Funding
	Sabarmati River Basin, Gujarat	Gupta and S.L. Srivastava + Central University , Gujrat		estimation of vertical recharge to groundwater is of utmost necessity.	
3.	Integrated Hydrological Investigations of Renuka Lake, Himachal Pradesh, for Its Conservation and Management	SD Khobragade (PI), Sudhir Kumar; Hukam Singh, Rajeev Gupta, Vipin Agarwal and Forest & Wildlife Dept., Govt. of HP	Jul 2020 – Jun 2023	***Continuing Study*** Dr. Khobragade informed that it was told during the field visit that the lake catchment is a protected reserved forest hence permission of the Dept. of Forests & Wildlife, Govt. of HP is necessary for carrying out the study. He further informed that communication in this regard has been made with the Forest Department but response is still awaited. Dr. Bhishm Kumar suggested that efforts be continued to get the response from the department.	
SPONSORED PROJECTS					
1.	Understanding of hydrological processes in Upper Ganga basin using isotopic techniques	Suhas Khobragade (PI) Sudhir Kumar Rajesh Singh M. Arora	Apr 2016 – Mar 2021 Extended to Sep2021 by sponsoring authorities	***Continuing Study*** Dr. Bhishm Kumar commented that different studies have given different contribution show/ice, GW etc to river Ganga. The final report should include a review of these studies and possible reasons for variation in reported contribution	NMSHE Project
2.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	MS Rao (PI) Sudhir Kumar S.K. Verma	Jun 2016 – May 2019 Extended till Dec 2022 by sponsoring authorities	***Continuing Study*** No specific action Suggested	IAEA
3.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) M. Someshwar Rao, S.K. Verma	Jan 2018 – Jan 2022	***Continuing Study*** No specific action Suggested	PDS under NHP
4.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M.S. Rao (PI), Sudhir Kumar, V.S. Jeyakanthan. SWID, Govt. of West Bengal	Mar 2018 - Jan 2022	***ContinuingStudy*** No specific action suggested	PDS under NHP
5.	Development of a comprehensive plan for conservation and	Suhas Khobragade (PI) Sudhir Kumar	Jan 2018 – Jun 2022	***Continuing Study***	PDS under NHP

SN	Project	Study Team	Duration	Status & Comments/ Suggestions	Funding
	sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Rajiv Gupta		No specific action Suggested	
6.	Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study	Sudhir Kumar (PI) MS Rao SM Pingale BK Purandra YRS Rao	Apr 2019 – Mar 2020 Extended upto Sep 2021 by sponsoring authorities	***Continuing Study*** No specific action Suggested	MoES through NCESS
7.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	Sudhir Kumar (PI) MS Rao SM Pingale	Jun 2019 – May 2021 Extended upto May 2022 by sponsoring authorities	***New study*** No specific action Suggested	IIT Bombay, Mumbai
8.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh	S S Rawat (PI) Sudhir Kumar P G Jose, Suman Gurjar, D S Bisht	Aug 2017- Mar 2022	***Continuing Study*** No specific action Suggested	PDS under NHP
9.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	S S Rawat (PI) P G Jose, Suman Gurjar, D S Bisht	Jan 2019 – Dec 2021	***Continuing Study*** No specific action Suggested	NMHS

Recommended Work Programme for the year 2021-22

S. N.	Project Title	Study Team	Duration	Status
	INTERNAL STUDIES:			
1.	Hydrological investigations of selected springs in Tehri Garhwal District , Uttarakhand	S M Pingale (PI), Sudhir Kumar S. D. Khobragade Soban Singh Rawat Er. Padam Singh, (UUHF, Ranichauri) Rajeev Gupta	Apr 2019-Mar 2022	Continuing Study
2.	Assessment of impact of land use and land cover change on groundwater conditions in parts of Sabarmati river Basin, Gujarat	M. Someshwar Rao (PI) Sudhir Kumar Vipin Aggarwal	Apr 2021 – Mar 2023	***Revised New Study***
3.	Integrated Hydrological Investigations of Renuka lake, Himachal Pradesh, for	SD Khobragade (PI) Sudhir Kumar	Jul 2020-Jun 2023	Continuing Study

S. N.	Project Title	Study Team	Duration	Status
	its Conservation and Management	Hukam Singh Rajiv Gupta Vipin Agarwal Scientist from GoH.P.		
4.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal	Apr 2021-Dec 2022	New Study
	SPONSORED PROJECTS			
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	Suhas Khobragade (PI) Sudhir Kumar, Rajesh Singh, M. Arora	Apr 2016 – Mar 2021 Extended upto Sep 2021	NMSHE Project
2.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	M. Someshwar Rao (PI) Sudhir Kumar	Jun 2016 – Dec 2022	IAEA under CRP
3.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal	Jan 2018 – Jan 2022	NHP (PDS)
4.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M. Someshwar Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan	Jan 2018 – Jan 2022	NHP (PDS)
5.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Suhas Khobragade (PI) Sudhir Kumar	Jan 2018 – June 2022	NHP (PDS)
6.	Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study	Sudhir Kumar (PI) SM Pingale, M. Someshwar Rao, BK Purandara, YRS Rao	Apr 2019 – Sep 2021	Study under NCESS, MoES
7.	Groundwater Rejuvenation As Climate change Resilience for marginalized and gender sensitive GangeS (GRACERS)	Sudhir Kumar (PI) M. Someshwar Rao SM Pingale	Jun 2019 – May 2022	(IIT Bombay, Mumbai)
8.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh	S S Rawat (PI) Sudhir Kumar, P G Jose, Suman Gurjar, D S Bisht	Aug 2017 – Mar 2022	NHP (PDS)
9.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	S S Rawat (PI) P G Jose, Suman Gurjar, D S Bisht	Jan 2019– Dec 2021	NMHS

SURFACE WATER HYDROLOGY DIVISION

Dr. A.K.Lohani, Sc G & Head, Surface Water Hydrology Division presented the various activities of the division. The number of research papers published in various journals, lectures delivered in various training courses and number of M.Tech./Ph.D. students guided/under guidance during the period were also reported. The concerned PI of the study presented the progress of his study during the working group meeting. The record of discussions for the respective study is given below:

Work Program for the year 2020-21

S. N.	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/ Suggestions
	Completed Internal Studies	
1	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f **Study Group:** Sushil K. Singh **DOS:** April, 2020; **DOC:** March, 2021	**Status:** Completed Not presented.
2	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f) **Study Group:** Sanjay Kumar, Rakesh Kumar, J.P. Patra, Pankaj Mani **DOS:** April 2017; **DOC:** March, 2021	**Status:** Completed Study presented. Queries from Dr. Pawan Labhasetwar, NEERI were answered.
3	Study of Hydrological Changes in selected Watersheds in view of Climate Change in India (completed) **Study Group:** L.N. Thakural, D.S. Rathore, Surjeet Singh, Sanjay K. Jain, Sharad K. Jain **DOS:** April 2015; **DOC:** Dec., 2020	**Status:** Completed Study presented.
4	Evaluation of water quality of Government schools in Roorkee block, District Haridwar (completed) **Study Group:** N.K. Bhatnagar, M.K. Sharma, L.N. thakural, Reena Rathore **DOS:** Oct 2018; **DOC:** sept. 2020	**Status:** Completed Report is under Review
	Ongoing Sponsored Studies	
1	Hydrological modelling in Alaknanda basin and assessment of climate change impact (NMSHE) (Ongoing) **Study Group:** A.K. Lohani, Sanjay K. Jain, Archana Sarkar, V.S. Jeyakanthan, L.N. Thakural **DOS:** April, 2020; **DOC:** September, 2021 **Funding:** DST	**Status:** Ongoing Not presented.
2	Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation (NHP) **Study Group:** A.K. Lohani, R.K. Jaiswal, Sushant Jain, Sanjay Agarwal, Shailendra Kumar **DOS:** April, 2020; **DOC:** April, 2022 **Funding:** NHP	**Status:** Ongoing Not presented.
	Ongoing Internal Studies	
1	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin (Ongoing) **Study Group:** Archana Sarkar, Surjeet Singh, Suman Gurjar, Sunil Gurrapu **DOS:** Nov. 2018; **DOC:** Mar 2021. **Funding:** NIH	**Status:** Ongoing Study presented. Dr S.K. Manik from IMD enquired why IMD data of precipitation and temperature was not used for rainfall

		runoff modeling to which Dr Sarkar replied that daily data of precipitation for 19 stations was readily available from WRD, Rajasthan at no cost so it was used, and about temperature data, as gridded data was available in the institute and 90% of the study area does not have very high altitude so it was used. Another member from NEERI, Nagpur appreciated the study and enquired whether it was possible to assess water allocation under climate change scenarios from the reservoir to which Dr Sarkar replied that it is possible provided accurate discharge data is made available. Chairman agreed the extension of the study to upto August 2021
2	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario. **Study Group:** Ashwini Ranade, Archana Sarkar **DOS:** April 2018; **DOC:** Mar 2021.	**Status:** Ongoing Study presented. Dr Ranade requested for the 6 months extension in order to complete the remaining project work, which has been accepted by the committee members.
3	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent **Study Group:** Sunil Gurrapu, Ashwini Ranade, J.P. Patra **DOS:** Nov 2018; **DOC:** October 2021.	**Status:** Ongoing Not presented.
4	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan **Study Group:** J.P. Patra, Rakesh Kumar, Pankaj Mani, Sunil Gurrapu **DOS:** August 2020; **DOC:** July 2022.	**Status:** Ongoing Not presented.

Recommended Work Program for the year 2021-22

SN	Title of Project/Study	Study Team	Duration	Status & Comments	Funding
Ongoing Sponsored Studies					
1	Hydrological modelling in Alaknanda basin and assessment of climate change impact(NMSHE)	A.K.Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	5 years (April 2016 to September 2021)	On-going	DST
2	Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation (NHP)	A.K. Lohani R.K. Jaiswal Sushant Jain WRD Rajasthan Sanjay Agarwal Shailendra Kumar	24 months (Oct. 2019 to April 2022)	On-going	NHP

Ongoing Internal Studies					
1	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2.5 years (Nov. 2018 August 2021).	On-going Extended upto August 2021	NIH
2	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 October 2021)	On-going Extended upto October 2021	NIH
3	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent	Sunil Gurrapu Ashwini Ranade J.P. Patra	3 years (Nov 2018 to October 2021)	On-going	NIH
4	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.	J.P. Patra Rakesh Kumar Pankaj Mani Sunil Gurrapu	2 years (July 2020 to August 2022	On-going	NIH
New Internal Studies					
1	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Godavari subzone-3e.	S.K. Singh	One year (April 2021 to March 2022)	New Study Not Presented	NIH
2	Uncertainty in rating curves and discharge estimation	Sanjay Kumar, L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra	2 Years (April 2021 to March 2023)	New Study Presented	NIH

Training Courses/Workshops and Research Publications Completed During 2020-21

Trainings/ Workshops Organized	Research publications				
	International Journals	National Journals	International Conferences	National Conferences	Chapters in books
21	20	1	35	16	7

Training Courses/Workshops and Research Publications Proposed During 2021-22

Trainings/ Workshops to be Organized	Research publications				
	International Journals	National Journals	International Conferences	National Conferences	Chapters in books
10	10	1	18	8	4

WATER RESOURCES SYSTEMS DIVISION

Dr. Sanjay K Jain (SKJ), Sc. G and Head, presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Dr. Jain remembered Late Dr. Renoj J. Thayyen, Sc-E, who left us on 22 April, 2021 due to Covid-19, for his valuable contributions to the division and NIH. Thereafter, individual studies were presented by the respective PIs as given below:

Work Programme for the year 2020-2021

SN	Study	Status and Recommendations/ Suggestions
Completed Sponsored/ Internal Studies		
1.	**Title:** Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework **Team:** P. K. Singh (PKS); P. K. Mishra; M. K. Goel; Suman Gurjar **Duration:** 2 years (12/18-12/20) **Funding:** NIH **Status:** Completed	PKS presented the completed study on "Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework". He described methodology in brief. He explained all the results obtained and conclusions drawn from the study. SKJ informed that the draft report of the study has been prepared and submitted for review. The work was appreciated by the experts/members of the working group. Dr. Sudhindra Sharma inquired whether we can have the estimates of the land and water productivity at the block/district level. PKS replied that the maps available are of coarse resolution, in case fine resolution maps are available then the study can be done at district/block level. Dr. Manoj Samuel asked whether we can include climate scenarios in the WA+ Framework. The inclusion of the climate scenarios in WA+ is not possible as it requires a lot of data, which is only available in real or near-real time and scenarios are not available for these datasets.
2.	**Title:** Real time flood modelling using HEC-RTS modelling framework **Team:** Vishal Singh (VS); A. K. Lohani **Duration:** 2 years (12/18-12/20) **Funding:** NIH **Status:** Completed	VS presented study on Real time flood modelling using HEC-RTS framework in Periyar river basin. He briefly presented the different components under HEC-RTS and methodology through a flow chart. He explained the results with different scenarios. SKJ informed that the draft report of the study has been prepared and submitted for review. Director, NIH suggested to add the basin name (Periyar) in the study title. Dr. Dimri suggested if NIH can develop its own new integrated flood model for flood forecasting in a new project in which he also shown his willingness of participation. Dr.Manoj Samuel shown interest in the study and asked if some study jointly can be taken up. SKJ asked VS to send the report to Dr. Manoj and then formulation of joint study can be explored.
Ongoing Sponsored/ Internal Studies		
1.	**Title:** Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1).** **Team:** M. K. Goel; M. Arora; A. K. Lohani; D. S. Rathore; D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra **Duration:** 5 years (01/16-03/21)	**Not presented.**

	(Extended till Sept., 2021) **Funding:** DST **Status:** Ongoing	
2.	**Title:** Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2).** **Team:** D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V. S. Jeyakanthan; L. N. Thakural; **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Ongoing	**Not presented.**
3.	**Title:** Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3).** **Team:** Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS) **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Ongoing	**Not presented.**
4.	**Title:** Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)** **Team:** ~~Renoj J.Thayyen;~~ Sanjay K. Jain; Sharad K. Jain (Retd.); P. K. Mishra; M. Arora; AP Dimri (JNU) **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Ongoing	**Not presented.**
5.	**Title:** Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)** **Team:** M K Nema; Sharad K. Jain (Retd.); ~~Renoj J.Thayyen;~~ Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal; AP Dimri (JNU) **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Ongoing	**Not presented.**
6.	**Title:** Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11).** **Team:** P. K. Mishra; M. K. Nema; ~~Renoj J. Thayyen;~~ Pradeep Kumar **Duration:** 5 years (01/16-03/21)	**Not presented.**

	(Extended till Sept., 2021) **Funding:** DST **Status:** Ongoing	
7.	**Title:**Investigating Water Stress using Hydro-meteorological and Remote Sensing data **Team:** D. S. Rathore; (Now L. N. Thakural is PI); Sanjay Kumar; B. Venkatesh; M. K. Jose; T. Chandramohan **Duration:** 3 years (08/2017-09/2020) (Extended up to June, 2021) **Funding:** PDS under NHP **Status:** Ongoing	**Not presented.**
8.	**Title:**Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya **Team:** Sanjay K. Jain; P. K. Singh; M. Arora; ~~Renoj J. Thayyen;~~ A. K. Lohani; Vishal Singh; **Duration:** 3 years (11/19-11/22) **Funding:** NMHS-MoEF **Status:** Ongoing	**Not presented.**
9.	**Title:**Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin **Team:** ~~Renoj J. Thayyen~~; Vishal Singh; A. P. Dimri (JNU); Sanjay K. Jain **Duration:** 3 years (06/19-11/22) **Funding:**NRDMS-DST **Status:** Ongoing	**Not presented.**
10.	**Title:**Permafrost mapping and characterization of Ladakh Region **Team:** ~~Renoj J. Thayyen;~~ A. P. Dimri (JNU) will lead now; G. Jeelani (KU); V. Agnihotri (GBPNI) **Duration:** 3 years (11/19-11/22) **Funding:** NMHS-MoEF **Status:** Ongoing	**Not presented**.
11.	**Title:**Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework. **Team:** P K Singh (PKS); P K Mishra; P K Agarwal **Duration:** 2 years (08/20-07/22) **Funding:** NHP **Status:** Ongoing	PKS presented the progress of the study on "Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework" which is undertaken under NHP. Dr V. C. Goyal asked to include the latest time period, i.e., up to 2020 in this WA+ study. The PI responded affirmatively on the inclusion of the latest datasets (open source satellite datasets) depending on the availability of the data.
12.	**Title:**Seasonal Characterization of Gangotri Glacier melt runoff and	This study was not presented in the WG. This study is under progress. SKJ informed that the visit to the Bhojwasa site and

	simulation of streamflow variation under different climate scenarios **Team:** M. Arora; P K Mishra; Vishal Singh **Duration:** 3 years (04/18-03/22) **Funding:** NIH **Status:** Ongoing	observations could not be taken in 2020 due to Covid. In 2021, the site visit was planned in April, 2021 but due to Covid, it was not taken up. If situation improves then the site visit will be taken up from July 2021. During this period the collected data is being processed and analyzed.
13.	**Title:**Impacts of glacier and climate change on runoff for selected basins of Himalayan region **Team:** Vishal Singh (VS); Sanjay K. Jain (SKJ); Manohar Arora **Duration:** 2 years (08/20-07/22) **Funding:** NIH **Status:** Ongoing	VS presented the study on 'Impacts of glacier and climate change on runoff for selected basins of Himalayan region'. He presented the outcome of one of the basin i.e. Baspa basin modelled so far. He informed that snow and glacier maps of 2000, 2006, 2011 and 2018 have been prepared to see the impact of glacier change on runoff. He further said that the whole basin is divided in 17 watersheds. SKJ informed that the calibration of the model has been carried out for the basin up to Sangla site then the same model was applied on different watersheds to see the impact of glacier change on each watershed. He informed that a paper in Journal of Hydrology (Int. Journal) has already been published from the work carried out so far. Dr. Dimri asked about the melt runoff range from different watersheds given in the conclusion. He said that the conclusion presented is contradictory. VS informed that the range is given on the basis of each watershed response however response varies as per the total area of glaciers in the different watersheds. SKJ informed that the details of outcome for each watershed will be given in results/conclusions of the report so that there will not be any confusion in the outcome.
14.	**Title:**Monitoring and Hydrological Modelling of Henvel watershed in Lesser Himalaya (Phase II) **Team:** M K Nema; Sanjay K Jain; ~~Renoj J. Thayyen;~~ P K Mishra; P K Agarwal; Manohar Arora **Duration:** 3 years (08/20-07/23) **Funding:** NIH **Status:** Ongoing	MKN presented the progress of the study focused on soil moisture modelling. In the beginning, he informed that in Phase I instrumentation and data collection was done in the experimental Henval catchment. He said that in this phase, data collection is continued and under progress. He explained the development of an empirical model based on the meteorological observations made. Parameters of the model were optimized using GRG non-linear optimization methods, and equations were developed for different soil depths. He presented the model calibration and validation results, which indicated that the model performed very well at shallow soil depths, but the efficacy of the model was not as good at the deeper soil depths. Director, NIH suggested to correct the name of the study in the agenda notes of the working group meeting and also asked to compare soil moisture output of the SWAT model with the observed values and simulated output of this empirical model. MKN noted the suggestion. The working group members made no specific suggestions or comments during the presentation.
15.	**Title:** Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package **Team:** D. Chalisgaonkar; M. K. Goel **Duration:** 1 year (08/20-07/21) **Funding:** NIH **Status:** Ongoing	This study was not presented in the WG. This study is under progress and will be completed in July 2021.

Recommended Work Programme for the year 2021-2022

SN	Title of Project/Study	Study Team	Duration	Status & Comments	Funding
	Ongoing Sponsored/ Internal Studies				
1.	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; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra	5 years (01/16-03/21) (Extended till Sept., 2021)	On-going **Not presented**	DST
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V. S. Jeyakanthan; L. N. Thakural;	5 years (01/16-03/21) (Extended till Sept., 2021)	On-going **Not presented**	DST
3.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS)	5 years (01/16-03/21) (Extended till Sept., 2021)	On-going **Not presented**	DST
4.	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 (Retd.) P. K. Mishra; M. Arora; AP Dimri (JNU)	5 years (01/16-03/21) (Extended till Sept., 2021)	On-going **Not presented**	DST
5.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	M K Nema; Sharad K. Jain (Retd.); ~~Renoj J.Thayyen;~~ Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal AP Dimri (JNU)	5 years (01/16-03/21) (Extended till Sept., 2021)	On-going **Not presented**	DST
6.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra; M. K. Nema; ~~Renoj J. Thayyen;~~ Pradeep Kumar	5 years (01/16-03/21) (Extended till Sept., 2021)	On-going **Not presented**	DST
7.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore; (Now L. N. Thakural is PI); Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan	3 years 2017-2020 (Extended upto June, 2021)	On-going **Not presented**	PDS under NHP
8.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P. K. Singh; M. Arora ~~Renoj J. Thayyen;~~ A. K. Lohani; Vishal Singh;	3 years (11/19-11/22)	On-going **Not presented**	NMHS-MoEF
9.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	~~Renoj J. Thayyen~~ Vishal Singh A. P. Dimri (JNU) Sanjay K. Jain	3 years (06/19-11/22)	On-going **Not presented**	NRDMS -DST
10.	Permafrost mapping and characterization of Ladakh Region	~~Renoj J. Thayyen;~~ A. P. Dimri (JNU) will lead now; G. Jeelani (KU); V. Agnihotri (GBPNI)	3 years (11/19-11/22)	On-going **Not presented**	NMHS-MoEF

11.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh; P K Mishra; P K Agarwal	2 years (08/20-07/22)	On-going **Presented**	NHP
12.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora P K Mishra Vishal Singh	3 years (04/18-03/22)	On-going **Not presented**	NIH
13.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	Vishal Singh; Sanjay K. Jain; Manohar Arora	2 years (08/20-07/22)	On-going **Presented**	NIH
14.	Monitoring and Hydrological Modelling of Henvel watershed in Lesser Himalaya (Phase II)	M K Nema; Sanjay K Jain; ~~Renoj J. Thayyen;~~ P K Mishra; P K Agarwal	3 years (08/20-07/23)	On-going **Not presented**	NIH
15.	Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package	D. Chalisgaonkar M. K. Goel	1 year (08/20-07/21)	On-going **Not presented**	NIH
	New Internal/ Sponsored Studies				
1.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh; P K Agarwal	2 years (06/21-05/23)	New **Presented** Due care will be taken to use the latest available open access dataset preferably up to 2020, as advised by Dr. V. C. Goyal.	NHP
2.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	2.5 years (06/21-05/24)	New **Presented** No specific comments were received from the members.	NHP
3.	Monitoring of Hydrological Processes in Glaciated and Non Glaciated Watersheds of North-West Himalaya	M K Nema; Sanjay K Jain; Manohar Arora; Vishal Singh; Praveen Thakur (IIRS)	3 years (07/21-06/24)	**Presented** This study was not presented in the WG. SKJ informed that this study will be taken up after MOU is signed with IIRS.	IIRS

DETAILS OF RESEARCH PUBLICATIONS DURING APRIL, 2020 - MARCH, 2021

Research studies	Research papers	Training courses	Training of personnel
3	**43**	**9**	**16**

DETAILS OF TRAINING/ WORKSHOP COMPLETED DURING APRIL, 2020 - MARCH, 2021

SN	Title of Training Course/Workshop	Coordinators	Duration	Venue
1.	Training on Hydrologic modelling using HEC RAS and HEC HMS	Dr. Vishal Singh, Scientist 'C' and Dr. A. K. Lohani, Scientist 'G'	5 days	Online
2.	One-day online workshop on "Machine Learning for Remote Sensing Data Classification" conducted by Indian Institute of Remote Sensing (IIRS), Dehradun	Dr. M. K. Nema, Scientist 'D'	1 day	Online
3.	Training Programme on "Remote Sensing Application in Agricultural Water Management" from August 03-07, 2020 conducted by Indian Institute of Remote Sensing (IIRS), Dehradun.	Dr. M. K. Nema, Scientist 'D' and Dr. P. K. Mishra, Scientist 'C'	5 days	Online
4.	Training Programme on "Hydrological Modeling using SWAT" for more than 65 participants.	Dr. M. K. Nema, Scientist 'D' and Dr Vishal Singh, Scientist 'C'	5 days September 21-25, 2020	Online
5.	Training Programme on "Understanding of Coastal ocean processes using RS and Numerical Modeling" under IIRS Outreach Programme conducted by Indian Institute of Remote Sensing (IIRS), Dehradun.	Dr. P. K. Mishra, Scientist 'C'	5 days September 21-25, 2020	Online
6.	Training Programme on "Application of Water Accounting Plus (WA+) Tool for Water Resources Management" under NHP.	Dr. P. K. Singh, Scientist 'D' and Dr P. K. Mishra, Scientist 'C'	5 days November 16-21, 2020	Online
7.	Training Programme on 'Advanced Hydrology' under National Hydrology Project (NHP).	Dr. Manohar Arora, Scientist 'E'	5 days November 23-27, 2020	Online
8.	Training Programme on "Hydrological Modeling using SWAT" from November 30-04, 2020	Dr. M. K. Nema, Scientist 'D' and Dr Vishal Singh, Scientist 'C'	5 days	Online
9.	Stakeholders' Workshop on "Snow and Glacier Contribution and Impact of Climate Change in Teesta River Basin, Eastern Himalaya a project sponsored under NMHS" at Gangtok	Dr. Sanjay K. Jain, Scientist 'G' and Dr. P. K. Singh, Scientist 'D'	February 23, 2021.	Gangtok

DETAILS OF TRAINING/ WORKSHOP PROPOSED DURING APRIL, 2021 - MARCH, 2022

SN	Title of Training Course/Workshop	Tentative Date & Month	Place	Target Participants	Team
1.	One-day Stakeholders Workshop on the Water Accounting Plus (WA+) study for the Subernarekha basin	Aug., 2021	Online	WRD officials from three states (Jharkhand, Odisha, West Bengal)	Dr. P. K. Singh and Dr. P. K. Mishra

2.	Advanced Hydrology	August 2021	On line	Under NHP	Dr. Manohar Arora and Dr. J P Patra
3.	Training Programme on "Application of Water Accounting Plus (WA+) Tool for Water Resources Management" under National Hydrology Project (NHP).	Nov. - Dec., 2021	Shillong/ Kohima	WRD officials from Meghalaya and Nagaland states	Dr. P. K. Singh and Dr. P. K. Mishra
4.	Training Programme on "Hydrological Modeling using Soil SWAT – Theory and Hand-on" under NHP.	Aug., 2021	Online	Field Engineers from IAs under NHP; State Depts.	Dr. M. K. Nema and Dr. Vishal Singh
5.	Training Programme on "Hydrological Modeling using Soil SWAT – Theory and Hand-on"	Jan., 2022	Online	Research Scholars, Academician	Dr. M. K. Nema and Dr. Vishal Singh

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Dr. V C Goyal, Sc. G & Head, presented an overview of the Division's activities and progress of studies during 2020-21. He also presented tables showing the studies and outreach activities proposed for the F.Y. 2021-22. Individual studies were presented by the respective PIs as given below:

Work Program for the year 2020-21

SN	Title of Project/Study	Study Team	Duration	Funding	Status & Comments/ suggestions
		INTERNAL STUDY			
1	Conservation of ponds in Ibrahimpur-Masahi Village and performance evaluation of natural treatment system	NIH: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka; CEH-UK: Prof. Laurence Carvalho & Team	Apr 2018-Mar 2021 (Extended upto Jul 2021)	NIH, CEH-UK	Sh. Omkar Singh (PI) informed that the performance evaluation of the CW-NTS has been carried out based on about 25 field investigations. As suggested by UK-CEH, a request was made for extension upto Sept. 2021 to carry out additional field investigations and perform planned outreach activities. Director, NIH advised to complete the study and submit the final technical report by July 2021. He assured that NIH will continue to facilitate the logistic support required by UK-CEH to complete their part of the study.
2	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sept.2020-Feb. 2023	NIH	Dr. Jyoti P Patil (PI) presented the data inventory, trend analysis, climatic indices, and WEAP model formulation Dr. Man Singh

	region				(PD-WTC) asked about water-saving technologies in the Bundelkhand region and Dr. Manoj Samuel (CWRDM) asked the basis of selection of different scenarios and the effect of all scenarios on water resources, which were answered by the PI.
3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020-Jun 2022	NIH	On-going **Not presented**
4	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Jul 2020-Jun 2022	NIH	Dr. A. R. Senthil kumar (PI) presented the progress made for setting up of WEAP and LINGO models. The chairman suggested to carry out cost-benfit analysis and scenario analysis with deficit irrigation and crop cutting experiments/crop related data. He also suggested to include one Agrnomist/Economist who can contribute in this study. Dr. Man Singh, PD-WTC) was requested to suggest a Scientist from WTC for this purpose.
	SPONSORED PROJECTS				
1	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora	Mar 2016-Mar 2021	DST-NMSHE	On-going **Not presented**
2	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018-Dec. 2020	MoJS (through Scheme funds)	Completed **Not presented**

3	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	DST (GoI)	The progress was jointly presented by Er. Omkar Singh and Dr. Rajesh Singh. Dr. Manoj Samuel (CWRDM) wanted to know about plants/root & shoot analysis, Dr. Sudhindra M Sharma (Indore) enquired about treatment systems, and Dr. Sushil Rohilla (WIHG) & Dr. Pawan Labhasetwar (NERI) about its overall applicability in rural and urban areas. PI responded to all queries.
4	Preparation of Guidebook on S&T Interventions on Pond Rejuvenation	V C Goyal (PI), Jyoti Patil	Sep 2020-Jun 2021 (Ext. upto Dec 2021 from DST)	DST (GoI)	On-going **Not Presented.**

Training Courses/ Workshops Organised

S.N.	**Name of activity**	**Period**	**Coordinator**	**Venue**
1	Webinar on “Hydrology of Upper Ganga basin in climate change perspective organized on the occasion of Himalaya Day (under aegis of INC-IHP of UNESCO)	Sept. 9, 2020	Dr. V C Goyal	Online mode
2	Training course on “Water security for resilience to deal with disasters and outbreaks”	Nov. 2-6, 2020	Dr. V C Goyal Dr. Jyoti Patil	Online mode
3	One day Webinar on “Ecohydrology-Engineering harmony for a sustainable World” under INC-IHP	Jan.27, 2021	Dr. Jyoti Patil Er. Rohit Sambare	Online mode

Awareness Activity Organized

S.N.	**Name of activity**	**Period**	**Venue**
1	Lecture on Water Conservation by Dr. V C Goyal & Er. Omkar Singh	29 Sept., 2020	KV-1, Roorkee
2	Activities under Swachhta Pakhwada	16-31 Mar, 2021	Roorkee
3	Lecture on Water Conservation by Dr. V C Goyal	22 April, 2021	KV-1, Roorkee
4	Expert lecture on “Nature based solutions for water and wastewater in a circular economy by Dr. V C Goyal	22 April, 2021	Amity University, Gwalior
5	Programe on Water Conservation Awareness	12 Nov., 2020	GIC, Roorkee
6	Programe on Water Conservation Awareness	18 Nov., 2020	Govt. Hr. Sec. School, Sohalpur (Tehsil Bhagwanpur) Dist. Haridwar
7	Exhibition under Atma Nirbhar Bharat	11-12 Jan., 2021	Udaipur, Rajasthan
8	Special session on Technical Communication Skills by Prof. A K Saraf, IIT, Roorkee	16 Feb., 2021	NIH, Roorkee

Research Publications	
1	International Journal - **7**
2	International Conferences - **2**
3	Chapters in Books - **2**

NIH video series "Hydrology for People"

S.N.	Topic	Link
1	Improving our understanding of the aquifer systems in Sundarbans – Dr Gopal Krishan	https://www.youtube.com/watch?v=qUrQBgnsSuQ
2	Groundwater Salinity Study Model -Dr Gopal Krishan	https://www.youtube.com/watch?v=9jEzl5kvX1o
3	Water Census and Hotspot analysis in selected villages in Upper Ganga Basin-Dr. P K Mishra	https://www.youtube.com/watch?v=r_vuMD_hqRQ
4	Ladakh: Water resources research in Ladakh (Glaciers , snow and permafrost)- Dr. Renoj Thayyen	https://www.youtube.com/watch?v=6KDZnh2XIlw
5	GLOF Study- Dr Sanjay Jain, Dr A.K. Lohani	https://www.youtube.com/watch?v=S9w9FKoK0_Y
6	Observations and Hydrological Modelling in the Henval watershed-Dr Manish Nema	https://www.youtube.com/watch?v=uPSi7LY4QRQ
7	Water footprints of Internet- Dr V.C. Goyal	https://www.youtube.com/watch?v=e4eWE8_YfkE
Other films		
1	Himalaya Diwas Webinar	https://www.youtube.com/watch?v=jd7ncLljygM
2	वर्षाजलप्रबंधनएंवसंरक्षण	https://www.youtube.com/watch?v=HVzcQ0Sh6mI
3	NIH Library : An overview	https://www.youtube.com/watch?v=UcNdibjVDM4
4	Virtual Water and Smart Economy	https://www.youtube.com/watch?v=yKTiB4zpdhU
5	Follow Water Footprints to Find Virtual Water.	https://www.youtube.com/watch?v=5fAGemhzO2I
6	राष्ट्रीयजलविज्ञानसंस्थानकेस्वच्छताप्रहरी	https://www.youtube.com/watch?v=-xAB3WrtQrM

Recommended Work Program for the year 2021-22

SN	Title of Project/Study	Study Team	Duration	Funding	Status
		INTERNAL STUDY			
1	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka; CEH-UK: Prof. Laurence Carvalho & Team	Apr 2018-Jul 2021	NIH, CEH-UK	On-going
2	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Jul 2020-Dec 2022	NIH	On-going

3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020- Jun 2022	NIH	On-going
4	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Jul 2020- Jun 2022	NIH	On-going
SPONSORED PROJECTS					
1	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora	Mar 2016- Mar 2021 (Extended upto Sep 2021)	DST-NMSHE	On-going
2	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019- Mar 2024	DST (GoI)	On-going
3	Preparation of Guidebook on S&T Interventions on Pond Rejuvenation	V C Goyal (PI), Jyoti Patil	Sep 2020- Jun 2021 (Ext. requested upto Dec 2021 from DST)	DST (GoI)	On-going

<u>Proposed Training/Webinar/Outreach Activities of RMOD (2021-22)</u>

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Webinar on "Water for Public Health (W4PH): Preparing for Disasters & Pandemics"	Jul 2021	Online mode	Medical and WASH professionals, water utility professionals, researchers	V C Goyal, Jyoti Patil, Varun Goyal, Amrendra Bhushan
2	Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands	Sep 2021	NIH Roorkee	R&D Institutes/University/Govt. Organizations	NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst

3	Awareness Programme for School Children	July-Sep 2021	2 Schools in Roorkee/ Nearby	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
4	Awareness Programmes on “Water Conservation/Pond Rejuvenation” for Stakeholders in Ibrahimpur Masahi village/schools	Sep-Dec, 2021	Ibrahimpur Masahi/ schools	Villagers/ School children	Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka
5	Life cycle approach for rejuvenation of ponds and lakes using Nature Based Solutions (4 training courses of 5-days duration) Funded by NWM (MoJS, GoI)	Sep’21 – Jul ’22	Roorkee/ Online	Field engineers and practitioners	Jyoti Patil, V C Goyal, Omkar Singh, Digambar Singh, Rohit Sambare, N R Alakka

Other Outreach Activities:

S.N.	**Activity**
1	• Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi
2	• Coordination of 75 planned Activities at HQ & RCs under Bharat Ka Amrut Mahotsav @ India 75 • Organizing activities as per mandate of Division under Bharat Ka Amrut Mahotsav @ India 75
3	• River Walk of Solani River (stretch to be identified)
4	• Any other Outreach activity on demand/assigned

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 51st WG meeting

1.	Dr. J V Tyagi, Director, NIH	Chairman
2.	Dr. A. K Das and Sh. S M Manik, IMD, New Delhi	Member
3.	Sh. Sudhindra Mohan Sharma, Ex-Nodel Officer, MoDWS, Indore	Member
4.	Sh. Prashant Rai, CGWB, Dehradun	Member
5.	Dr. Manoj P.Samuel, CWRDM, Kozhikode	Member
6.	Dr. Sushil Kumar, WIHG, Dehradun	Member
7.	Dr. R K Goyal, CAZRI, Jodhpur	Member
8.	Dr. Pawan Labhasetwar, NEERI, Nagpur	Member
9.	Dr. Man Singh, WTC, ICAR-IARI, New Delhi	Member
10.	Prof. Varun Joshi, GGSIPU, New Delhi	Member
11.	Prof. A K Saraf, IIT Roorkee	Member
12.	Dr. Bhishm Kumar, IAEA (Retd.), Roorkee	Member
13.	Prof. A P Dimri, JNU, New Delhi	Member
14.	Dr.Kaushal K Garg,ICRISAT, Hyderabad	Member
15.	Dr. Debashish Sen, PSI, Dehradun	Member
16.	Dr. Sadhana Malhotra, Mindspace, Dehradun	Member
17.	Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH	Member
18.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
19.	Dr. M. K. Goel, Sc. G & Head GWH Division, NIH	Member
20.	Dr. A.K. Lohani, Sc. G & Head SWH Division, NIH	Member
21.	Dr. R P Pandey, Sc.G & Head EH Division, NIH	Member
22.	Dr. V C Goyal, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from NIH

	EH Division		**RMO Division**
1	Dr. M.K. Sharma, Sc.E	18	Er. Omkar Singh, Sc.F
2	Dr. Rajesh Singh, Sc.D	19	Dr. A R Senthil Kumar, Sc.F
3	Dr. Pradeep Kumar, Sc.D	20	Dr. (Mrs.) Jyoti P. Patil, Sc.D
4	Sh. Rajesh K. Nema, Sc.B	21	Sh. Digamber Singh, Sc.C
5	Ms. Anjali, Sc.B		**SWH Division**
	GWH Division	22	Dr. Sanjay Kumar, Sc.E
6	Dr. Anupama Sharma, Sc.F	23	Dr. Archana Sarkar, Sc.E
7	Dr. Surjeet Singh, Sc.F	24	Dr. L.N. Thakural, Sc.D
8	Dr. Sumant Kumar, Sc.D	25	Dr. J.P. Patra, Sc.D
9	Mrs. Suman Gurjar, Sc.D	26	Dr. Ashwini A. Ranade, Sc.C
10	Dr. Gopal Krishan, Sc.D	27	Sh. Sunil Gurrapu, Sc.C
11	Sh. Nitesh Patidar, Sc.B	28	Sri N K Bhatnagar, Sc.B
	HI Division		**WRS Division**
12	Dr. Suhas Khobragade, Sc.F	29	Smt. Deepa Chalisgaonkar, Sc. G
13	Dr. M.S. Rao, Sc.F	30	Dr. Manohar Arora, Sc.E
14	Dr. Soban S. Rawat, Sc.D	31	Dr. P K Singh, Sc.D
15	Dr. Santosh M Pingale, Sc.C	32	Dr. Manish Nema, Sc.D
16	Ms. Nidhi Kalyani, Sc.B	33	Dr. P K Mishra, Sc.C
17	Sh. Hukam Singh, Sc.B	34	Dr. Vishal Singh, Sc.C
		35	Sh. P K Agarwal, Sc.B

ANNEXURE – B

Division-wise Work Programme

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. R P Pandey	Scientist G & Head
2	Dr. M K Sharma	Scientist E
3	Dr. Rajesh Singh	Scientist D
4	Dr. Pradeep Kumar	Scientist D
5	Sh. Rajesh K. Nema	Scientist B
6	Mrs. Anjali	Scientist B
7	Sh. Shekhar Saini	SRA
8	Smt. Babita Sharma	SRA
9	Smt. Bina Prasad	RA

Approved Work Programme for the Year 2021-22

SN	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) Pradeep Kumar M. K. Sharma Sumant Kumar **Partner:** Irrigation Department, Punjab	3 Years (09/17-03/22) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** Report submitted to NHP
2.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar J. V. Tyagi M. K. Sharma **Partner:** CGWB (Delhi unit)	3 Years (11/19-10/22) **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress
3.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R.P. Pandey, (PI). Er. Jagdeesh Patra, Dr. Rajesh Singh, Sh N. K. Bhatnagar	3 years (12/17-03/22) Extension till 03/22, further extension requested **Project cost:** Rs. 75.0 Lakh **Status:** In-progress
4.	Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanasi and surrounding area	Rajesh Singh (PI) R. P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 years (07/21-07/24) **Project cost:** Rs. 10.0 Lakh **Sponsored by**: BHU **Status:** In-progress
Internal Study (Ongoing)			
5.	Water quality assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh J. V. Tyagi Pradeep Kumar	2 years (05/19-06/21) **Project cost:** 17.10 lakh **Status:** Completed
6.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema	4 years (11/19-10/23) **Project cost:** Rs.43.02 lakh **Status:** In-progress
7.	Development of rejuvenation plan for Hindon river system	M. K. Sharma (PI) Sudhir Kumar	3 Years (07/20-06/23) **Status: Transferred to HI Division** and merged with DST-NWO Project on River Hindon
8.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi R. P. Pandey R.K. Nema Pradeep Kumar M. K. Sharma	2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** In-progress
9.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI) R. K. Nema Sumant Kumar Pradeep Kumar M. K. Sharma	3 Years (07/21 – 06/24) **Project Cost:** 30.1 Lakhs **Sponsored by:** Internally **Status:** In progress
Consultancy Projects			

10.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	J. V. Tyagi (Lead PI) R. P. Pandey (PI) P. Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural P. K. Singh Rajesh Singh	2.5 Years (03/20-08/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** In-progress
11	Hydrological Study of New India Garden (NIG) Project at Village Indraprasth, New Delhi	J.V. Tyagi R. P. Pandey (PI) J. P. Patra Pradeep Kumar	10 months (03/21-01/22) **Project Cost:** Rs. 41,30,000/- **Sponsored by:** CPWD New Delhi **Status:** Completed
12.	Hydrological Study for Design of Drainage System and Evaluation of Flood Diversion Channel for the RBI Campus, Dehradun	J.V. Tyagi R. P. Pandey J. P. Patra Pradeep Kumar (PI) Rajesh Singh	03 months (12/21-03/22) **Project Cost:** Rs. 8,37,800/- **Sponsored by:** CPWD Dehradun **Status:** Completed
13.	Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-I Power Station, NHPC	J.V. Tyagi R.P. Pandey Rajesh Singh (PI) M. K. Sharma	15 months (09/21-03/23) **Project Cost:** Rs. 3,24,500/- **Sponsored by:** Innovate Solutions Pvt. Ltd. Noida. **Status:** In-progress

Training Programmes/Workshop organized:

SN	Topic	Duration	Place
1	Online National Level Training Programme on “Floods and Drought Risk Mitigation Under Climate Change” Jointly Organized by NIH and NIDM New Delhi (Coordinator: Dr. R. P. Pandey)	3 Days 2-4 February 2022	Roorkee
2	Online Training Course titled “Data Processing for Water Quality Assessment and Management, NHP” (Coordinator: Dr. M. K. Sharma)	5 Days 6-10 December 2021	Roorkee
3	Online Mandatory Level-II training for Senior Research Assistants (SRAs) of CWC, (Coordinator: Dr. M. K. Sharma)	4 Days 20-23 October 2021	Roorkee

Publications:

Int. Journal	Nat. Journal	Int. Conference	Nat. Conference	Book Chapter	Total
15	-	13	-	05	**33**

Research Papers in Journals (15 Nos.)

International Journal

1. Bhagwat, A., Rajat Kumar; Chandrashekhar Prasad Ojha, Mukesh Kumar Sharma, Apourv Pant, Babita Sharma and Jai Vir Tyagi (2021) Assessing efficiency and economic viability in treating leachates emanating from the municipal landfill site at Gazipur, India, Environmental Science and Pollution Research, https://doi.org/10.1007/s11356-021-16724-y (IF: 4. 3).
2. Kumar S., M. Kumar, V. K. Chandola, V. Kumar, R. K. Saini, N. Pant, N. Kumari, A. Srivastava, S. Singh, R. Singh, G. Krishan, S. P. Induwar, S. Kumar, B. K. Yadav, N. S.

Maurya, A. Chaudhary (2021). Groundwater Quality Issues and Challenges for Drinking and Irrigation Uses in Central Ganga Basin Dominated with Rice-Wheat Cropping System. Water, 13, 2344 (IF: 3.103).

3. Kumar S., V. Kumar, R. K. Saini, N. Pant, R. Singh, A. Singh, S. Kumar, S. Singh , B. K. Yadav, G. Krishan, A. Raj, N. S. Maurya, M. Kumar (2021). Floodplains Landforms, Clay deposition and irrigation return flow govern arsenic occurrence, prevalence and mobilization: A geochemical and isotopic study of the Mid-Gangetic floodplains. Environmental Research, In Press (IF: 6.498).
4. Malakar A., R. Singh, K. A. Weber, J. Westrop, C. N. Elofson, M. Kumar, D. D. Snow (2021). Occurrence of arsenite in surface and groundwater associated with a perennial stream located in Western Nebraska, USA. Journal of Hazardous Materials, 126170, In press (IF: 10.588).
5. Malyan S. K., S. S. Kumar, R. K. Fagodiya, P. Ghosh, A. Kumar, R. Singh, L. Singh (2021). Biochar for environmental sustainability in the energy-water-agroecosystem nexus. Renewable and Sustainable Energy Reviews, 149, 111379 (IF: 14.982).
6. Malyan S. K., S. Yadav, V. Sonkar, V. C. Goyal, O. Singh, R. Singh (2021). Mechanistic understanding of the pollutant removal and transformation processes in the constructed wetland system. Water Environment Research, In Press (I.F.: 1.946).
7. Mishra PK., Thayyen RJ, Singh H, Das S, Nema MK, Kumar P. 2021. Assessment of cloudbursts, extreme rainfall and vulnerable regions in the Upper Ganga basin, Uttarakhand, India. International Journal of Disaster Risk Reduction (in Press, available online at https://authors.elsevier.com/a/1eLBX7t2zZ5nlG).
8. Panday B. K., R. Singh, R. P. Pandey, S. Das, J. Kumar, P. Kumar, S. Kumar, V. K. Pandey (2021). Water quality appraisal of a mountainous river: A case study of Rispana River, Dehradun. Water & Energy International, 64(1), 14-23 (IF: 0.21).
9. Pandey R.P., Pradeep Kumar, B.K. Panday, J.V. Tyagi, Rajesh Singh, Sumant Kumar, S. Saini, (2021). Development of Rejuvenation Plan for Rispana River System, Uttarakhand, India. Water & Energy International, 64(2), 6-18 (IF: 0.21).
10. Pant N., S. P. Rai, R. Singh, S. Kumar, R. K. Saini, P. Purushothaman, Y. S. Rawat, K. Pratap, M. Sharma (2021). Impact of geology and anthropogenic activities over the water quality with emphasis on fluoride in water scarce Lalitpur district of Bundelkhand region, India. Chemosphere, 279, 130496 (IF: 7.086).
11. Prakasam, C., Saravanan R., Kanwar, Varinder S., Sharma, M.K. and Sharma, Monika (2020) Assessment of Environmental Changes using GIS Applications, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, 9(11), 16-20, DOI: 10.35940/ijitee.J7559.0991120.
12. Prakasam, C., Saravanan R., Sharma, M.K. and Kanwar, Varinder S. (2021) Assessment and distribution of water quality of Pandoh river basin (PRB), Himachal Pradesh, North India, Applied Water Science, 11(137), 1-9. https://doi.org/10.1007/s13201-021-01468-4.
13. Sharma M. K, Pradeep Kumar, Kunarika Bhanot and Parul Prajapati (2021) Assessment of Non-point Source of Pollution using Chemical Mass Balance Approach: A case study of River Alaknanda, a tributary of River Ganga, India, Environmental Monitoring and Assessment, 193:424 https://doi.org/10.1007/s10661-021-09203-x.
14. Sharma M. K., Mohit Kumar, D. S. Malik, Surjeet Singh, A. K. Patre, Beena Prasad, Babita Sharma,Shekhar Saini, A. K. Shukla and P. C. Das (2022) Assessment of groundwater quality and its controlling processes in Bemetara District of Chhattisgarh State, India, Applied Water Sciences (IF: 3.874) (Under Printing).
15. Yadav, M., Pandey, G. and Kumar, P. (2021). Low Flow Frequency Analysis of Tawi River Discharge at Jammu Location. Int. J. of Hydrology Science and Technology, Inderscience (accepted for publication), (IF: 0.68).

Papers in Conferences (13 Nos.)

International Conferences

1. Bhagwat, A. (2021) "Rejuvenation of River Assi", 2nd International Conference on "River Health: Assessment to restoration (RHAR-2021)" during 22-24 Oct. 2021.
2. Bhagwat, A. and Himanshu Jain (2022). Modelling the solute migration through the landfill profile for Gazipur landfill site, Delhi, India. Roorkee Water Conclave 2022, 2-4 March, 2022.
3. Bhanot, K., M. K. Sharma and R. D. Kaushik (2022) Hydrochemical assessment of river Alaknanda, Uttarakhand, India using multivariate statistics, Roorkee Water Conclave 2022, 2-4 March 2022
4. Kumar, M., M. K. Sharma and D. S. Malik (2022) Groundwater quality evaluation of a semi-arid region for irrigation using Irrigation Water Quality Index (IWQI): A case study of Bemetara district of Chhattisgarh, India, Roorkee Water Conclave 2022, 2-4 March 2022.
5. Maithani C., Singh R., Goyal V. C., Singh O., Rao P. V., Malyan S, Yadav S., Kumar J., (2022). Wastewater pollutants removal in deep horizontal subsurface flow constructed wetlands for a circular water economy. International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022), 28 Feb – 1 March, 2022.
6. Malyan S., Maithani C., Goyal V. C., Singh R., Singh O., Yadav S., Kumar J., (2022). Removal of coliforms from domestic wastewater in deep horizontal subsurface flow constructed wetlands for a circular water economy. International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022), 28 Feb – 1 March, 2022.
7. Pandey R. P. (2021) "Application of hydrologic model for assessment of vulnerability to drought", A keynote Paper Presented in Hydro-2021, Organized by Indian Society of Hydraulics (ISH), 23-25 Dec 2021, at SVNIT Surat.
8. Pandey R. P. (2021) "Hydrological Impacts of Climate Change on Water Resource System and its Implications for Energy and Food: A Countrywide Assessment" under Theme-1: Food-Energy-Water-Climate Security Nexus and the Challenges, Key note paper presented in XV Agricultural Science Congress, 13-16 Nov. 2021 at BHU Varanasi.
9. Pandey R.P. (2022). Implications of Climate Change and Sustainable Water Resource Management in India, Key Note Paper under one of the themes "*Climate Change and Sustainable Development*" presented in International Seminar on Ecosystem Functioning in Anthropocene (ISEFA-2022), Organised by Banaras Hindu University (BHU) during 23-25th Feb 2022.
10. Pant, A. and Anjali Bhagwat (2022). Microplastics: Quantification, identification, and its effects on aquatic invertebrates, Roorkee Water Conclave 2022, 2-4 March, 2022.
11. Prakasam, C., Saravanan, R., Kanwar, Varinder, S. and Sharma, M. K. (2021) Environmental flow monitoring system– the need of the hour, Proceedings of International Conference on Advances In Multi-Disciplinary Sciences and Engineering Research (ICAMSER – 2021) at Dept. of Applied Sciences, Chitkara University, District Solan (H.P.) during 2-3 July 2021, (Eds: S. R. Sharma, Ishwar Dutt, Arun Lal Srivastav) ISBN No.: 978-81-953416-1-0, Paper No. 21, pp. 30.
12. Sharma M. K., Manohar Arora, Babita Sharma and Beena Prasad (2022) Diurnal variations of hydrological and hydro-chemical parameters in the meltwater of Gangotri Glacier, Uttarakhand, India, Roorkee Water Conclave 2022, 2-4 March 2022
13. Singh K., Pandey G., Singh R. (2022). Heavy Metals Occurrence in Groundwater of Punjab, India: A Review. International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022), 28 Feb – 1 March, 2022.

Book Chapters (05 Nos.)

1. Kumar, A., Tripathi, V. K., Sachan, P., Rakshit, A., Singh, R.M., Shukla, S. K., Pandey, R., Vihwakarma, A. and Panda, K.C. (2022). Sources of ions in the river ecosystem. In: S. Madhav, S. Kanhaiya, A. L. Srivastav, V. B. Singh and P. Singh (Eds.). 2022. Ecological

Significance of River Ecosystems: Challenges and Management Strategies, Elsevier Publications, Amsterdam, Netherlands, pp. 187-202.

2. Pandey, R.P., Kale, R.V., Patra, J.P. and Galkate, (2021) "Impact of Climate Change on Occurrence and Severity of Drought" Chapter accepted for publication in edited book on "Drought Assessment, Prediction and Management" under changing climate scenario (eds: Jhajhariya, D; V. P. Singh; R. Mirabbasi and R. Kumar), Publisher CRC Press, USA. (in press).
3. Patidar N. and Bhagwat A. (2022). *Data Assimilation in Groundwater Modelling*, Advances in Hydrology and Climate Change Historical Trends and New Approaches in Water Resources Management, CRC Press, a Taylor & Francis Group.
4. Prakasam, C., Saravanan R. and Sharma, M.K. (2022) "Assessment of Environmental Flow Requirements through Rainfall-Runoff Modelling for Hydropower Project", Lecture Notes in Civil Engineering 232 in the Book titled "Environmental Restoration" (Eds.: D. K. Ashish and J. de Brito), Springer Nature Switzerland AG
5. Prakasam, C., Saravanan R., Kanwar, Varinder S., Sharma, M.K. and Sharma, Monika (2021) "GI Science for Land Use Suitability Analysis in the Himalayas – A Case Study of Himachal Pradesh, India", Chapter published in the Book titled "Geographic Information Science for Land Resource Management" (Eds.: Suraj Kumar Singh, Shruti Kanga, Gowhar Meraj, Majid Farooq, and Sudhanshu, Scrivener Publishing LLC, pp. 301–318.

PROPOSED WORK PROGRAMME FOR THE YEAR 2022-23

SN	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar J. V. Tyagi M. K. Sharma **Partner:** CGWB (Delhi unit)	3 Years (11/19-10/22) **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress
2.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R.P. Pandey, (PI). Er. Jagdeesh Patra, Dr. Rajesh Singh, Sh N. K. Bhatnagar,	3 years (12/17-12/20) Extension requested till 03/22 **Project cost:** Rs. 75.0 Lakh **Status:** In-progress
3.	Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanasi and surrounding area	Rajesh Singh (PI) R. P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 years (07/21-07/24) **Project cost:** Rs. 10.0 Lakh **Sponsored by**: BHU **Status:** In-progress
Internal Study (Ongoing)			
4.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema	4 years (11/19-10/23) **Project cost:** Rs. 43.02 lakh **Status:** In-progress
5.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi R. P. Pandey R.K. Nema Pradeep Kumar M. K. Sharma	2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** In-progress
6.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI) R. K. Nema Sumant Kumar Pradeep Kumar M. K. Sharma	3 Years (07/21 – 06/24) **Project Cost:** 30.1 Lakhs **Sponsored by:** Internally **Status:** In-Progress
Internal Study (New)			
7.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims of groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	M. K. Sharma (PI) RC, Kakinanda CGWB	2 years (04/22-03/24) **Sponsored by:** Internally **Status:** Proposed
Consultancy Projects			
8.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	J. V. Tyagi (Lead PI) R. P. Pandey (PI) P. Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural P. K. Singh	2.5 Years (03/20-08/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** In-progress

		Rajesh Singh	
9.	Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-I Power Station, NHPC	J.V. Tyagi R.P. Pandey Rajesh Singh (PI) M. K. Sharma	15 months (09/21-03/23) **Project Cost:** Rs. 3,24,500/- **Sponsored by:** CPWD Dehradun **Status:** In-progress

Proposed Training Programmes

SN	Topic	Duration	Place
1.	Water Quality: Concepts and Analysis under NHP for IRI officials (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
2.	Estimation of Recharge for improving the Water Quality using MODFLOW & MT3D under NHP (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
3.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days	Roorkee
4.	Water Quality Data Processing (Coordinator: Dr. Pradeep Kumar)	5 Days	Roorkee
5.	Leachate Transport in Groundwater under NHP-PDS (Coordinator: Ms. Anjali)	5 Days	Roorkee

Study - 1 (Sponsored Project)

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

2. **Study Group:**

<table>
<tr><td rowspan="3">Lead Organization</td><td>Project Investigator
Dr. Rajesh Singh,Sc. 'D'</td></tr>
<tr><td>Co-Investigator
Dr. Pradeep Kumar, Sc. 'D'
Dr.Mukesh K. Sharma, Sc. 'E'
Er. Sumant Kumar, Sc. 'D'</td></tr>
<tr><td>Scientific/Technical Staff
Sandeep Singh, RA
RakeshGoyal, Tech. Gr. I
MeenakshiRawat, JRF
Prashant Kaushik, TA</td></tr>
<tr><td rowspan="2">Partner Organization</td><td>Project Investigator
Er. Harminder Singh, Chief Engineer, Water Resources</td></tr>
<tr><td>Co-Investigator
Er. Narinder Kumar Jain, Director, WR&ED
Dr. K. K. Kaushal, Sr. Hydrogeologist, WR&ED
Mr.SanjeevBansal, Sr. Tech. Asst., WR&ED</td></tr>
<tr><td>Collaborators</td><td>Dr. S. P. Rai, Assoc. Professor, BHU, Varanasi
Dr. Karrie A. Weber, Assoc. Professor, UNL, Lincoln
Dr.Brijesh K. Yadav, IIT Roorkee
Dr.Naseem Ahmed, IIT Roorkee</td></tr>
</table>

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:** 03/2022 with extension
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 a. (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, Ferozepur, 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:

Sr. No.	**Activities**	**YEAR 1**				**YEAR 2**				**YEAR 3**				**YEAR 4***			
		Q1	Q2	Q3	Q4	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																
8	Training & capacity building																

9	Scientific publications																
10	Final technical report																

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1	Purchase of equipment & consumables	• Laptop, Multiparameter ion analyzer, GWB & AquaChem software has been purchased. • Syringe pump purchase has been dropped due to escalation in the price. • Standards and consumable has been procured.
2	Delineation of villages and finalization of sampling location	• Delineation of villages and finalization of sampling locations has been completed.
3	Collection and analysis of samples	• The pre-& Post-monsoon sampling for the delineated villages has been completed. • Analysis of organoleptic, major ions, trace metals, pesticides, and radon has been completed.
4	Statistical analysis of data and Carcinogenicity test	• The statistical analysis and human health risk due to drinking water was computed.
5	Contaminant remediation	• The literature review related to contaminant remediation of major contaminants in the drinking water completed.
6	Training & capacity building	• A training course for the government officials was organized during June 17-21, 2019. • One stakeholders' workshop is proposed to be organized in May 2022.
7	Scientific publications	• 01 research paper in national journal, • 01 research paper in international journal, • 01 research paper in international conference, & • 03 manuscripts in review stage • 02 manuscript in writing stage
8	Final technical report	• The draft final report has been prepared and submitted.

13. Recommendation / Suggestion:

Recommendation / Suggestion	**Action Taken**
No specific comments/suggestions	--

14. Analysis & Results:

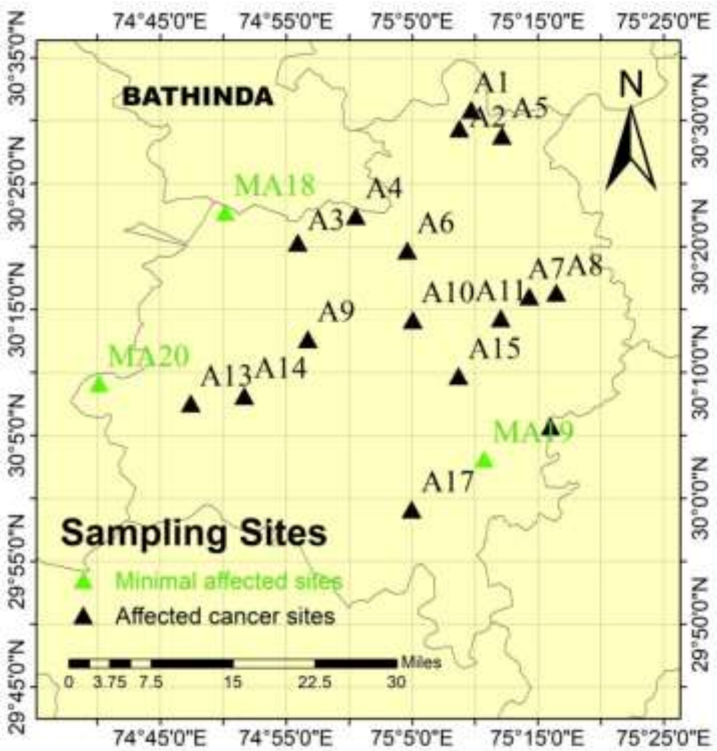
Upgrading literature and data collection:

- The recently published literature related to carcinogens in the water and their assessment was reviewed and a review paper titled 'An overview of carcinogenic pollutants in groundwater of India' is published in "Biocatalysis and Agricultural Biotechnology", published https://doi.org/10.1016/j.bcab.2019.101288. Three more research articles are under writing stage.

- Cancer related patient data collected from district and other Hospitals.
- Translation of cancer related data (2016-2018) from Punjabi to English language has been completed for of all districts.
- The cancer wise data has also been collected from all the districts except Faridkot.

Delineation of villages and finalization of sampling location

The village-wise number of cases for year 2016, 2017, & 2018 were collected from the district hospitals and Dept. of Health & Family Welfare, Govt. of Punjab, and was used for selecting the sampling sites. The village wise population data was downloaded from the MHA website (https://censusindia.gov.in/2011census/Listofvillagesandtowns.aspx). Each district was divided into grid of 10x10 km, and the cancer prone grids were identified and selected based on number of cancer cases, per capita cancer cases, and number of villages. Further, the village for sampling in a cancer prone grid was selected based on highest per capita cancer cases. Twenty sampling locations were finalized for each district, 17 from cancer prone grids, and 03 from minimal affected grids as shown in below figure for Bathinda district.



Sampling Sites of Bathinda District

Sampling & Analysis

- Drinking water samples from the identified villages were collected after discussion with the villagers based on the usage. The handpump were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of groundwater aquifer. All the groundwater samples were collected from the sources, which are being used extensively.
- The samples from all the districts of the study were collected for pre- and post – monsoon period.
- The organoleptic parameters, major ion, trace metals, and pesticides analysis has been completed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).

- Onsite Radon measurement in groundwater from different locations in SW Punjab has been completed.

Carcinogenicity / Mutagenicity/ Health Risk

- The overall health risk was calculated based on F, NO_3, NO_2, SO_4, Li, B, Fe, Co, Ni, Pb, Be, As, Se, Hg, U Al, As, Cr, Cu, Fe, Mn, Pb, and Zn concentration in drinking water respectively. During the pre-monsoon period, 96.9% of samples were in the high-risk category which reduced to 88.1% in the post-monsoon period. The cancer-associated risk based on Ni, Pb, As, Hg, U, Cr, Be, Co, Se, Cd, and NO_3 was computed and around 83.7% of samples were in the high-risk category during pre-monsoon which got reduced to 61.1% in the post-monsoon period.
- The experiments to develop the mutagenicity scale is under progress. The initial experiments of Ames test have low success rate.
- The PCA analysis indicated SO_4 in the pre-monsoon samples and As, Al, Fe, and Zn in post-monsoon samples as a result of anthropogenic activities.
- The concentration of radon in the shallow groundwater (depth: 25-150 ft bgl) ranges from 11.1 pCi/l to 209 pCi/L, with average concentration 95.02±2.91 pCi/l and in the deep groundwater (>150 ft bgl), it ranges from 37.5 pCi/l to 319 pCi/L, with average concentration 104.5±6.6 pCi/l. Maximum concentration of radon was observed in the groundwater of Jalalabad, Fazilka. Carcinogenic risk assessment due to radon intake through drinking water, indicates possible number deaths/million population/year in the range from 197 to 1670 with average value of 548 for deep borewells, and 58.2 to 1100 with average value 498 for shallow borewells.
- The experiments for mutagenicity were repeated several times with the mutagens but the results were not consistent and therefore, the results of mutagenicity could not be estimated with the desired accuracy and it requires comprehensive investigation.

Contaminant Remediation

- Removal of U, As, Cr, and Pb from the groundwater samples will result in 93.9% and 98.4% groundwater samples under low-risk category for pre-monsoon and post-monsoon period respectively.

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

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, Punjaband Local people

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

23. Shortcoming/Difficulties: NA

24. Future Plan:

i) Organization of a stakeholders' workshop in May 2022.

Study -2 (Sponsored Project)

1. **Title of the Study:** Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures

2. **Study Group:**

Project Investigator/Co-Project Investigator
Er. Anjali, Scientist B, EHD Dr. Sudhir Kumar, Scientist G & Head, HID Dr. J. V. Tyagi, Director Dr. M. K. Sharma, Scientist E, EHD
Scientific/Technical / Project Staff
Mrs.Babita Sharma, RA, EHD Mrs.Beena Prasad, RA, EHD Dr.Apoorv Pant, RA, EHD Mr.Rajat Kumar, JRF, EHD
Collaborating Agency
Dr. G. Vijaykumar, Senior Hydrogeologist,, CGWB (Delhi Unit)

3. **Type of Study:** Sponsored project by NHP (PDS), Budget: Rs 76,10,000/-

4. **Nature of Study:** Applied Research

5. **Date of start:**1 November, 2019

6. **Scheduled date of completion:**31 October, 2022

7. **Duration of the Study:** 3 Years (+7 months extension)

8. **Study Objectives:**

i) Understanding of hydrodynamics of groundwater flow in the study area.
ii) Chemical characterization of Leachate.
iii) Isotopic characterization of leachate and its variation due to recharge and extraction of groundwater.
iv) Assessment of Micro-plastic and metals (Hg, Ni, Co) in landfill leachate.
v) Modelling of leachate migration pattern in groundwater in space and time.
vi) Suggesting ameliorative measures for contaminant plume migration.
vii) Dissemination of knowledge and findings to stakeholders through manuals, leaflets, booklets and workshops/training programs.

9. **Statement of the Problem:**

The growth in population, urbanization and industrialization has led to the increase in the generation of solid waste all over the world. It is believed that the rate of waste generation is an index of socio-economic development and an economic prosperity of a country. This is evident from the fact that the rate of waste generation is more prominent in the developing countries where there is an increased rate of unplanned urbanization of the cities.

In India, the total Indian urban population amounts to approximately 377 million (Census of India 2011). The cities which have more than 100,000 populations contribute to more than 72 percent of the total municipal solid waste.The growth rate of population in urban India is much higher than that in rural India. The Census figures also show Delhi to be the most urbanized State in India.Since waste generated by the city depends on its population and per capita income, it is estimated that the quantity of Municipal Solid Waste (MSW) would reach 17,000 – 25,000 MT/day by 2021 (Talyan et al.,2007).

For solid waste management in Delhi, twenty landfill sites were identified and developed since 1975, and of which 15 have already been closed and two were suspended. At present only three landfill sites are in operation. They are namely, Bhalaswa catering the needs of northern part of Delhi, Okhla in the southern part and Gazipur in the eastern part of Delhi.

The dumping of waste in these non-engineered landfill sites contributes to percolation of leachate in the groundwater. These percolating liquids have high concentration of hazardous chemicals. The harmful constituents of leachate then move along the groundwater in the surrounding region rendering it unfit for human consumption and pose various health risk.

The various attempts made so far to model leachate movement suffer from a common problem that no surety can be established as to whether the pollution is result of leachate or any other source is contributing towards groundwater deterioration in that region. The current study focuses on modeling of leachate movement through groundwater and apportionment of leachate which has not been attempted so far.

10. Approved Action Plan/Methodology:

i) Literature review on chemical and isotopic characterization of leachate, groundwater contaminant transport modeling etc.
ii) Field survey of the region and groundwater sampling – using standard protocols.
iii) Characterization of leachate using EPA methods- TCLP (method no.- 1310) & column study (method no.- 1312).
iv) Collection of groundwater levels to ascertain the flow direction.
v) Identification of groundwater recharge and discharge areas.
vi) Collection of groundwater samples on bi-monthly basis at identified locations.
vii) Analyzing the physico-chemical parameters: pH, EC, DO, COD, TOC, Major anions, cations, and trace metals (Fe, Mn, Zn, Pb, Cd, Cr, Radium etc).
viii) Analysing the stable isotopic characteristics of leachate and groundwater at various identified locations.
ix) Analysing the groundwater samples and leachate for micro-plastic.
x) Processing of hydro-chemical and isotopic data on bi-monthly basis.
xi) Modeling the leachate migration from the landfill to groundwater table. The model will be developed for one dimensional vertical transport of contaminants through unsaturated zone.
xii) Modeling of leachate plume movement in groundwater will be performed using MT3D MODFLOW and HELP. The leachate transport model will be calibrated based on chemical and isotopic data.
xiii) Suggesting ameliorative measure for containment of contaminant plume based on groundwater modeling.

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							■	■	■	■	■	

8.	Training & capacity building												
9.	Scientific publications												
10.	Final technical report												

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1st Year	Literature survey	Field investigation, data collection and literature survey	Groundwater sampling and data processing	Groundwater sampling and analysis, estimation of flow parameters, and interim report
2nd Year	Groundwater sampling and analysis, and leachate characterization	Groundwater sampling and analysis, plume characterization and model conceptualization	Groundwater sampling and analysis, model conceptualization, training and workshop	Groundwater sampling and analysis, development of mathematical model, and interim report
3rdYear	Development of mathematical model	Computational runs with the developed model and identification of vulnerable areas and hot spots	Computational runs with the developed model and identification of vulnerable areas and hot spots	Finding ameliorative measures, training, workshop and report writing

12. Objectives and achievement during last six months:

S. No.	**Activity**	**Achievements**
1.	Field Investigation and sampling plan	• Groundwater sample collection from 130 grids from the vicinity of landfill. • Leachate Samples taken from the landfill.
2.	Decolourization of samples	• Samples colour removal was undertaken • Reasons for coloured samples was identified • Field applicability of chemical treatment assessed
3.	Identifying Ameliorative measures	• Phytoremediation through marigold
4.	Literature survey	• Literature on Microplastics, leachate characterization and isotopes in landfill was extensively surveyed.

13. **Recommendation / Suggestion:**

Recommendation / Suggestion	**Action Taken**
The study was appreciated by the PDS committee	

14. Analysis & Results:

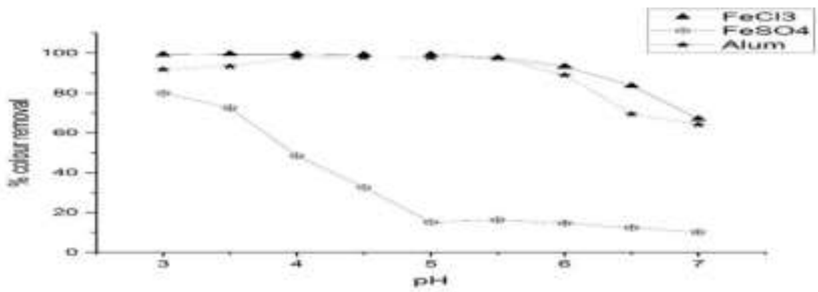
Coagulation and flocculation experiments:

- The samples were collected from the Gazipur landfill site and nearby areas. All the samples were analyzed for various water quality parameters. The results indicates high concentration of COD, BOD, TOC, EC in landfill leachate samples. The nearby ground water samples also shows high concentration of conservative chemicals such as chloride and fluoride.

- Leachate contains very high concentration of both organic and inorganic constituents that leach down in nearby groundwater and surface water resources.
- The landfill leachate samples were subjected to coagulation and flocculation experiments using ferric chloride ($FeCl_3$), ferrous sulfate ($FeSO_4$), and alum [$Al_2(SO_4)_3$] followed by advance fenton oxidation.
- The results show that ferric chloride leads to 99% color removal, 98% COD removal, 99% decrease in total organic carbon, 94.3% removal in NH_3–N, and 91.4% removal in total Kjeldahl nitrogen, and it proves to be the most efficient coagulant and surprisingly, proves to be even better than Fenton.
- Ammoniacal nitrogen and TKN are also very important wastewater treatment parameters. The three coagulants was compared on the ground of removal efficiency of ammoniacal nitrogen and TKN. The ammoniacal nitrogen (NH_3–N) after $FeCl_3$ treatment decreased to 70.62 mg/L (94.3% removal) at pH 3.5. The coagulation process with FeSO4 at pH 4.0 reduced the ammoniacal nitrogen (NH_3–N) to 168.3 mg/L making the removal efficiency 86.42%. The ammoniacal nitrogen (NH_3–N) value was observed to be 131.9 mg/L at pH 4.0 indicating 89.4% removal when treated with alum.
- Further, the results are compared with the UASB on-field application that proves ferric chloride ($FeCl_3$) treatment to decrease the operational cost by 71.9%, and conventional Fenton may decrease the operational cost by 76.8%.

Phytoremediation study:

- To evaluate a sustainable solution, a phytoremediation experiment is conducted using Marigold plants supplied with different concentrations of leachate.
- Growth of *T. erecta* exposure to 9 heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) affected all of the studied growth parameters of *T. erecta*, namely, shoot, leave and root height, stem diameter and number of flowers.
- Cr inhibits maximum growth in aerial parts, As, and Pb concentrations. However, plant height and no. of flowers varied with HMs concentration in a quadratic fashion, with plant height reaching an estimated maximum value of 58 cm at 47.76 ppb Cr (III) and 37.52 ppb of lead (Pb), whereas the lowest growth of 48cm is observed at 310.45ppb Cr (III) and 79.90ppb Pb
- Plant bioaccumulate the heavy metals in different parts of the plant (shoot, leaves, flowers and roots). Individual HMs absorption capacity of aerial parts (shoot, leaves, and flowers) show overall higher accumulation of Zn, Mn, and Cr.
- Various bioaccumulation factors that helps in evaluating the nature of a particular plant (hyperaccumulator or non-hyperaccumulator). The ability of a plant to accumulate metals from a growth medium, in this case, “soil,” can be assessed by computing shoot bioconcentration factor (BCF) – the ratio of shoot metal concentration to the metal concentration in soil, the translocation factor (TF) – the ratio of metal concentrations in the shoots to that in the roots.
- The BCF values of all the flowering plants for all the metals, i.e., Cd, Cr, Ni, and Pb, were significantly increased over control. The BCF values of Cd for all the plants grown in control and treated soil were much lower (varied from 0.28 to 0.61) than those of Cr (0.7–1.17), Ni (0.89–1.35), and Pb (0.85–1.30).
- Another indicator of the plants' reasonable amount of phytoremediation capacity is the phytoextraction coefficient (PHY); in this study, maximum treatments show a moderate value of phytoextraction coefficient, which indicates the average to good phytoremediation capacity of marigold plants.
- The marigold plant also serves the economic purpose of the local community. In this study the maximum flowers production was observed in leachate treatment of 12.5% diluted raw leachate which yield >50 flowers per treatment pot. Thus being a sustainable and cost effective option of treating the contaminated waste sites, the Marigold plant can also serves as a source of economical livelihood.



(a)

(b)

(c)

(d)

Fig. 1 (a) Variation in colour removal efficiency of the coagulants at different (b) intensity of colour observed in leachate treated with $FeCl_3$ at various pH. (c) Intensity of colour observed in leachate treated with $FeSO_4$ at various pH. (d) Intensity of colour observed in leachate treated with alum at various pH

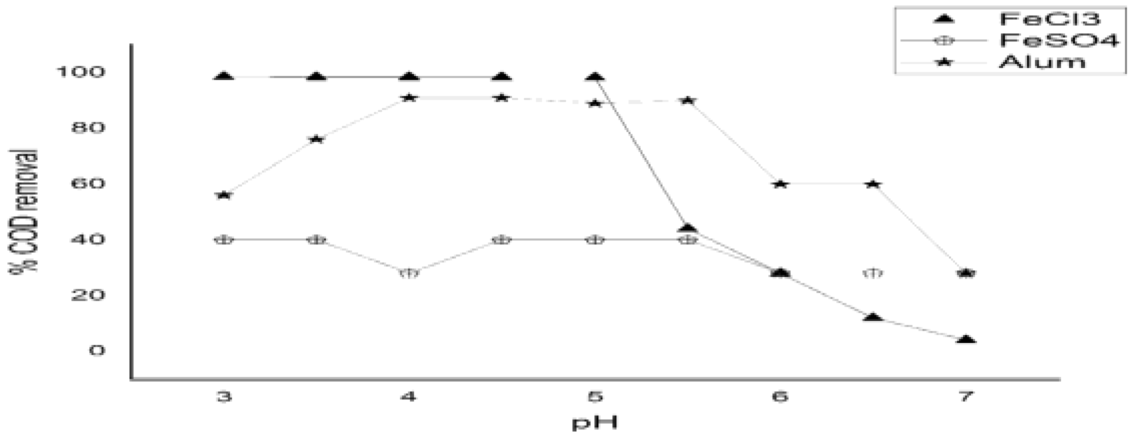


Fig.2 Percentage decrease in COD in leachate when treated with coagulants: $FeCL_3$, $FeSO_4$ and alum at different pH

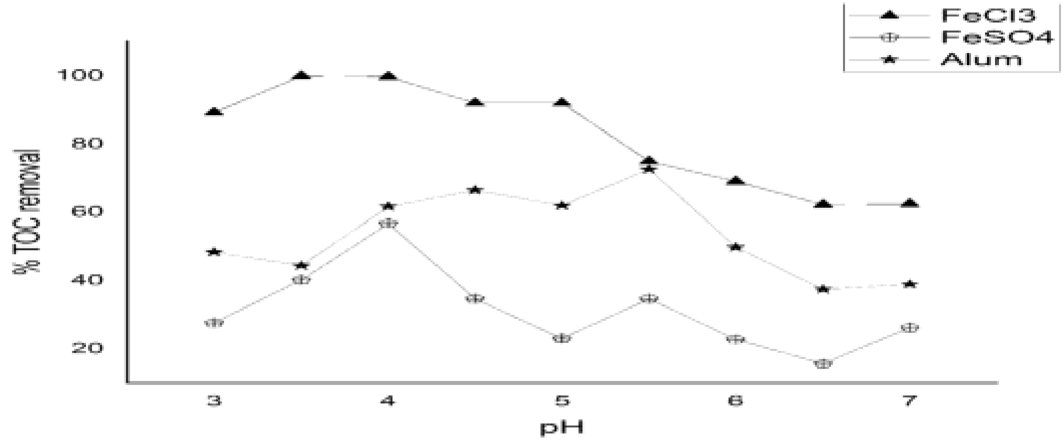


Fig. 3 Percentage decrease in TOC in leachate when treated with coagulants: $FeCL_3$, $FeSO_4$ and alum at different pH

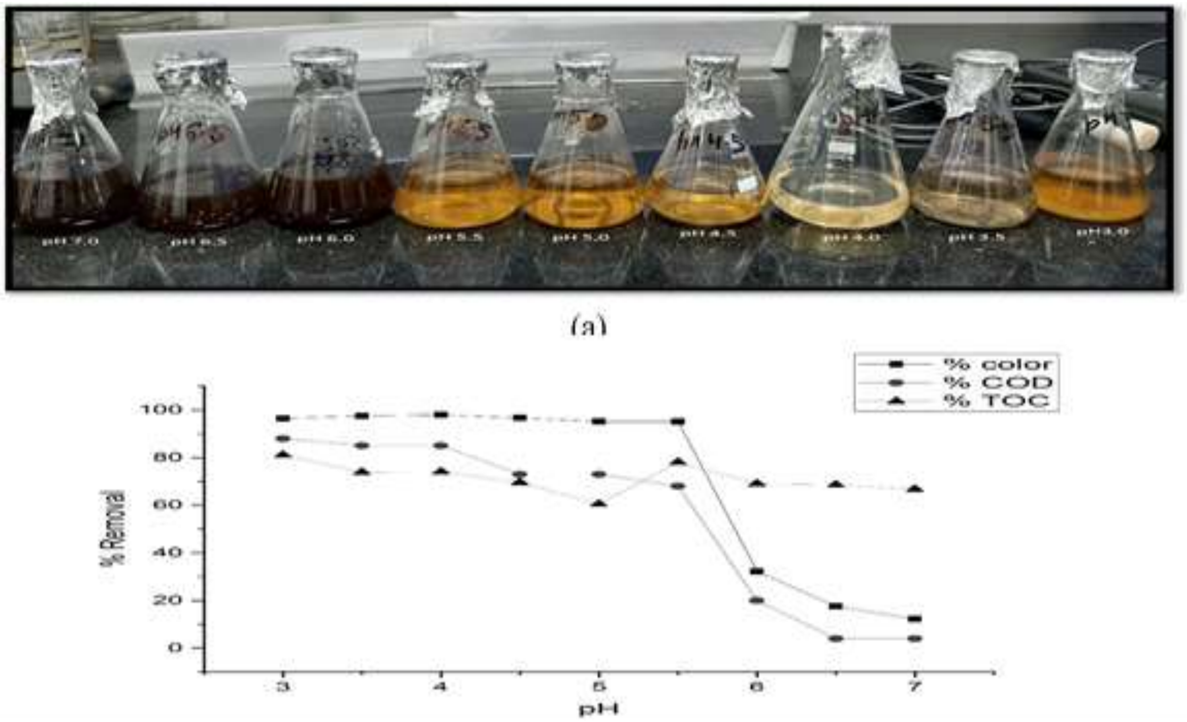


Fig. 4 a Variation in colour intensity of leachate treated with Fenton at various pH. b percentage decrease in colour, COD and TOC in leachate when treated with Fenton reagent at different pH

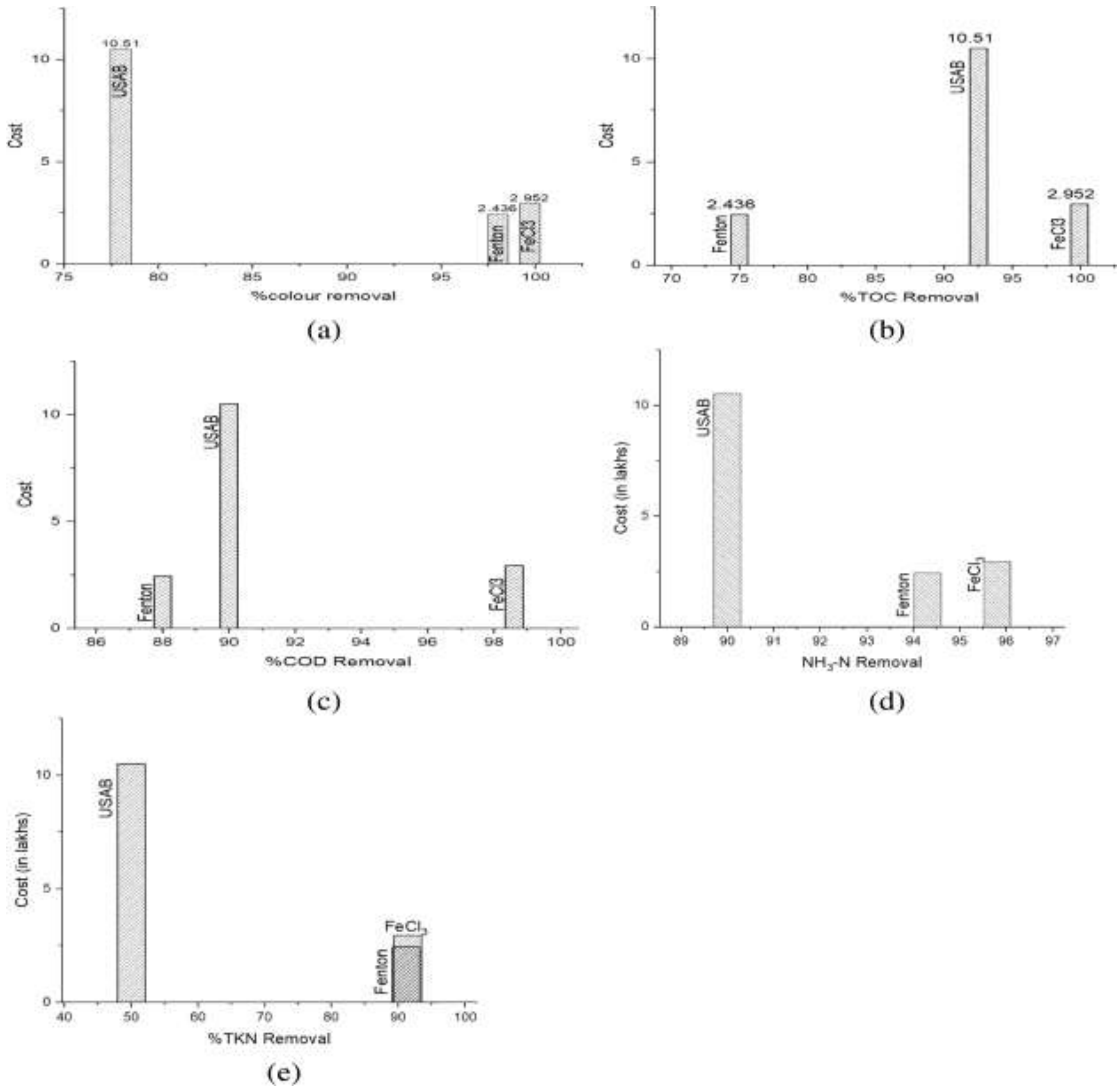


Fig. 5 Comparative bar charts for evaluating cost v/s efficiency of removal a colour, b TOC, c COD, d NH3–N and e TKN for the treatment methods: FeCl3, Fenton and UASB

12. **End Users / Beneficiaries of the Study:** Policy makers and planners of State Government Organizations, Delhi municipal corporation and CGWB and state groundwater board.

13. **Deliverables:** Technical report and research papers, First-hand information on water quality in and around Gazipur Landfill site, groundwater model simulating plume movement and fate and origin of pollutants will be described.

14. **Major items of equipment procured:** Procurement procedure for FTIR imaging system on e-GEM initiated, MODFLOW purchased and TLC meter is yet be delivered.

15. **Lab facilities used during the study:** Water Quality Laboratory (NIH) / Isotope Lab (NIH)

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

17. **Study Benefits / Impacts:**

The study will identify the chemical and isotopic characteristics of leachate originating from the landfill site and help explaining its role in groundwater pollution. A new dimension will be added to leachate transport through groundwater. Findings of the proposed PDS will be published in the form of leaflets/reports/research papers. It will also provide new data sets on leachate and groundwater quality, and thematic maps of contaminant plumes, vulnerable areas and hot spots of groundwater contamination in the study area.

Fig 6: Phytoremediation study (Marigold plant) with application of different dosage of landfill leachate.

21. **Involvement of end users/beneficiaries:** CGWB

22. **Specific linkage with Institution and /or end users / beneficiaries**: East Delhi Municipal corporation, CGWB.

23. **Shortcoming/Difficulties:** NONE

24. **Future Plan:**

- Field Visits will be planned and sample collection will be undertaken.
- TCLP test will be performed
- Soil column experiment

Study – 3 (Sponsored Project)

1. **Title of the Study:** Water Efficient Irrigation by using SCADA system formedium Irrigation Project (MIP) Shahnehar

2. **Study Group:**

Project Investigator/Co-Project Investigator
Dr. R.P. Pandey, Scientist G. Er. Jagdish Prasda Patra, Scientist D Dr. Rajesh Singh, Scientist D, Sh. N. K. Bhatnagar, Scientist B
Collaborating Agency
Department of Irrigation & Public Health Engg. (I&PHE), Hydrology C&M Division, Tutikandi, Shimla-4. Himachal Pradesh

Type of study: PDS
Total Project Cost: Rs.75.0 lakh (**Funded by NHP)**
NIH Cost Allocation Rs. 18.1 lakh

Project Duration: **3-years**

Date of start: **December, 2017**

Scheduled Date of Completion: **March, 2022 (after extension)**

OBJECTIVES OF THE STUDY:

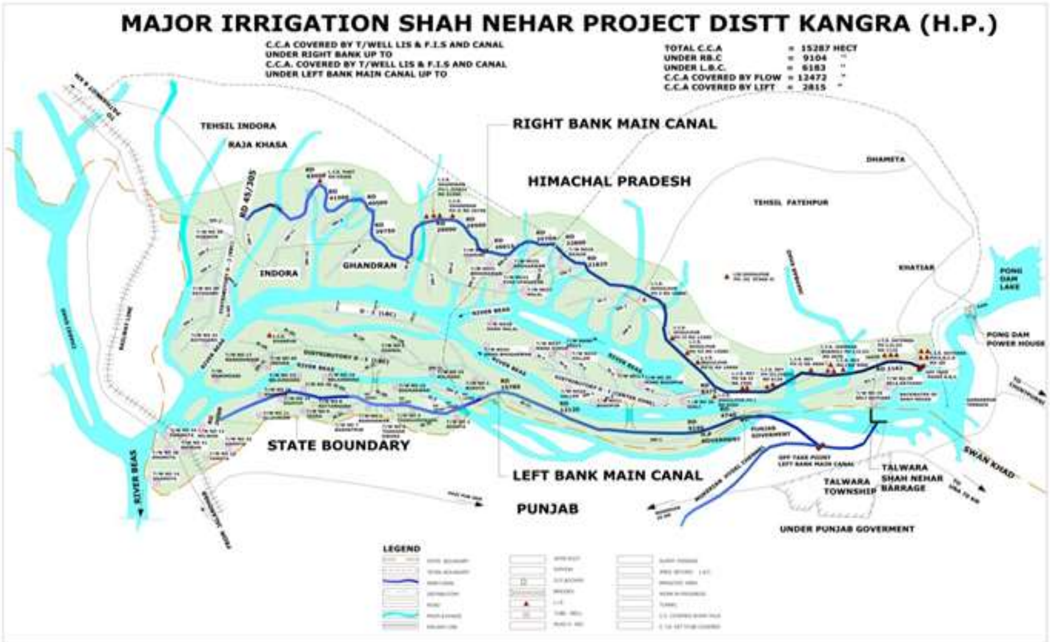
The primary objectives of this study is to **Devise a suitable approach to improve irrigation water use efficiencyin Shah Nehar Project.** The specific objectives of the study are as follows:

- 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 : Shah Nehar Command Area, Himachal Pradesh
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.

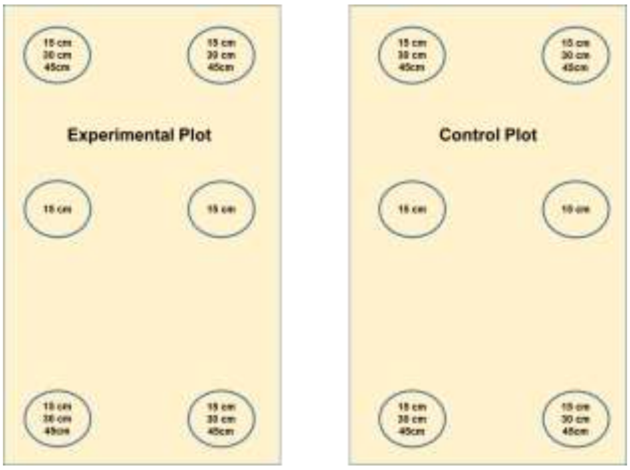
From the data collection and analysis of the data, Water efficient Irrigation by using SCADA System will be provided so that water can be used more efficiently and hence it will increase the effectiveness of the Irrigation Project.

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 meteorological 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. Base maps for the study sites have been prepared.
5. The experimental sited identified are as follows:
6. Lift Irrigation Scheme (LIS) Sthana, Terrac Sub-Division—for SCADA experimentation.
7. Selected sites/field plots in distributary-1 (D-1) command area –Badukhar Sub-Division -- for experimentation-1 in middle reaches.
8. Selected sites/field plots in distributary-2 (D-2) command area- for experimentation-2 in tail reaches.

9. Field investigations have been carried out and the layout of the experimental plots for installation of moisture sensors for measurement of crop root-zone moisture at the three sites have been prepared as follows.



S.N. (1)	Instrument/ Sensor (2)	At one Site (3)	For Three Site (4)=(3)*3
1	Moisture and temperature sensor • at 15, 30, 45 cm depth • at 15 cm depth	 8 4	 24 12
2	Flow meter (Discharge measurement)	3	9
3	Data logger/transmitter	1*	3*

Department of I & PHE, Shimla, Govt. of Himachal has processed for procurement of discharge & Moisture measurement sensor and installation in the field. The procurement is under process at present.

10. Installation of sensors and telemetry system for soil moisture monitoring and data transmission. (Work in progress).
11. Estimation of Irrigation requirement for different crops in the Shahnehar Command areas using meteorological data has been carried out and it will be presented in the working group meeting for comments/suggestion, if any. The summary of the estimated crop water requirement is as follows.

    Crop Water Requirement (CWR), Potential Evapotranspiration (ETo) and Irrigation scheduling in the subtropical humid region are crucial in efficient use of irrigation supply, water resources assessment, hydrology and designing the irrigation projects as the supply of water through rainfall varies in space and time. In this context, dependable monthly rainfall at 80% and 50% probability level during the period 1982-2018 has been to assess distribution of effective rainfall and the minimum expected rainfall during the crop growing period in Shahnahar command area. FAO (Food and Agriculture Organisation) CROPWAT 8.0 crop simulation model has been used to estimate reference evapotranspiration (ETo), effective rainfall, crop water and irrigation requirement and irrigation scheduling for the Rice and Wheat crop. It is found that the average annual ETo is 4.11 mm/day and varies with highest value of 6.67 mm/day in the month of June and lowest value in January (1.99 mm/day). From the observation of probability analysis at P80 and P50, it is also found that the maximum deficit can be in the order of 33.02 mm in month of July and minimum deficit of 1.32 mm rainfall in the month of November. For seasonal agricultural planning, the 80% dependable rainfall level may be considered for safer and better irrigation management planning in the study area.

Further Proposed Work Plan for next year

1. Application of field irrigation under measured and controlled conditions. (replication at three sites).
2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.
3. To evolve irrigation scheduling (revision) considering the crops, soil moisture and prevailing climatic conditions.
4. Demonstrations and conducting workshops on OFWM practices for all the stakeholders including farmers.
5. To review the role of existing Water Use Associations (WUA) and suggest suitable
6. To extend the improved/scientific modifications for encouraging the better OFWM practices and equitable water distribution among the farmers.
7. Review of the existing Cropping patterns during different sowing seasons and suggest suitable crops for each season to enable optimum utilization of available water.

Deliverables:

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.

Study – 4 (Sponsored Project)

1. **Title of the Project:** Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India

2. **Project Team**

Lead Investigator	Dr. S. P. Rai, Assoc. Professor, Geology Dept., BHU Varanasi
Collaborator 1	Dr. Rajesh Singh, Sc. D, EHD, NIH Roorkee
Collaborator 2	Dr. Noble Jacon, Sc. G, Hydrology Section, BARC Mumbai
Collaborator 3	Dr. Laszlo Palcsu, Sr. Researcher, ICER, Hungarian Academy of Sciences, Hungary

3. **Type of Study: In collaboration with BHU** **Budget:** Rs. 10 lacs

4. **Nature of Study:** Applied Research

5. **Date of start:** July 2021

6. **Scheduled date of completion:** June 2024

7. **Duration of the Study:** 3 Years

8. **Objectives**
   i) Identification of recharge sources and zones of aquifer system
   ii) Transit time and flow velocity of groundwater
   iii) Interaction with aquifer and surface water bodies
   iv) Rock water interaction affecting the water quality and assessment of impact of anthropogenic activities on groundwater.

9. **Statement of the Problem**
   Understanding the properties of available water resources is a key factor for sustainable water management. These properties include recharge conditions of the infiltration area, safe yield of groundwater, transit times, direction and velocity of an accidental pollution, hydraulic connection between aquifers, water – rock interactions affecting the water quality etc. These processes cannot be understood without the integrated approach of isotope and water chemistry. The investigation will help to better manage the groundwater resources of the study area and it will be a model study for the country too. Exploitation of depleting water resources results in deterioration of water quality. Groundwater contamination has also emerged as a serious issue that has posed serious threat to the people living in the Ganga River Basin. Groundwater, which is extensively used for drinking, cooking and/or irrigation, is contaminated with arsenic in many part of the Ganga Basin and is having severe detrimental effects on human health. Presently, the main problem of depletion of groundwater in Ganga Basin is due to the unsustainable abstraction of groundwater (Rodell et al., 2009; Tiwari et al., 2009). As the groundwater level is declining, people are drilling to deeper aquifers, to meet the groundwater demand. In the arsenic affected areas, deeper aquifer has been tapped for the extraction of groundwater to meet the drinking and other demands. The groundwater extracted from deeper horizons is becoming the most important fresh water resource in Ganga River Basin. However, little is known about the deeper aquifers which are in semi-confined and to confined condition.

Keeping in view of same, the study aims at identification of recharge sources and zones of aquifer system, understanding the surface and groundwater interactions, and the rock water interaction and anthropogenic activities affecting the groundwater quality.

10. Approved Action Plan/ Methodology:

i) Thorough review of aquifer system and water quality status of the study area.
ii) Collection and characterization of the water samples from the study area for physico-chemical, bacteriological, and isotopic parameters.
iii) Geochemical, isotopic, and statistical modeling to understand the rock-water interaction, recharge zones, surface water interactions, and anthropogenic influence.

11. Timeline (Approved):

Sr. No.	Major Activities	2021-22			2022-23				2023-24				2024-25
		Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q1
1.	Field Investigation and sampling plan												
2.	sample collection and analysis												
3.	Geochemical, isotopic, and statistical modeling												
7.	Publications												
8.	Interim Report												
9.	Final Report												

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Samples were collected from the selected locations. • Analysis for organoleptic, major ions, and coliforms in the collected samples is in progress.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	No specific suggestion	--

14. Analysis & Results:

Field Investigation and sampling plan

- Sampling locations were selected on grid basis uniformly distributed over the study area.

Sampling & Analysis

- The handpumps/tubewells of the identified location were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017).

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

16. **Deliverables:** Technical report and research papers, GW recharge sources and aquifer zonation, SW-GW interaction, and rock-water and anthropogenic influence on water quality.

17. **Major items of equipment procured:** None

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

19. **Data procured or generated during the study:** Water quality data of the study area and anthropogenic influence on the water quality.

20. **Study Benefits / Impacts:**
The outcome of the project would help the managers for the sustainable development and management of this scarce resource and plan for augmentation measures to ensure continuous supply of water to meet the demands of the people in the region.

21. **Involvement of end users/beneficiaries:** None

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

23. **Shortcoming/Difficulties:** None.

24. **Future Plan:**
    - Collection and analysis of water samples.
    - Geochemical and statistical modelling.

Study - 5 (Internal Study)

1. **Title of the Study:** Water quality assessment of Haridwar District
2. **Study Group:**

Project Investigator	Er. Rajesh K. Nema, Sc. B, EHD
Project Co-investigator	Dr. Rajesh Singh, Sc. C, EHD Dr. J. V. Tyagi, Director Dr. R. P. Pandey, Sc. G & Head, EHD Dr. Pradeep Kumar, Sc. D, EHD
Scientific Staff	Mrs. Anju Chaudhary, PRA Mr. Rakesh Goyal, Tech. Gr. 1

3. **Type of Study:** Internal Study, **Budget: Rs 17.1 lacs**
4. **Nature of Study:** Applied Research
5. **Date of start:** June 2019
6. **Scheduled date of completion:** May 2022
7. **Duration of the Study:** 3 Years
8. **Study Objectives:**

   i) Spatial variability determination of groundwater quality.

   ii) Statistical analysis and water quality indexing for different designated uses namely drinking and irrigation.

9. **Statement of the Problem:**

Water of sound quality is the key for vital socio-economic functions on Earth. Most users of water depend on adequate levels of water quality. When these levels are not met, these water users must either pay an additional cost for water treatment or incur at least increased risks of damage or loss. As populations and economies grow, more pollutants are generated and degradation of water resources has become one of the most pressing global concerns currently facing mankind. Increasingly, the major efforts and costs involved in water management are devoted to water quality protection and management. Conflicts among various users of water are increasingly over issues involving water quality as well as water quantity. Evidently, there is a need for effective management efforts, where one possible action is to focus on minimizing pollutant load from pollutant-producing areas to water resource areas.

After creation of Uttarakhand state in 2002, several industrial parks were developed in Haridwar district. In addition, the cities in Haridwar district also expanded. The industrial and urban development results in contamination of water resources. Groundwater is the main source of drinking in the district and hence, requires analysis of water quality parameters. Keeping in view of the same, this study aims at analyzing the water samples for organoleptic parameters, major ions, trace metals, and pesticides to understand the suitability of water for different usage and to understand the weathering processes controlling the water quality.

10. **Approved Action Plan/Methodology:**

   a) Collection of groundwater samples during pre and post monsoon from selected locations of Haridwar district.
   b) Analysis of water samples for organoleptic parameters, major ions, trace metals, and pesticides.
   c) Processing the data to understand the contamination of water and suitability of various designated use.

11. Timeline (Revised):

Sr. No.	Major Activities	2019-20			2020-21				2021-22	
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1.	Field Investigation and sampling plan									
2.	Sample Collection and Analysis									
3.	Data Processing and Interpretation									
4.	Interim Report									
5.	Final Report									

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Pre- and post-monsoon samples were collected from 68 locations. • Analysis for organoleptic, major ions, trace metals, pesticides, and coliforms in the collected samples completed.
3.	Data Processing and Interpretation	• The statistical analysis and indexing for various designated usage completed.
4.	Interim Report	• 1st interim report prepared and submitted.
5.	Final Report	• Final report has been submitted.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) appreciated the study and its outcomes. He suggested that the study has very significant contributions in determining the deterioration in water quality at different areas in the Haridwar district and he suggested for further investigation to find out the causes of deterioration in next study. He also suggested that the outcomes of the study should be presented before the district administration for suitable dissemination of results of this study for the benefit of the mass.	A 1-day workshop will be conducted with the district administration in June 2022
2.	Dr. Sudhindhra Mohan Sharma (Former National Nodal Officer, MoDWS) suggested to incorporate layer of drainage map with the maps of water quality parameters. He also suggested publicizing the outcomes of the study.	The suggestions were incorporated in the report.

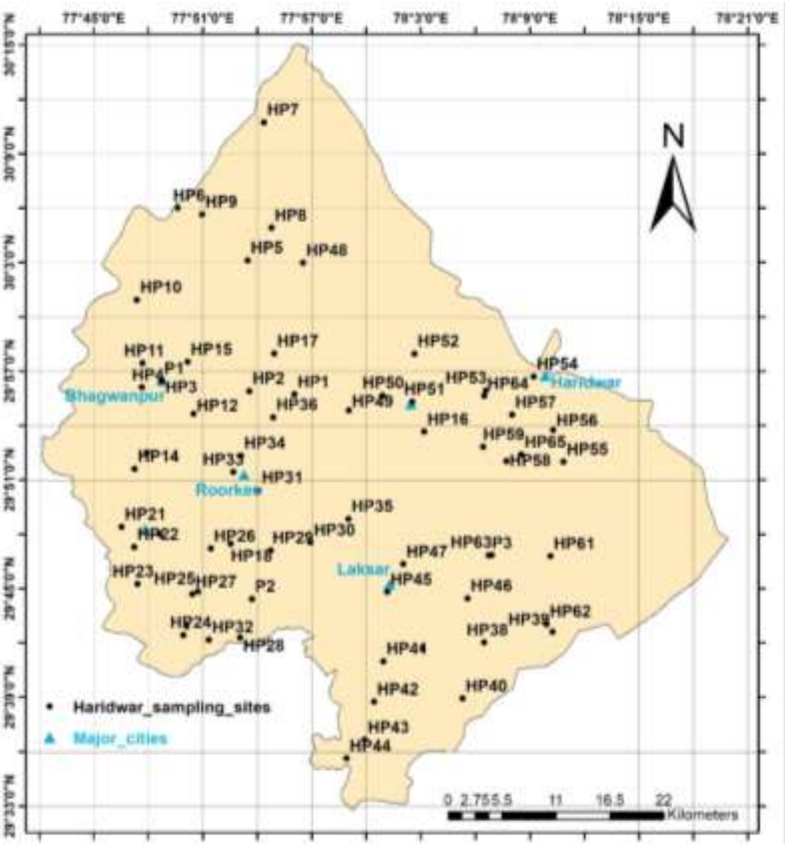
14. Analysis & Results:

Field Investigation and sampling plan

- The district was divided into grid of 5x5 km, and one village in each grid, totaling to 68 locations, was selected for sampling of organoleptic parameters, major ions, and bacteriological parameters.
- 19 samples for pesticide analysis were collected by dividing the district into 10x10 km grid.

Sampling & Analysis

- Groundwater and pond samples from the identified villages were collected after discussion with the villagers based on the usage. The handpumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of groundwater aquifer. The water samples were collected in appropriate sampling bottles using grab sampling method and preserved as per standard methods (APHA, 2017).
- The organoleptic parameters, major ions, trace metals, pesticides, and bacteriological analysis of samples completed for both pre- and post-monsoon samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA 2017).
- The WQI for drinking and irrigation was computed following weighted arithmetic method.



Sampling Sites for Haridwar District

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

16. **Deliverables:** Technical report and research papers, First-hand information on water quality of the Haridwar District

17. **Major items of equipment procured:** None

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH) / 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. The project will also evaluate the health hazard impact, which will be beneficial for the state government agency for providing safe drinking water.

21. **Involvement of end users/beneficiaries:** None

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

23. **Shortcoming/Difficulties:** None

24. **Future Plan:**

    - Organization of 1-day workshop

Study - 6 (Internal Study)

1. **Title of the Study:** Simulation of Non-Point Source Pollution Processes in Song River
2. **Study Group:**

Project Investigator	Dr. Pradeep Kumar, Sc. 'D', EHD
Project Co-investigator	Dr. J. V. Tyagi, Sc. 'G' & Director, NIH Dr. M. K. Sharma, Sc. 'E', EHD Dr. Rajesh Singh, Sc. 'D', EHD Er. R. K. Nema, Sc. 'B', EHD
Scientific Staff	Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. **Type of Study:** Internal Study**, Budget:** Rs. 43.02 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** Nov 2019
6. **Scheduled date of completion:** Oct 2023
7. **Duration of the Study:** 4 Years
8. **Study Objectives**

(i) Assessment of the point and non-point pollutant loads
(ii) Mapping of various non-point pollution sources
(iii) Simulation of various hydrological processes in the river catchment
(iv) Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment

9. **Statement of the Problem:**

Increasing population and subsequently increasing water, food and energy demands have put tremendous pressure on the water resources. The problem is more substantiated by the increasing consumption of the products with high water footprints. The food and energy demands of rapidly increasing population have caused intense agriculture, industrialization and urbanization. This has resulted in indiscriminate discharge of municipal and industrial wastes. Municipal wastes being biodegradable produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effects produced by them may be more serious as nature is often unable to assimilate them. Agriculture is also responsible for degrading the water quality through leaching and runoff from agricultural fields and animal husbandry units, which contain predominantly organic compounds from the use of mineral fertilizers and chemical pesticides. These pollutants ultimately contaminate aquifer system due to surface and groundwater interactions.

The planning of water as a national resource is not merely a question of ensuring the availability of water in the right quantity at the right time for diverse purposes, but also ensuring the right quality for the intended use. Further, for any proper water resources planning, whether long or short term, before going into alternative plans for development, it is very essential to assess water quality problems together with hydrological analysis.

Since, point source pollution meets the river at known locations, it may be addressed by STPs or ETPs. Non-point source pollution reaches the river through the landscape after following a number of hydrologic, physical, chemical and biological processes. Hence, it is very complex to assess the causes and plan for its remediation. Very few assessments of non-point source pollution have been made in Indian rivers and they are mostly limited upto quantification of pollutant loads through the flux balance approach. Therefore, this study is being envisaged to simulate the non-point pollution process in a lower Himalayan catchment to identify the sources and causes of non-point source pollution.

10. Approved Action Plan/Methodology:

a. Procurement of secondary data required for the analysis from various govt. agencies (discharge, sediment, other water quality parameters, soil map etc.)
b. Collection of water samples at monthly frequency during non-monsoon and daily frequency during monsoon season from selected locations of Song river
c. Collection of data on usage of fertilizers and pesticides in the Song river catchment.
d. Analysis of water samples for general water quality parameters, total suspended solids, nutrients and pesticides
e. Hydrological and water quality modelling using SWAT model

11. Timeline:

S. No.	Major Activities	2019-20		2020-21				2021-22				2022-23				2023-24		
		3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr
1	Literature survey																	
2	Reconnaissance visit and sampling plan																	
3	Secondary data collection																	
4	Field surveys																	
5	Sample Collection and Analysis																	
6	SWAT Model: Preparation of database																	
7	SWAT Model: Calibration, Validation & Simulation																	
8	Interim Report																	
9	Final Report																	

12. Objectives and achievement during last twelve months:

S. No.	Objectives	Achievements
(i)	Assessment of the point and non-point pollutant loads	Four sites have been chosen for the assessment of point and non-point source pollutant loads. Plan for field sampling and other field investigations has been prepared starting from Apr2021, due to restrictions in the current Covid-19 situation.
(ii)	Mapping of various non-point pollution sources	After the assessment of pollutant loads, the mapping will be carried out.
(iii)	Simulation of various hydrological processes in the river catchment	The preliminary SWAT model set-up has been completed using the secondary data sources (freely available web sources). Discharge data from CWC and soil maps from NBSS&LUP have been obtained and the same have been used for the analysis.
(iv)	Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment	The model set-up for simulation of non-point source pollution processes will be carried out only after the primary data for at least one year is collected.

13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	No comments	--

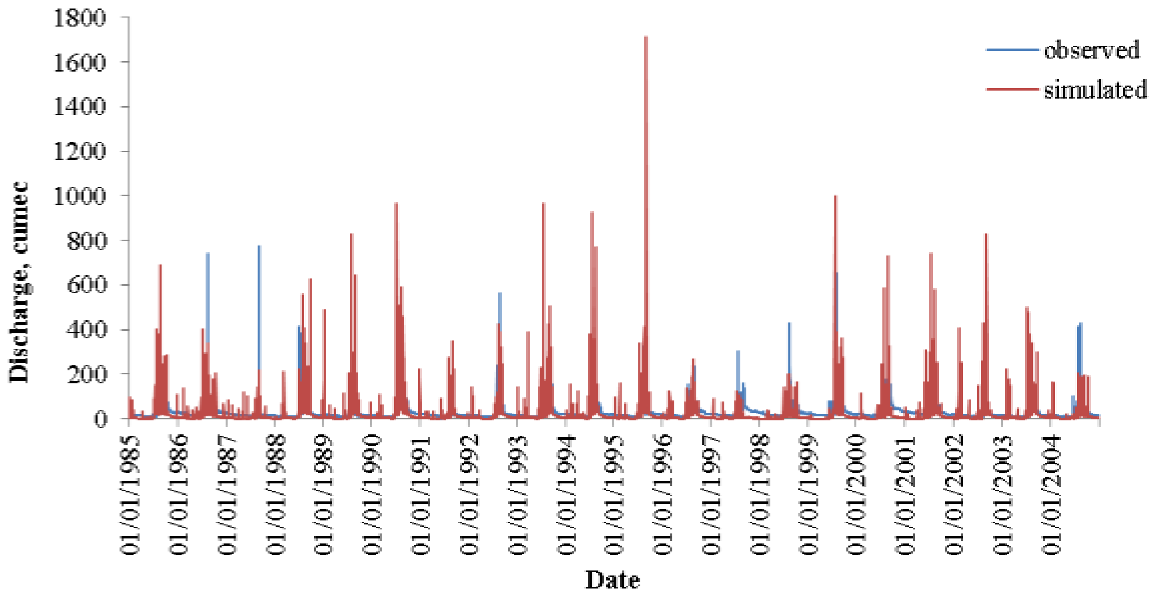
14. Analysis & Results:

Field Investigation and sampling plan

Four sites in the Song catchment have been selected for simulating non-point source pollution processes through the SWAT model. The first site selected is the CWC G&D site at Satyanarayana. Suswa is a major tributary of Song river and it meets Song river few kilometers upstream of Satyanarayana G&D site. So, the second site has been selected on Suswariver just before the confluence. Two other sites on the Song river have been selected upstream and downstream of Dehradun city boundaries. These sites have been selected to isolate the point and non-point sources of pollution. Although sampling was planned to be started in April 2021, but, due to Corona pandemic, the same will be started from April 2022.

SWAT Model setup

Most of the secondary data required for calibration of SWAT model i.e. discharge, meteorological data, soil map, LULC map etc. have been obtained. The same for the period of field investigations and monitoring will be obtained after the monitoring is over. SWAT model has been set up using the discharge data of Satyanarayana site and freely available web data sources. SWAT-cup is being run for improving the calibration results.



15. **End Users / Beneficiaries of the Study:** Deptt. of Irrigation & Deptt. of Agriculture, Uttarakhand

16. **Deliverables:** Technical report and research papers

17. **Major items of equipment procured:** None

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH) / 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 various sources of point and non-point pollution and will suggest various scenarios for mitigating these impacts. The research outcomes from the study will be as follows:

a. Point and Non-Point pollutant loads at various locations in Song river
b. Quantum of non-point source pollution for various scenarios of fertilizers/ pesticides applications
c. Technical report and papers

21. **Involvement of end users/beneficiaries:** None

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

23. **Shortcoming/Difficulties:** The facility for analysis of pesticides is presently not available in the institute so the samples will be analysed at IITR facility.

24. **Future Plan:**

i) Collection and analysis of samples (monthly sampling during non-monsoon and daily sampling during monsoon) from four selected sites in the Song catchment.
ii) Secondary data procurement through various agencies required for SWAT model set-up.
iii) SWAT Model calibration and validation both for flows and for water quality.

Study - 7 (Internal Study)

1. **Title of the Study:** Development of rejuvenation plan for Hindon river system

   The study has been transferred to HI Division and merged with DST-NWO Project on River Hindon

Study - 8 (Internal Study)

1. **Title of the Project:** Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar

2. Project Team

Project Investigator	Dr. Rajesh Singh, Sc. D, EHD
Project Co-investigator	Dr. J. V. Tyagi, Director Dr. R. P. Pandey, Sc. G & Head, EHD Er. Rajesh K. Nema, Sc. B, EHD Dr. Pradeep Kumar, Sc. D, EHD Dr. M. K. Sharma, Sc. E, EHD
Scientific Staff	Mr. Rakesh Goyal, Tech. Gr. 1

3. Type of Study: Internal Study, **Budget:** Rs. 23.71 lacs

4. Nature of Study: Applied Research

5. Date of start: July 2020

6. Scheduled date of completion: June 2022

7. Duration of the Study: 2 Years

8. Objectives

i) Improvement in river water quality due to covid-19 lockdown and deterioration due to anthropogenic activities over time and space,
ii) Self-purifying capability of river Ganga and factors responsible for it,
iii) Variability in drug resistance bacteria, and
iv) Water quality indexing.

9. Statement of the Problem

The lockdown due to Covid-19 epidemic lockdown has provided an opportunity for the rivers to revive upto certain extent due to the restriction on anthropogenic activities. The deterioration of Ganga river water quality starts as it enters Rishikesh. Most of the pollution is from the tourist/pilgrimage activities associated with Rishikesh and Haridwar. On an average, approximately 1 million tourists visit Haridwar monthly, however, the population of the city is only 0.28 million. This clearly indicates the multifold increase in pollution load due to tourism. The lockdown period will provide a baseline data for the river water quality. Apart from organic load, the influx of pharmaceutical active hydrocarbons also increases with increase in tourist load. Further, Maha Kumbh, the largest religious gathering, is scheduled for Haridwar during March 11-April 27, 2021, in which around 50 million people are expected to take dip in the river during this period. Therefore, there is a need to monitor the fluctuation in the river water quality and the extent of deterioration due to the onset of anthropogenic activities. It would be interesting to examine the self-purifying capacity of river.

There are few studies which has explored the non-putrefying nature of river Ganga. The first study goes back to 1896 by Ernst Hankin who demonstrated the antibacterial property of river Ganga water against Vibrio Cholera. Later on, in 1917, D'Herelles concluded that the antibacterial property is due to "bacteriophage". However, recent research from BHU and IIT

Delhi indicates high concentration of drug resistance bacteria in Ganga water which is a concern and requires close monitoring and would be interesting to see the variation in the population of these bacteria over time.

Keeping in view of same, the study aims at analyzing the river Ganga water sample for different physico-chemical and bacteriological parameters in a stretch from Rishikesh to Haridwar, on monthly basis or the dates which are of religious importance, to understand the impact of anthropogenic activities on the river water quality and its non-putrefaction ability. The variation in bacterial species with multidrug resistance is also studied to understand the source of drug resistance and their behavior.

10. Approved Action Plan/ Methodology:

i) Collection of Ganga river water samples from selected locations on monthly basis and on ritualistic mass bathing events.
ii) Analysis of water samples for organoleptic parameters, major ions, trace metals, and microbes.
iii) Processing the data to understand the contamination of water and suitability of various designated use and self-putrefaction properties of river Ganga.

11. Timeline (Approved):

Sr. No.	Major Activities	2020-21			2021-22			
		Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Field Investigation and sampling plan							
2.	Sample Collection and Analysis							
3.	Data Processing and Interpretation							
4.	Interim Report							
5.	Final Report							

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Monthly samples were collected from the selected locations. • Samples were also collected on the ritualistic mass bathing events. • Analysis for organoleptic, major ions, and coliforms in the collected samples completed. • Analysis of trace metals in part of samples completed. • Bacterial isolates were identified and tested for antibiotic resistance.
3.	Data Processing and Interpretation	• Data processing and interpretation is under progress.
4.	Interim Report	• 1st interim report prepared and submitted
5.	Final Report	• Final report is under preparation

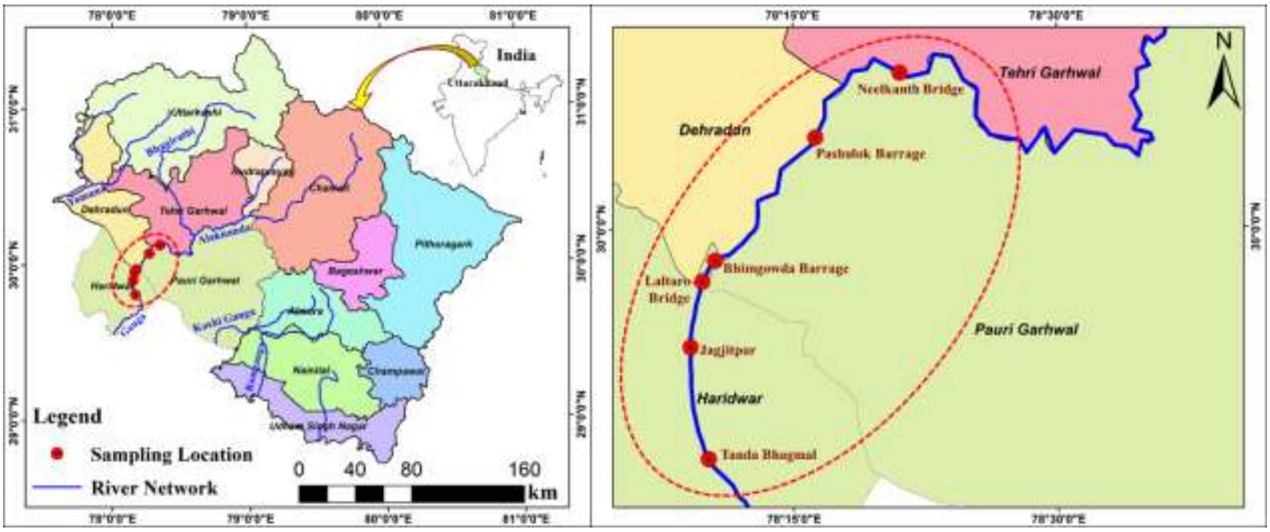
13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	There was no specific comments comments.	-

14. Analysis & Results:

Field Investigation and sampling plan

- Sampling locations were selected considering the centers contributing to the anthropogenic inputs as shown below.
- The sampling locations were also selected at Jagjitpur from the braided channels of the river.



Sampling Sites for River Ganga

Sampling & Analysis

- The samples were collected from the river on every month and on ritualistic mass bathing events. The water samples were collected in appropriate sampling bottles using grab sampling method and preserved as per standard methods (APHA, 2017).
- The organoleptic parameters, major ion, and bacteriological analysis completed for all the samples. Trace metals analyzed for 3 month samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).
- The bacterial isolates were identified through different biochemical tests in the water samples, and were subjected to eighteen antibiotics of different classes to check the susceptibility (Sept. 2020 & Feb. 2021).

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

16. Deliverables: Technical report and research papers, Impact of anthropogenic (religious) activities on the water quality of river Ganga, Processes/reasons responsible for non-putrefying nature of river, First-hand information on multidrug resistance bacteria in the study reach.

17. Major items of equipment procured: None

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

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

20. Study Benefits / Impacts:
The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the information on the water quality of the river reach (Rishikesh to Laksar). The project will also evaluate the variation in the microbial population, which will be beneficial for the government agencies to prepare the mitigate plan.

21. Involvement of end users/beneficiaries: None

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

23. Shortcoming/Difficulties: Continuous availability of a project staff of microbiology background.

24. Future Plan:

- Collection and analysis of samples.
- Data processing & interpretation of results.
- Final report and manuscript writing.

Study - 09 (Internal Study)

1. **Title of the Project :** Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures

2. **Project Team**

Project Investigator	Dr. Rajesh Singh, Sc. D, EHD
Project Co-investigator	Dr. R. P. Pandey, Sc. G & Head, EHD Dr. Sumant Kumar, Sc. D, GWHD Er. Rajesh K. Nema, Sc. B, EHD Dr. Pradeep Kumar, Sc. D, EHD Dr. M. K. Sharma, Sc. E, EHD
Scientific Staff	Er. Shekhar Saini, SRA

3. **Type of Study:** Internal Study, **Budget:** Rs. 30.1 lacs

4. **Nature of Study:** Applied & Basic Research

5. **Date of start:** July 2021

6. **Scheduled date of completion:** June 2024

7. **Duration of the Study:** 3 Years

8. **Objectives**

   i) To determine the mechanisms governing the As mobility, and quantify the rate and extent of these reactions in order to develop a reactive transport model to predict As mobility in groundwater, and

   ii) To design alternatives to mitigate As contamination of drinking water

9. **Statement of the Problem**

Groundwater is the most important source of domestic water in the Haridwar district and is generally free of health hazardous contaminants, however, with increasing population and intensive agricultural practices, the groundwater is getting polluted resulting in the abiotic and biotic weathering reactions of primary and authigenic minerals containing As and other trace metals. The release of previously sequestered arsenic from soils and sediments is well-recognized to result in geogenic contamination of drinking water and presents significant health risks to human and other living organisms. Our recent study on 'Water Quality Assessment of Haridwar District' indicated higher As concentration in the groundwater of Laksar and Manglaur tehsil at few locations in the range 10 to 30 µg/l. Although, the As concentration were below maximum permissible limit of 50 µg/l prescribed by BIS for drinking water, it exceeded the acceptable limit of 10 µg/l. Previously, As was reported in a location near Solani river which is a monsoonal river and in the non-monsoon the flow in the river is contributed through the untreated/partially treated domestic and industrial discharge. This clearly indicates the role of pollutants entering the aquifer and initiating the secondary reaction resulting on the release of As from the aquifer sediments and requires thorough investigation before it is too late. The identification of the factors responsible for the release of the As from the sediments will help in containing the As and reducing the associated health hazard risk to consumers.

Keeping in view of same, the study aims at analyzing the groundwater and sediment samples for their As content and other parameters. Efforts will be also made to identify the factors responsible for the release of As from the sediments through batch/column experiments.

10. Approved Action Plan/ Methodology:

i) Thorough review of abiotic and biotic geochemical mechanisms known to contribute to As mobility in aquifers and determine the groundwater constituents or parameters influencing As mobility.

ii) Collection and characterization of the groundwater samples from and in the vicinity of identified locations with higher As concentration.

iii) Characterization of the aquifer sediment and As mobility in the aquifer where As was observed in exceeding the prescribed drinking water limit.

iv) Batch and column experiments for identifying the factors responsible for As mobilization.

v) Develop a model to identify As mobility in groundwater.

vi) Design alternatives to mitigate As contamination of drinking water.

11. Timeline (Approved):

Sr. No.	Major Activities	2021-22			2022-23				2023-24				2024-25
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
1.	Field Investigation and sampling plan	■											
2.	GW sample collection and analysis		■	■	■	■	■	■	■	■			
3.	Aquifer sediments collection and characterization					■	■	■					
4.	Batch & column experiments								■	■	■	■	
5.	Model development for As mobility										■	■	
6.	Alternatives to mitigate As					■	■	■	■	■	■	■	
7.	Publications				■	■	■	■	■	■	■	■	■
8.	Interim Report							■					
9.	Final Report											■	■

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Samples were collected from the selected locations. • Analysis for organoleptic, major ions, and coliforms in the collected samples completed. • Analysis of trace metals is in progress.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) appreciated the proposed study and suggested that this is the right time to take up this study, for the benefit of society, before the problem exaggerates.	Suggestion noted and taken care of.

14. Analysis & Results:

Field Investigation and sampling plan

- Sampling locations were selected considering the identified location with high As concentration in the groundwater.

Sampling & Analysis

- The handpumps, which are being used extensively, of the identified villages were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017).
- The organoleptic parameters, major ion, and bacteriological analysis completed for all the samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017). Trace metal analysis is under progress.

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

16. Deliverables: Technical report and research papers, Factors impacting As mobilization, Model to identify As mobility, and alternatives for As mitigation.

17. Major items of equipment procured: Glove bag/anaerobic chamber will be procured for conducting experiments.

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

19. Data procured or generated during the study: Water quality data of the study area and As mobilization mechanism

20. Study Benefits / Impacts:

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the information on the factors impacting As mobilization in the groundwater. The alternatives for As mitigation will be also suggested which can be implemented by concerned departments of UK government.

21. Involvement of end users/beneficiaries: None

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

23. Shortcoming/Difficulties: None.

24. Future Plan:

- Collection and analysis of GW and aquifer sediment samples.
- Batch and column experiments.
- Procurement of glove bag/anaerobic chamber.

Study – 1 (Internal Study - New)

1. **Title of the Study: Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims of groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants**

2. **Study Group:**

Study Team		
NIH, Roorkee	**DRC, Kakinada**	**CGWB, Southern Region, Hyderabad**
Dr. M. K. Sharma, Sc. E (**PI)** Dr. Suhas Khobragade, Sc. 'G' Dr. Rajesh Singh, Sc. 'D'	Dr. Y. R. S. Rao, (PI) Sc. G & Head	Sri J. Siddhardha Kumar (PI) Sc. E & Head
Supporting Staff Mrs. Babita Sharma, SRA Mrs. Beena Prasad, RA Mr. P. R. S. Rao, PRA		

3. **Type of Study:** Internal
4. **Nature of Study:** Applied Research
5. **Date of Start:** April 2022
6. **Scheduled date of Completion:** March 2024
7. **Duration of the Study:** 2 years
8. **Study Objectives**

i) To study the groundwater level fluctuations in Krishna-Godavari Deltas
ii) Characterisation of groundwater using Hydro-chemical and Hydrogeochemical investigation
iii) Isotopic Characterisation of groundwater
iv) To study the status of Emerging Contaminants in the groundwater, their sources and its impacts on human health

9. **Statement of the Problem**

Krishna and Godavari rivers are major and large rivers in Peninsula India. Water availability is more in Godavari River. Krishna delta has the water scarcity problem due to unavailability of water in Krishna River. So Andhra Pradesh government took the decision to interlinking the rivers through Polavaram canal. Flood water from the Godavari River could be diverted to the paddy growing region of Rayalaseema, which often suffers from insufficient water. In order to link the two rivers a 174 km-long canal, known as the Polavaram Right Canal, was constructed and supplied with pumps that will remove excess water from the Godavari River and send it to the Krishna River. Paddy farmers in the Krishna Delta are the main beneficiary of the linking of the two rivers. Diverted water will also provide Amaravati, the planned state capital, with drinking water. The project is seen as a means to ensure the future water and food security of Andhra Pradesh.

Groundwater situation in different parts of India is diversified because of variation in geological, climatological and topographic set-up. Annual water level fluctuation of pre-monsoon has shown a fall in water levels for 59 % of the area, predominantly in Rayalaseema region. During post-monsoon about 90% area of the state experienced rise in annual water level fluctuation. Aquifer wise water level analysis shows that during pre-monsoon season shallowest water levels are observed in all the formations except in Intrusives. Deepest water levels are observed alluvium, Limestone and BGC. During post-monsoon season, shallowest water levels are observed in all formations except in Intrusives and Laterites. Deepest water levels are observed in Gneiss, Granite, Limestone, Quartz and Sandstone (CGWB GW Year Book 2019-20 AP).

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. Further, groundwater quality in a region is influenced by physical and chemical parameters that are strongly affected by natural processes such as water chemistry in the recharged area, water intermixing, groundwater recharge, aquifer discharge and recharge, water flow path.

The term emerging contaminants (ECs) is generally used to refer to compounds previously not considered or known to be significant in groundwater in terms of distribution and/or concentration, which are now being more widely detected and which have the potential to cause known or suspected adverse ecological or human health effects. ECs include perfluorinated compounds (PFCs), nanomaterials, pesticides, pharmaceuticals, industrial compounds, personal care products, fragrances, water treatment by-products, flame retardants and surfactants, UV-filters as well as caffeine and nicotine. Because of their rapidly increasing use in industry, transport, agriculture, and urbanization, these chemicals are entering the environment at increasing levels as hazardous wastes and non-biodegradable substances.

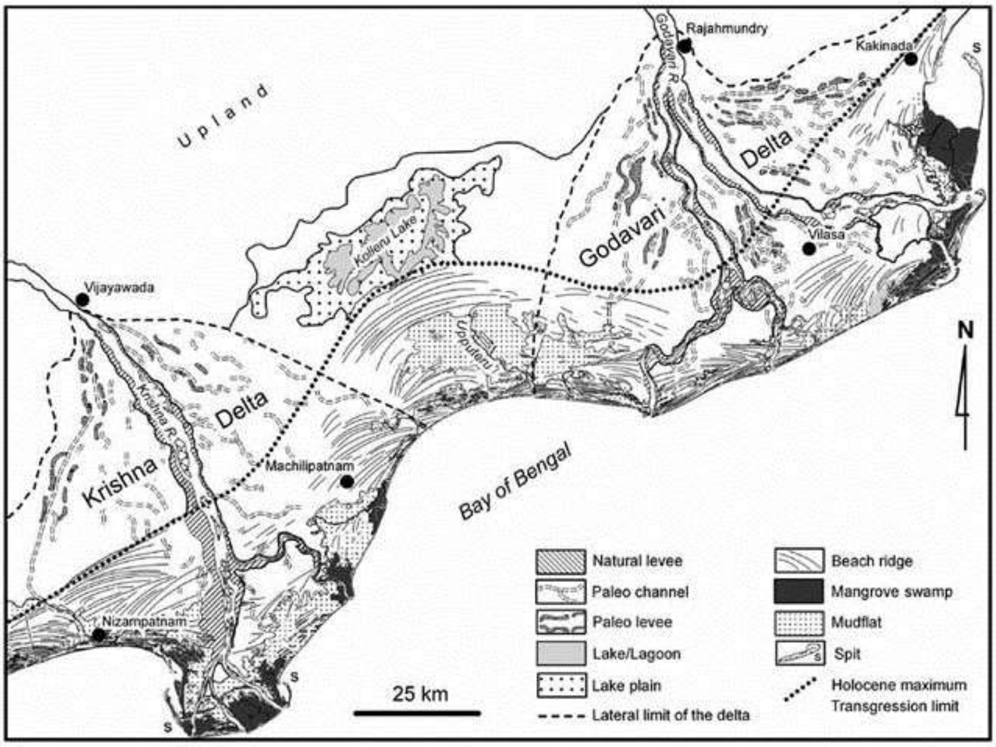


Fig. 1. Location map of Krishna Godavari deltaic region

The pathways through which these pollutants enter surface waters are well known and the main contributions are from effluents of wastewater treatment plants, where some residues are not removed, and from agricultural and industrial activities. Contacts and exchanges between the aquifers, rivers and sewage networks, and leaching from agricultural fields, can cause the contamination of shallow and deep groundwater. ECs may be a significant problem when surface and groundwater are used for drinking water production because the conventional drinking water treatments, like treatment with active carbon, flocculation, and disinfection, are not specifically designed to remove these micropollutants. Traces of ECs in drinking water are actually measured and reported in only a few studies and the spatial and temporal variability of the majority of ECs in the environment is still poorly understood.

In view of the above, characterization of groundwater dynamics in Krishna-Godavari Deltas interims has been proposed using geochemical, Isotopes and emerging contamination and their sources and its impacts on human health for sustainable drinking water supply.

10. Methodology

i) Collection of groundwater level data, lithological data, water quality data from published report, literature and from various govt. agencies.

ii) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.

iii) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.

iv) Analysis on flow and movement of groundwater.

v) Analysis for physico-chemical parameters [pH, EC, TDS, Eh, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (Cl, SO_4, NO_3, HCO_3), minor elements (Fluoride, PO_4, NH_4)] metal concentrations (As, Fe, Mn, Cd, Zn, Cu, Cr, Pb, Co, Ni, Ba, Sr, V, Sc), and emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected water samples.

vi) Analysis of Stable environmental isotopes of Hydrogen and Oxygen 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) 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.

ix) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.

x) Soil quality monitoring for metal concentrations (Zn, Cu, Cr, Co, Ni, Ba, Sr, V, Sc) in the petroliferous regions of the study area during pre- and post-monsoon seasons.

xi) Probable impact of emerging contaminants in groundwater on human health.

11. Work schedule / Timeline

S. No.	Major Activities	2022-23				2023-24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Data collection								
2	Field surveys & Sample collection								
3	Sample Analysis								
4	Data Processing								
5	Interim Report								
6	Final Report								

12. Cost estimate: Rs. 17,60,000 (NIH Internal Fund)

S. No.	Sub-Head	I Year	II Year	Total
1.	Manpower	480000	480000	960000
2.	Travelling expenditure	100000	100000	200000

3.	Infrastructure /Equipment /Consumable	150000	150000	300000
4.	Experimental charges/Analytical charges	100000	100000	200000
5.	Misc. Expenditure	50000	50000	100000
6.	**Grand Total**	**880000**	**880000**	**1760000**

a. Justification for sub-head-wise abstract of the cost

- Manpower: For timely analysis of water and soil samples and processing of data.

S. No.	Manpower Category	Nos.	Gross Salary per month	1st year	2nd year	Total
1.	Resource Person (Junior)	1	40000	480000	480000	960000

- Travelling expenditure: For visit to study area and Sampling, attending conferences, data collection, surveys etc.
- Equipment/Consumables: Purchase of chemicals, reagents, standards etc.
- Experimental/Analytical charges: Towards analysis of samples in outside laboratories and in NIH water quality lab.

13. Research outcome from the project:

a) The study will identify degraded groundwater quality zones, possible sources of pollution, understanding geochemical processes controlling the aquifer chemistry and will suggest the measures for sustainable groundwater supply for drinking purpose in the study area, therefore enable better planning and management of groundwater resources.
b) Technical report and papers

14. End Users/Beneficiaries of the study: Public Health Department, AP, Ground Water Department, AP, CGWB.

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. M K Goel	Scientist G & Head
2	Dr. Anupma Sharma	Scientist F
3	Dr. Surjeet Singh	Scientist F
4	Er. Sumant Kumar	Scientist D
5	Dr. Gopal Krishan	Scientist D
6	Sh. Nitesh Patidar	Scientist B
7	Mrs. Nidhi Kalyani	Scientist B
8	Mrs. Anju Choudhary	PRA
9	Sri Sanjay Mittal	SRA
10	Sri S.L. Srivastava	SRA
11	Sri Ram Chandra	SRA

APPROVED WORK PROGRAMME OF GWHD FOR THE YEAR 2021-22

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/ 19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh	2 years (05/19 - 04/21) *Status: Completed*	Internal Study
2. NIH/GWH/NIH/ 19-20	The Regional Hydrological Impact of Agricultural Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar (retired Sep, 2020), Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year 8 months (08/19 – 03/21) *Status: Completed*	Internal Study
3. NIH/GWH/DoW R/20-20	Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi	Gopal Krishan (PI), B. Venkatesh, Nitesh Patidar	11 months (07/20 – 05/21) *Status: Completed*	Referred by DoWR (MoJS)
4. NIH/GWH/NIH/ 20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan, Anupma Sharma	2 years (08/20 – 07/22) *Status: In progress*	Internal Study
Sponsored Projects				
5. NIH/GWH/NMS HE/16-20	Development of a project website and hydrological database in Upper Ganga basin (SP-1)	M. K. Goel (PI), M. Arora, A. K. Lohani, D. S. Rathore (retd. Jan. 2021), D. Chalisgaonkar, A. R. S. Kumar, Surjeet Singh, P. Mani, A. Sarkar, M. K. Nema, Suman Gurjar, P. K. Mishra	5 years (01/16 - 03/21) Extended up to Sept. 30, 2021 *Status: Completed*	DST under NMSHE
6. NIH/GWH/BGS /17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency GW Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (retired Sep, 2020), M. S. Rao *From: BGS, UK* Dan Lapworth (PI) Alan MacDonald	5 years (12/17-11/22) Extension from 06/21 to 11/22 with approval of DoWR, RD & GR *Status: In progress*	BGS, UK
7. NIH/GWH/PDS/ 17-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Org.:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT-R and N. S. Maurya, NIT Patna	3.5 years (12/17-06/21) *Status: Completed*	NHP under PDS
8. NIH/GWH/PDS/ 17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (retired Sep	4 years (12/17-07/22)	NHP under PDS

	Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	2020), *IIT-Roorkee:* Brijesh Yadav (PI) M. L. Kansal *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	*Status: In progress*	
9. NIH/GWH/PDS/ 17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar (retired Sep 2020), Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-07/22) *Status: In progress*	NHP under PDS
10. NIH/GWH/DST/ 18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (PI), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	4 years (01/18 - 12/21) *Status: Completed*	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
11. NIH/GWH/DST/ 18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants	Anupma Sharma (PI) Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* Cranfield University, Water Harvest, Excellent Develop. (UK based NGO)	4 years (01/18 - 12/21) *Status: Completed*	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
12. NIH/GWH/CEH M/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Vishal Singh, Nitesh Patidar *Partners:* Haryana Irr. & WR Dept., UP GW Deptt., UYBO, CWC	6 years (04/18-03/24) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)
13. NIH/GWH/DST/ 19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey	Anupma Sharma (PI) Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI &	5 years (03/19 - 02/24) *Status: In progress*	DST

	Water	CIAH, Bikaner, NIAM Jaipur)		
14. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator)	3 years (07/20 – 06/23) *Status: In progress*	Federal Min. of Education and Research, Germany
15. NIH/GWH/DST-SERB/21-24	Partitioning ET into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), M.S. Rao	3 years (04/21 – 03/24) *Status: In progress*	DST-SERB
Consultancy Projects				
1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	2.5 years (03/19-10/21) *Status: Completed*	Punjab Government
3.	Water Availability Study based on HI and RF-RO Modeling of Upper Hindon Basin	Anupma Sharma (PI)	2.5 years (04/19-09/21) *Status: Near completion*	Irrigation Deptt., Saharanpur
4.	Hydro-geological Study in Vicinity of SEL Manufacturing Co. Ltd., Nawanshahr, Punjab	Surjeet Singh (PI)	6 months (02/21-08/21) *Status: Completed*	NIT, Jalandhar (Punjab)
5.	Geo Environmental study in/around OMC's in Manglia, Indore	Sumant Kumar (PI)	6 months (11/20-5/21) *Status: Completed*	BPCL, Indore
6.	Study of Scenarios for Long-term Effect of Enroute Canal Irri. for Proposed M - G Link	M. K. Goel (PI)	12 months (07/20-06/21) *Status: Draft report submitted.*	NWDA, Delhi

PROPOSED WORK PROGRAMME OF GWHD FOR THE YEAR 2022-23

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/ NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan Anupma Sharma	2 years (08/20 – 07/22) *Status: In progress*	Internal Study
2. NIH/GWH/ NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S. Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel	3 years (04/22 – 03/25) Status: **New Study**	Internal Study
3. NIH/GWH/ NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Nidhi Kalyani	2 years (04/22 – 03/24) Status: **New Study**	Internal Study
4. NIH/GWH/ NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	Nidhi Kalyani (PI), Anupama Sharma, Nitesh Patidar, Sumant Kumar	2 years (04/22 – 03/24) Status: **New Study**	Internal Study
Sponsored Projects				
5. NIH/GWH/ BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency)	Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody	5 years (12/17-11/22) *Status: In progress* ***Corrected time specified***	BGS, UK
6. NIH/GWH/PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (Retd.), *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav *Sehgal Foundation:* Lalit Mohan Sharma	4 years (12/17-07/22) *Status: In progress*	NHP under PDS
7. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-07/22) *Status: In progress*	NHP under PDS
8. NIH/GWH/ CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, V. Singh, N. Patidar, N. Kalyani *Partners* Haryana Irr. & WR Dept., UPGW Dept., UYRB, CWC	4 years (04/18-03/24) *Status: In progress* ***Corrected time specified***	Special Project under "Centre of Excellence" (NHP)

9. NIH/GWH/ DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (PI), Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 02/24) *Status: In progress*	DST
10. NIH/GWH/ CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & C0-coordinator)	3 years (07/20 – 06/23) *Status: In progress*	Federal Min. of Education and Research, Germany
11. NIH/GWH/ DST-SERB/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), MS Rao	3 years (04/21 – 03/24) *Status: In progress*	DST-SERB
12. NIH/GWH/ APN/22	Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools	Nitesh Patidar (PI), S. Singh, G. Krishan *IIT Roorkee (lead)*: Basant Yadav, Ashish Pandey, R D Singh, B. J. Deka *In-kind support:* KU, Japan: Yutaka Matsuno, PNU, South Korea: Sanghyun Jeong	10 months (01/22-10/22) *Status: New Study*	Asia-Pacific Network (APN)
Consultancy Projects				
1.	Groundwater Investigations of Rana Sugars Ltd. Buttar Seviyan Area of Amritsar District, Punjab	Surjeet Singh (PI)	6 months (01/22 – 06/22) *Status: In progress*	NIT, Jalandhar (Punjab)

The details of the studies are given in Annexure-I.

Trainings organized:

GWHD organized **three** training courses, and **one** workshop since last WG meeting.

Outreach activities since previous WG meeting:

1. Scientists published/accepted **39** papers in international/national journals & conferences.
2. Scientists guided/guiding **6** M/Sc./M.Tech./Ph.D. students for their thesis work.
3. Scientists conducted **4** mass awareness activities.
4. Scientists developed **3** Modelling software:
    a. NIH_ReSyP
    b. IIT-Kgp NHM – GW module
    c. M-G Link System model for SW-GW interaction

1. PROJECT REFERENCE CODE: NIH/GWH/NIH/20-22

Title of the Project: *Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System*

Study team: PI Dr. Nitesh Patidar, Scientist-B
Co-PIs Dr. Gopal Krishan, Scientist-D
Dr. Anupma Sharma, Scientist-F

Type of study: Internal (On-going)

Duration: Two years (August 2020 – July 2022)

Objectives vis-à-vis Achievements

Objectives	Achievements
Development of the integrated GEE-MODFLOW model to estimate groundwater recharge and to disseminate model outputs	*Near completion* Development of the integrated model is near completion. Various modules to download data from GEE, process and utilize in MODFLOW have been developed. A surface water module to estimate infiltration, ET and percolation from the top soil layer has been developed. MODFLOW has been integrated with developed surface water module and GEE. A web-based interface to run and disseminate the model outputs has also been developed.
Evaluation of the estimated recharge using in-situ observations	*In-progress* The integrated model is being tested against the observed groundwater heads and soil moisture.
Assessment of the impacts of various recharge/abstraction scenarios on groundwater system of Hindon river basin	*In-progress* Modules for assessing the impacts of changes in recharge and pumping is in progress.

Brief background

The excessive groundwater withdrawal led by growing water demands has resulted in rapid and widespread groundwater declines in many parts of India. To manage water resources in a sustainable manner, comprehensive understanding of groundwater system is essential. Of particular importance are the understanding of recharge processes, quantification of recharge from various sources, such as rainfall and surface water bodies, assessment of the impacts of groundwater withdrawal, and understanding the exchange of fluxes between surface and subsurface hydrological systems.

With the improved understanding of hydrological processes and recent advancements in the field of computers, many hydrological models have been developed. Although the models developed during the past decades produce useful results, a model alone may not be implemented to support decision making for groundwater management mainly due to (i) difficulties in incorporating the frequent changes in impervious surface, vegetation phenology and surface water bodies, and (ii) no provision to disseminate the outputs to open platforms so as to support decision making. Therefore, a Groundwater Recharge Assessment System that integrates state-of-the-art hydrological models, allows to incorporate frequently available remote sensing data, data visualization and dissemination, is required for precise estimation of groundwater recharge and to support decision making in India. In this context, the proposed system will help assessing the replenishable groundwater considering recharge from various sources (e.g. rainfall and surface water bodies), investigating impacts of various recharge/abstraction scenarios on groundwater system and analyzing the outputs on an open web-based GIS platform through Google Earth Engine (GEE).

Study area

The model will be tested in Hindon river basin. Hindon river originates from Saharanpur district of Uttar Pradesh and joins Yamuna river near Delhi. The basin lies between the latitudes 28°30′15″ to 30°15′12″ N and longitudes 77°20′18″ to 77°50′10″ E and has an area of ~7000 km^2. It is largely composed of Pleistocene and Quaternary alluvium represented by sand, clay and kankar. The ever-increasing groundwater abstractions to cater the agricultural needs have led to depleted groundwater levels in the area. These depletions have not only reduced the groundwater availability but also have made the groundwater more susceptible to pollution and have reduced the baseflow contribution to the streams. The alarming groundwater declines, emerging groundwater quality issues and ever-increasing water demand in the region necessitate proper planning and management of groundwater resources. This requires precise quantification of groundwater recharge, assessment of various recharge/abstraction scenarios on groundwater system and forming and implementation of water management strategies. As the groundwater is a dynamic resource which varies with the recharge and extraction, frequent assessments are needed for better planning.

Progress

A data preparation module is developed using GEE, a free cloud-based platform, and Python. A surface water module is developed to simulate processes in the top soil layer, named Root Zone Flow (RZF) Module. RZF simulates runoff using SCS-CN method or Grreen-Ampt method, potential evapotranspiration using Penman–Monteith, and percolation using soil water balance. The RZF is integrated to UZF (Unsaturated Zone Flow) module of MODFLOW which simulates the flow in unsaturated zone. The RZF and UZF are integrated such a way that the ET is partial estimated from top soil using RZF and partially from the bottom soil using UZF wherein the proportions depend on the root fractions in the top and bottom soil layers. An option is provided to estimate irrigation water requirement and recharge from irrigation using the model. The actual recharge from the UZF is used as recharge to GWF (Groundwater Flow) modules of MODFLOW. All the module, i.e. GEE, RZF, UZF and GWF are integrated using python programming so as reduce efforts in preparing input files for the model.

A web-based interface for the developed integrated model is also developed. The interface also includes Interactive output visualization module for visualizing outputs of the model.

Action plan and timeline (month-wise from Apr 2022 to Jul 2022)

Work element	Apr 2022	May 2022	Jun 2022	Jul 2022
Model calibration and validation				
Simulation runs for investigating various recharge/abstraction scenarios				
Preparation and submission of reports, model manuals and research papers				

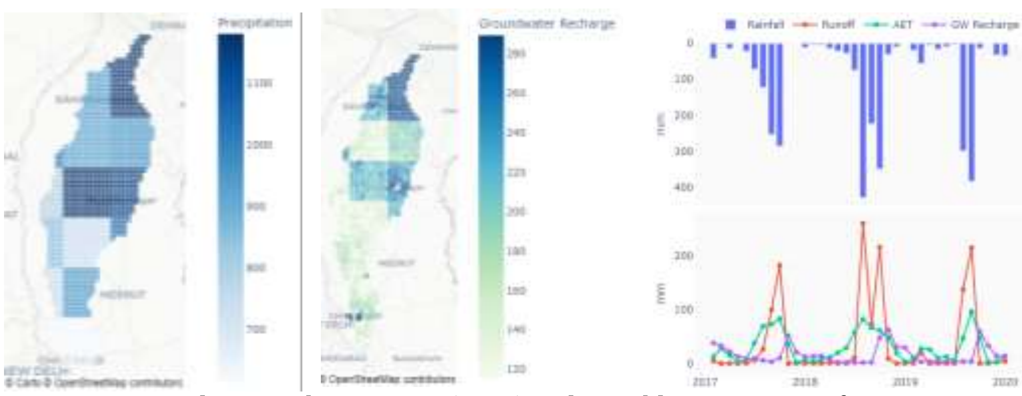


Fig. 1 Precipitation and GW recharge maps (2018) and monthly time series of precipitation, runoff, actual ET and GW recharge for the years 2017-19.

2. PROJECT REFERENCE CODE: NIH/GWH/NMSHE/16-20

Title of Project: *Development of a project website and hydrological database in UGB (SP-1)*

Study team

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

Objectives & Achievements

The objectives and achievements of the project are:

Objectives	Achievements
Development of a hydrological and hydro-meteorological database for study basin.	Completed
Processing and analysis of hydro-meteorological data in study area.	Completed
Assessment of adequacy of hydro-meteorological network in study area.	Completed
Investigation and referencing of available spatial database from various sources.	Completed
Capacity building for use of hydrological data entry and processing software.	Few workshops organized in beginning of project.
Development of interactive project web site with hydrological information system.	Completed

Sponsored by DST, New Delhi

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 used in hydrological analysis.

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

The study has been completed and the report of the sub-project has been finalized and is being submitted shortly to DST. In this sub-project, extensive efforts have been made for the processing of hydro-meteorological data of IMD and CWC. Trend analysis has been carried out on different hydro-meteorological variables. Network analysis has been carried out and areas of probable new instrumentation have been identified using entropy analysis. Gridded reanalysis and satellite spatial data have been investigated for use in UGB. Finally, a project website has been designed which integrates the major outcomes of various sub-projects for their mass-communication.

A number of data processing techniques (graphical plotting, spatial homogeneity, double-mass curve analysis, trend analysis) have been applied in the present study and some suspect values have been identified. Majority of the errors can be identified by just simply plotting the long-term observations (say, plot of daily precipitation, precipitation at nearby stations, max. and min. temperature, long-term monthly observations, flow observations at u/s and d/s gauging stations, double-mass curves etc.) and cause of error (human, instrumental, or change in setting etc.) can be identified and corrected at the time and place of occurrence.

Using the spatial homogeneity test, around 24 events have been identified (during 1972 to 2016) with abnormal high or low rainfall. Using double mass analysis, 8 stations out of 30 stations of IMD/CWC have been identified with significant change of slope since different years (from break-point of slope). Plot of data also identified some entry errors in max. and min. temperature. Further, plot of monthly data of Uttarkashi gauging station identified significant low flow observations during 1986 to 2009.

Trend analysis has been carried out for the precipitation data, number of rainy days, temperature data, and flow data for various stations in Alaknanda and Bhagirathi basins and in the downstream UGB up to Rishikesh. It is broadly inferred that precipitation is increasing in UGB in the pre-monsoon and monsoon seasons with net increase at the annual time step. In the Bhagirathi and Alaknanda sub-basins, most stations show rising trend of rainy days in the pre-monsoon (April - May) and monsoon (June – September) seasons. The results at the annual time step show mixed trends with some stations having increasing and some stations having decreasing rainy days. With regard to the river flows, it is inferred that flows are increasing in the Alaknanda basin as a whole with significant increasing trend in the monsoon, post-monsoon and winter months while in the Bhagirathi sub-basin, the Tehri dam has redistributed the flows with significant increase in the non-monsoon months at the cost of monsoon months.

Network analysis using average annual rainfall and 'Cv' method indicates sufficient network of hydro-meteorological stations (around 50) in UGB. However, it would be desirable if all the discontinued stations of IMD can be operationalized along with weather sensors. Entropy analysis has been carried out to indicate desirable areas of probable new stations in the UGB. To explore the potential usage of global precipitation estimates available from reanalysis products or satellite estimates, two reanalysis products (ERA5-Land hourly data and IMDAA daily dataset) and precipitation estimates from GPM-IMERG have been investigated. Though all these products were found to capture the seasonality of precipitation regime of UGB, IMERG is found to be satisfactorily representing the monthly magnitudes of precipitation and is found to be best suitable alternative for the UGB.

A website has been developed for the mass-communication of the findings of various sub-projects. It also provides average estimates of hydro-meteorological variables at various stations in UGB and trend results. Snow cover estimations (2000 – 2020) have been made for all the Himalayan basins in India and have been provided in Web-GIS.

3. PROJECT REFERENCE CODE: NIH/GWHD/BGS/2017-22

Title of the study Groundwater fluctuations and Conductivity Monitoring in Punjab- Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands

Name of PI and members : **NIH, Roorkee, India**
Dr. Gopal Krishan (PI)
Er. C.P. Kumar (co-PI) (Retired on Sept. 2020)
Dr. M.S. Rao (co-PI)
Dr. Surjeet Singh (co-PI)
BGS, UK
Dr. Dan Lapworth (PI)
Prof. Alan MacDonald (Project coordinator)
Prof. Daren Goody (Co-PI)

Type of study : **Sponsored,** BGS, UK.
Date of start (DOS) : December 2017
Scheduled date of completion : November 2022
Location : Bist- Doab and SW Punjab

S. No.	Objectives (3 New added)	Achievements
1	To characterize multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers	**Achieved** – There is a trend of GW depletion mainly due to the onset of pumping for irrigation during the Kharif season, a part of which is in the monsoon season. So the contribution of pumping could exceed natural replenishment. The rainfall increase is the dominant factor, suggesting that without considering pumping effects, the rainfall patterns indicator of climate change could provide larger GW sustainability in Northwestern India, currently experiencing depletion for supporting irrigated agriculture Agriculture and number of groundwater structures have positive correlation with the depth to groundwater indicating agriculture crop/paddy as the main source of GW depletion in Jalandhar, Kapurthala and part of Nawanshahr districts
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	**Achieved (80%)-** Analysis carried out so far indicated that there is inter-relation between various source waters. There are some commonalities in isotope values at a certain percentile. Satluj water and canal originating have highly depleted values as compared to Beas river values Reservoir samples are highly enriched.
3	Characterize groundwater residence times and water quality in southern Punjab through detailed sampling to assess the resilience of groundwater abstraction as an adaptation	**Achieved** (30%)– Sampling has been done from network of piezometers from 10 selected sites in southwest Punjab and samples has been sent to BGS, UK for analysis of CFC and

	strategy for continued food production.	SF6
4	Assess groundwater vulnerability to salinization from water-logging from increased surface water flows (including canal flows) through glacial melt-water and identify potential solutions for future priority research, and inform robust conceptual models of GW salinization in this region.	**Achieved (30%)-** Analysis carried out so far indicated that there is inter-relation between various source waters. There are some commonalities in isotope values at a certain percentile.
5	Deliver a new groundwater data set from southern Punjab to enable comprehensive and transparent discussions of adaptation solutions to water resources in this region	Is under process
6	To prepare a status report on groundwater issues in Punjab	Will be prepared after getting the results of tracers

Statement of the problem

Punjab is underlain by the Indus Basin aquifer which has been rated as the second-most over stressed aquifer in the world. Among all the states of India, Punjab is drawing highest amount of groundwater resulting in its declination at an alarming rate. Bist-doab is one of the important regions of Punjab comprising of the districts of Hoshiarpur, Jalandhar, Kapurthala and SBS Nagar. In recent years, a large volume of groundwater reported to be extracted in Hoshiarpur and Jalandhar districts. Agriculture is dependent on groundwater irrigation and concerns exist over the sustainability of current and future exploitation of groundwater; tracer data can help quantify groundwater renewal processes. In the joint study with BGS (UK), high frequency water level and conductivity data is interpreted along with the analysis of water samples for a suite of tracers.

In addition to the study in Bist-Doab, the study area has been extended to SW Punjab where groundwater samples were taken from the network of depth wise piezometers developed by Department of Agriculture and Farmers Welfare at 40 sites in Fazilka, Faridkot and Muktsar districts of south-west Punjab. A total of 142 piezometers were developed in another study in the depth range of 5 m-32 m and categorized as shallow (<10 m); intermediate 1st (10-15 m); intermediate 2nd (18-20 m) and deep (28-32m). Electrical conductivity of the groundwater samples was measured on site. Analysis results for the values of EC show that 11% of groundwater in the study area is fresh. Of this, the major fraction is present in the shallow to 1st intermediate depth aquifer (less than < 15 m depth). The fresh GW of this aquifer should be preserved for drinking water needs, should be safeguarded from any contamination; and their active recharge areas should be preserved from any unwanted encroachment which may affect the groundwater quality of these aquifers. Major fraction (58%) of the groundwater in (shallow to deep depth) is of marginal to moderately fresh water type. This is well suited for the purpose of irrigation and livestock. This groundwater may be used for irrigation after marginally mixing with fresh water and directly may be used by the industrial sector and for the salt tolerant crops. About 31% groundwater is marginally saline to saline. This may be used for salt tolerant crops, industrial applications, and other secondary water uses.

On the basis of the salinity profiles of the aquifers, in the present study, groundwater samples were collected from 10 selected sites for analysis of CFC, SF6 for better understanding of the aquifer systems

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 loggers were installed in Saroya, Bhogpur and Sultanpur Lodhi in the month of May, 2019 (Fig. 1). In addition to these sites water level loggers were installed in Bhogpur, Tanda and Nakodar in October, 2019 (Fig. 1). For extending the studies to southwest Punjab the samples from a network of piezometers from 10 sites were taken for analysis of CFC and SF6 to characterize groundwater residence times

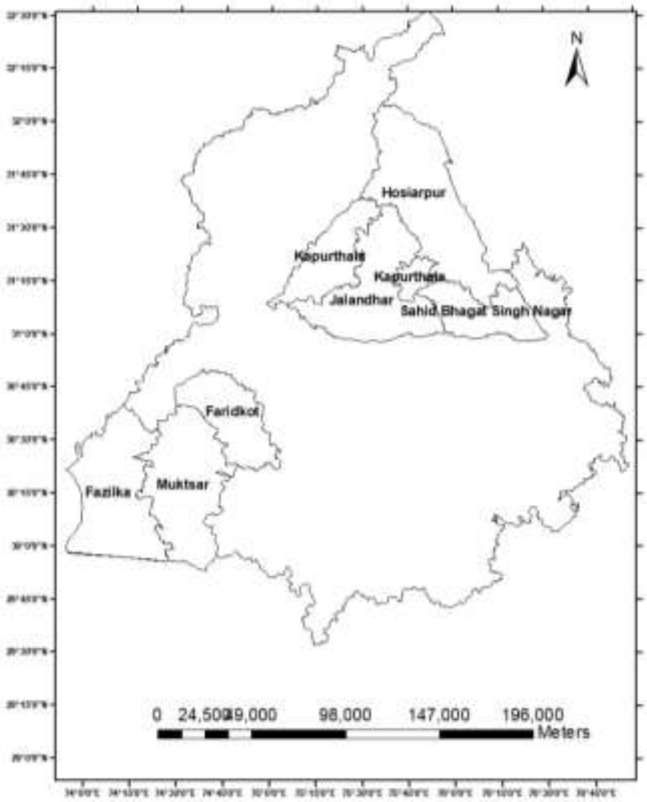


Fig. 1. Study area, Bist Doab and SW, Punjab

Some of the findings of the study states that there is a sharp decline in groundwater levels during the monsoon season due to higher extraction but this has also resulted in enhanced groundwater recharge in post monsoon season.

Water stable isotopes are tracers of physical processes water molecules undergo between evaporation from the ocean and arrival in the aquifer via recharge. It has been found that Sutlej river and canals origination from these rivers have depleted signatures due to the origin from Himalayan sources compared to the meteoric monsoon signature makes this an excellent tracer for assessing the significance of river/canal water sources in shallow groundwater recharge in this region.

Long-term average amount weighted isotope values for precipitation were also used to compare with groundwater isotope values to understand recharge sources and processes.

The contrasting isotope signatures of precipitation and surface waters in this area clearly demonstrate that both shallow and deep groundwater recharge is dominated by meteoric sources, rather than surface water sources including canal irrigation water which have been found dominating in SW Punjab in other study. Given the widespread canal coverage in this region this is an important finding, and contrasts with other areas in southwest Punjab where canal return recharge is thought to dominate shallow groundwater recharge

The depleted water isotope signatures in the deep groundwater relative to the shallow groundwater in entire Punjab can be explained by recharge sources from the deep groundwater having a component of groundwater recharged some distance up gradient from the sampling points at a higher elevation

Work is also going on to investigate the occurrence of low flow/ stagnant zones which may contain high residence time groundwater within unconsolidated sedimentary settings using environmental tracers.

Some unanswered questions are:

What is the synchronisity between deep and shallow groundwater level responses?

Do the slopes of the drawdown differ (between and within sites) – does this tell us anything about the aquifer system or just the rates of pumping or both?

Action plan:

Year	**Dec. 2017 to Nov., 2022** (Annexure 1)	Remark
Dec. 2017 to Nov. 2022	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 2022)

Activity	1st to 4th	5th To 8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Downloading data	♦	♦	♦			♦		♦		♦		♦		♦
Sample collection and analysis	♦	♦	♦							♦				
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 study has been extended to SW Punjab
- The water samples has been collected from piezometers

Future plan

- Downloading data from water level loggers and conductivity 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

4. PROJECT REFERENCE CODE: NIH/GWH/PDS/17-20

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

Team members: 1) Dr. Sumant Kumar- Sc.- D & PI
2) Dr. Sudhir Kumar, Sc.-G
3) Dr. Rajesh Singh, Sc.-D
4) Dr. Gopal Krishan , Sc.- C
5) Mrs. Anju Chowdhary, PRA
6) Mr. Ramchander, RA

Partner Organization: Minor Water Resources Dept., Govt. of Bihar

Collaborators: Dr. Brijesh Yadav, IIT, Roorkee
Dr. N.S. Maurya, NIT, Patna

Type of study: Sponsored (NHP)

Date of Start: December, 2018

Scheduled Date of Completion: October, 2021

Budget: Rs.70 Lakh

Location: Bhojpur District, Bihar (Figure 1)

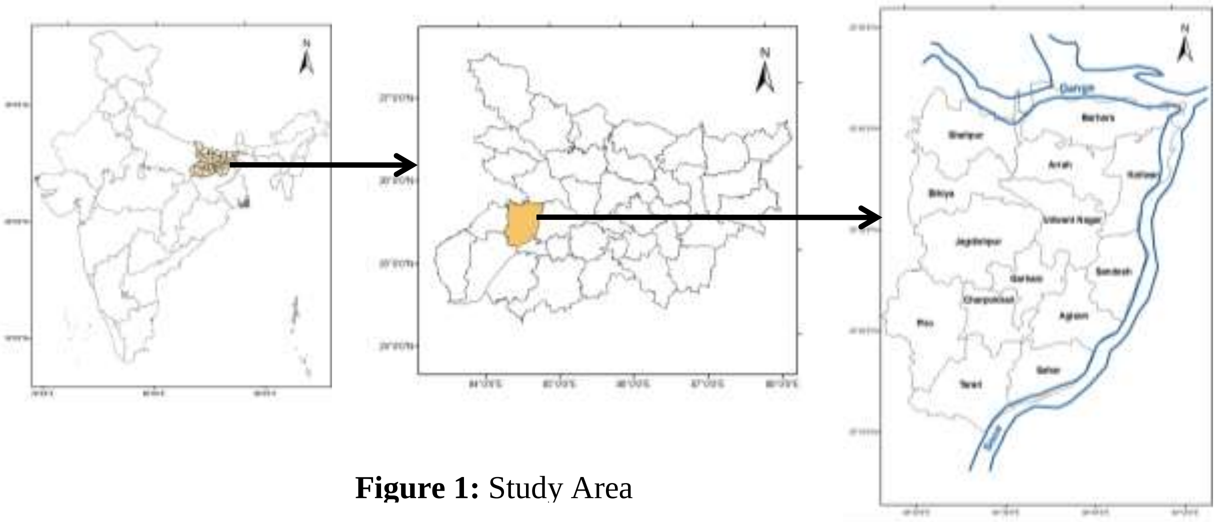


Figure 1: Study Area

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

The symptoms of chronic arsenic (As) from prolonged consumptions including skin lesions began to be observed in 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 decades, 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 GW.

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.	Completed
Delineation of arsenic safe zone for drinking water supply.	Completed
Evaluation of the controls of regional and local hydrology on arsenic contamination through monitoring of aquifer	Completed
Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.	Completed

Analysis and Results:

Groundwater abstraction from the alluvial aquifer system is reported to be approximately one-fourth of the world's total groundwater abstraction and supports the agricultural activity of south Asia. The alluvial formation of the Ganga plain in the state of Bihar and Uttar Pradesh comprises productive soils and aquifers. The use of groundwater for irrigation and domestic purposes have increased manifold in these states. The Indo-Gangetic aquifer is one of the most heavily exploited aquifer in the world. The excessive withdrawal of groundwater has adversely affected groundwater resources both in terms of quantity and quality. Water quality challenges mainly includes contamination by agricultural runoff, sewage leakage and seepage into groundwater and geogenic contamination such as arsenic, fluoride etc. Arsenic (As) contaminated drinking water is the most challenging environmental problem and is currently affecting around 220 million people across the globe, out of which around 94% affected people are in Asia. Chronic exposure to groundwater having an arsenic concentration of more than 10 μg/L leads to numerous adverse health impacts like lower intelligence quotients, type 2 diabetes, skin lesions, melanosis, keratosis, and cancer etc. Arsenic contamination of water is producing the greatest impact on livelihoods in terms of public health and thus arsenic calamity in the Ganga river basin has put millions of population in danger.

Many researchers have reported rampant occurrence of As with elevated concentration in drinking water by evaluating groundwater quality in the middle and lower Ganga plain. However, very few studies have been carried out in the middle Ganga plain to understand arsenic geochemical behavior, seasonal change of arsenic, understanding groundwater recharge and its effect on arsenic mobilization in groundwater, its relation with declining/rising groundwater level, mineralogical analysis and leaching of arsenic from solid to groundwater phase etc. Thus, there is a considerable knowledge gap in understanding the role of anthropogenic and geogenic factors in controlling the mechanism of arsenic mobilization in the middle Ganga basin. The present study explores the causes of rampant occurrence of arsenic and processes controlling the mobilization of As in groundwater of the Bhojpur district, Bihar located in central Ganga basin. The Bhojpur district is bounded by the rivers Ganges and Ghaghra in the north and east. The objectives framed under the study are: (i) determination of the spatio-temporal variation of arsenic along with other water quality parameters in groundwater, (ii) delineation of arsenic safe zone for drinking water supply, (iii) evaluation of the controls of hydro-geology on arsenic contamination through monitoring of contaminated aquifer and sediment characterization, and (iv) identification of the mechanism of release and transport of arsenic in GW through a column experiment. Significance of the study is to help in demarcating safe aquifer, improved monitoring and mitigation measures at regional level.

To achieve the objectives, 94 water samples for water chemistry and 62 samples for isotopic analysis, were collected in the Nov. 2018 (post- monsoon season) from the entire district by making grid of size 4 km x 4 km in northern side (along river Ganga) and 8 km x 8 km in southern part of the study area. The groundwater samples collected during sampling were generally from hand pumps with depth ranging from 15 to 80 m. After understanding the spatial variation of water quality parameters, particularly arsenic, the sampling and detailed investigation started in arsenic affected areas. The water samples (45 Nos.) from pre & post monsoon season (year 2019) were collected from arsenic affected area. Eight number of shallow piezometers (80-140 feet depth) were constructed in the study area for sediment characterization and water quality monitoring. The composite sediments samples were collected depth wise from top to bottom at an interval of 10 feet and when a changes in lithology were observed, while drilling. The XRD and XRF analysis were done for mineralogical study. The sediments were also used for performing batch and column experiment.

Based on the present analysis, the geochemistry of the groundwater is mainly controlled by carbonate weathering with less contribution from silicate weathering in the study area. It is observed that the dissolution/weathering of carbonate rock acts as a major contributor for Ca, Mg, and HCO_3, however, alumino-silicates minerals are the major contributor for Na, K, and SiO_2. Similar observations have been made by other researchers regarding the geochemistry in the middle Ganga plain. The hydro-geochemical facies for groundwater in the study area is Ca-Mg-HCO_3 type. In the study area (covering entire Bhojpur district), concentration of arsenic in groundwater during post-monsoon season (year 2018) varies between not detected (ND) to 206 ppb (Semaria ojha Patti of Sahpur block) with average concentration of 15 ppb. The results reveal that about 30 % of analysed ground water samples having As concentration above acceptable limit (10 ppb) and 8 % exceeding the permissible limit (50 ppb) as prescribed by BIS (2012) for drinking purposes. Spatial distribution map of arsenic shows that northern part of the study area associated with Ganga alluvium plain is more arsenic affected in comparison with southern part of the district. The As concentration is almost negligible in river water, i.e. Ganga water and Son water samples, varies between 2 to 5 ppb and ND to 2 ppb respectively. On the other hand, during pre-monsoon sampling (year 2019) results from arsenic affected areas suggest that about ~60% of water samples are enriched with dissolved As concentrations >10 μg/L, and it ranges from ND to 337 ppb (average 78 ppb). Arsenic in groundwater exhibited a wide spatial variation, even more than 100 times within a distance of 200 m. The elevated concentration samples area mainly from Sahapur and Barahara block of the study area which is located in younger alluvium of Ganga flood plain. Based on depth wise sampling, it is observed that arsenic is mainly contaminated in depth range of 20 m to 60 m and As conc. decreases rapidly beyond 60 m. It implies that only upper aquifer is contaminated by As. The temporal variation of arsenic indicates that it is more in pre-monsoon season as compared with post monsoon season and approximately 10-40 % reduction in As concentration was observed in post monsoon season. For the present case, variation in arsenic concentrations in groundwater are supposed to be due to the dilution effect and changes in redox conditions, which may cause desorption of arsenic from metal oxides. The parameters such as oxidation-reduction potential (ORP), Fe, Mn, NO_3 and SO_4 are the main redox parameters that control the release of As in groundwater. The good correlation between As and ORP (0.61) suggest a redox-dependent mobilization played an important role in As liberation. Fe is positively correlated with As, (0.627), but As shows a weak positive correlation with Mn, which indicate that As might get mobilized from dissolution/desorption from iron hydroxides in the sediment. It is evidently noticeable that arsenic is high when ORP is negative and DO is less, reflecting the occurrence of arsenic in reducing conditions.

The isotopic analysis was also carried out to identify the zones of recharge, and recharge sources in the study area. The Son river is highly enriched in isotopic signatures as compare to the Ganga river, indicating highly enriched source or evaporation of the water during the travel from the Vindhyan mountains. The spatial variation of $\delta^{18}O$ reveals that there is a distinct isotopic difference between groundwater samples from the proximity of Ganga and Son rivers. The Ganga river has an average $\delta^{18}O$ value of -5.78‰ whereas the isotopic value for Son river is -3.17%. The groundwater samples for both the river water region ranges close to its river accompanying it, indicating depleted groundwater near to Ganga river and enriched groundwater close to Son river. We infer that the enriched value of groundwater samples close to Son river is due to recharge through the Son river, while the groundwater close to Ganga is contributing to Ganga river. This is also corroborating from the groundwater flow direction which is toward the Ganga River. The isotopic signature of the groundwater also indicates the vertical mixing of groundwater from the irrigation return flow or other sources.

The mineralogical properties of sediment was studied using X-Ray Diffraction (XRD) and X-ray fluorescence (XRF) technique for the selected samples. From XRD analysis, it is found that quartz, clay and feldspar are the major minerals for most of the samples, whereas goethite and dolomite are present rarely in few sample only as minor minerals. However, some minor peaks were observed which indicates the arsenic bearing minerals present in the soil sample such as the presence of iron arsenate ($Fe_2As_4O_{12}$). In general, the analysis reveals that all samples contain major amounts of SiO_2 as well as substantial Al_2O_3 concentrations. More specifically, average major elements of all the sediment samples indicate a predominant SiO_2 mass component (37.4% - 50.0%) with significant Al_2O_3 (4.0% - 16.2%), Fe_2O_3 (1.7% -10.0%), MnO (0.1% - 6.37%) and CaO (0.8 - 5.2 %) contributions; a few percent of K_2O (1.7% - 3.3%), MgO (0.2 - 1.8 %), P_2O_5 (0.1% - 0.9%) and TiO_2 (0.3% - 1.0%), as well as trace amounts (<1%) of SO_3, Cr_2O_3, NaO, ZnO, CuO, BaO, SrO and NiO. The arsenic concentration in the sediment samples varies from 1 mg/Kg 19 mg/Kg. Sediment samples were also analysed for organic matter concentrations. The results indicate that organic matter has been found less whereas As and Fe have been found more concentrated in the depth range of 30-55 ft, which also support the mobilization of arsenic in groundwater by microbial reductive dissolution of iron oxides from shallow aquifer consisting organic rich clay.The batch and column experiment was performed to study the leaching of arsenic from sediment to water phase. Initially, batch experiment was performed on contaminated soil (simariya village sediment) in a single run of experiment for 8 days. It has been observed that the maximum arsenic leaching (52 µg/Kg) found on 1st day followed by 2nd (34.6 µg/Kg) and 3rd day (38 µg/Kg). After that leaching rate was found to be constant i.e. 12 µg/Kg. The water which mixed with sediment for batch experiment was artificially made groundwater (concentration of salts and pH (7.35) was kept same as it was in groundwater of simariya village). In the second run of experiment, the pH was varied from 6 to 8.5 and it is noticed that maximum arsenic leaches at pH 8. After completion of batch experiment, column experiment was started with a packing of contaminated soil in a column with flow rate of 2 ml/min of artificially made groundwater. the constant leaching rate of arsenic from sediment was found to be 4 ppb/day.

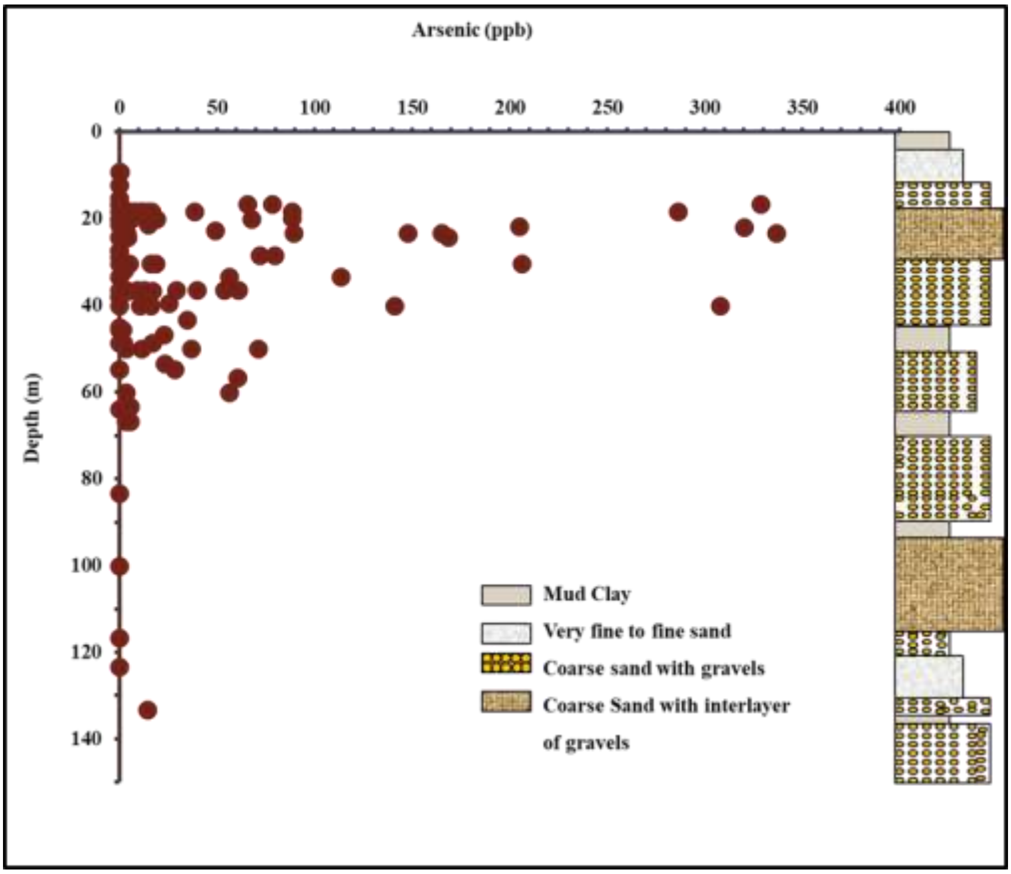


Fig 2.: Depth-wise variation of arsenic in the study area

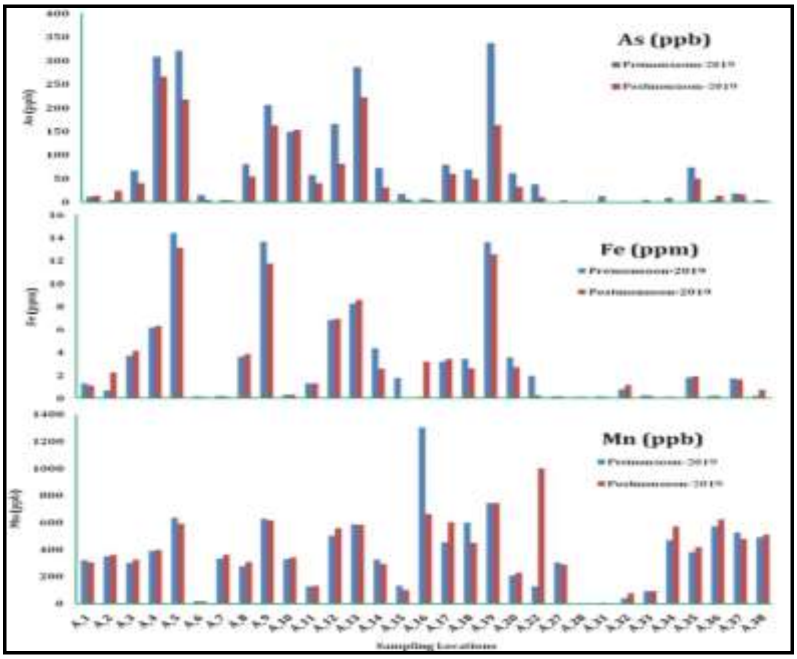


Fig 3.: Temporal variation of arsenic, iron and manganese in the study area

5. PROJECT REFERENCE CODE: NIH/GWHD/2018-21

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
Name of PI and members	:	**NIH, Roorkee, India** Dr. Gopal Krishan (PI) Er. C.P. Kumar (retired Sep, 2020) Dr. Surjeet Singh, Dr. M.S. Rao **Haryana Irrigation Department** X'en Mewat **Consultants** **IIT-Roorkee** Prof. M.L. Kansal, Dr. Brijesh Yadav **Sehgal Foundation, Gurgaon** Sh. Lalit Mohan Sharma
Type of study	:	Applied Research
Date of start (DOS)	:	January, 2018 (NHP-PDS)
Scheduled date of completion	:	July, 2022
Location	:	Mewat district, Haryana

S. No.	Study objectives	Achievements
1	Assessment of lowering of water table (depletion in groundwater level) in the salinity impacted area using the historical data.	**Achieved** – Historical data collected from State groundwater Cell of Agriculture department, Haryana and found that water levels in Tauru, Firozepur zhirka and Punhana blocks is decreasing while no such observations are for salinity affected areas in Nagina block
2	Detailed qualitative analysis of the area and the aquifer depth impacted by higher salinity levels, and preparation of maps.	**Achieved –** Salinity variations maps on spatial and temporal levels have been prepared
3	To monitor influx of saline groundwater into fresh water zone	**Achieved (90%)-** Salinity variations have been found
4	To assess the impact of groundwater salinity on socio-economic aspects	**Achieved-**Work is completed
5	To develop and demonstrate management and resilience building measures	**Achieved (90%)** -Experimental model developed and tested for development of fresh water bubble and recovery efficiency under controlled as well as field conditions.

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.

The proposal deals with to undertake a comprehensive study 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 Harayana as the pilot study areas. 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 are also proposed to undertake. Development of a model to predict changes in groundwater salinity as a result of aquifer recharge and extraction is another focus of the study.

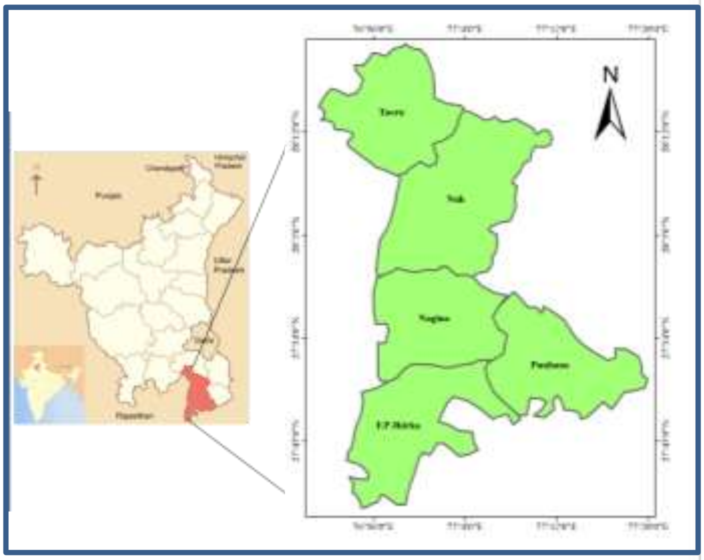


Fig. 1. Map of Mewat district

Whether Study is a New Study/Extension of Previous Studies: Ongoing

Methodology:

This work is being accomplished in five phases as identified below:

In Phase 1, socio-economic based survey is being carried out by Sehgal Foundation, Gurgaon to find out the impact of salinity on the socio-economic condition of the people on the basis of some selected indicators. The findings of the study will help in initiating the development activities as coping strategies for the survival of humankind in the presence of salinity in the district of Mewat. The study proposed to employ both qualitative and quantitative method. Under the quantitative method, a well structured coded interview schedule will be used. Focus Group Discussion (FGD), as a qualitative method, will be administered to collect information on the above socio economic characteristics of the farmers.

Phase 2 of the study is developing of a hydrogeological framework of the aquifer system in Mewat district based on all existing lithologic, stratigraphic and hydrologic information collected from various agencies. The saline areas in the district are being mapped.

Phase 3 include a hydro-chemical characterization (on the basis of anions, cations, physico-chemical characteristics etc.) and quantification of salinity

Phase 4 is to target the areas surrounding the drinking water wells that showed presence of salinity in Phase 2 using existing and new tube wells. Further, the water extracted from tube wells within and down gradient from the industrial areas will be examined where untreated wastewater may have been disposed on the surface (e.g., in infiltration ponds) or injected into the subsurface. The main purpose of the study in Phase 3 will be to identify cause/source areas using isotopes (release locations).

Phase 5 includes suggestion and development of resilience building measures. Some proposed measures are development of fresh water bubble; construction of hydraulic barrier, solid barriers (clay); high pressure recharge etc.

Progress

Socio-economic survey was carried out and found that the choice of subsistence crops is similar across all salinity categories. The subsistence crops cultivated in the region are wheat and mustard during rabi season and mustard and sorghum during kharif season. In highly saline villages, it was found that the percentage of people cultivating millet was relatively less. In commercial crops, diversity can easily be seen in sweet water villages with a predominance of water-intensive crops and onion cultivation. Interestingly, the crop choice is specific to villages in each category. Overall, it is found that in saline regions, crop choices (mainly commercial crops) are very restricted, whereas in sweet water villages, many diverse commercial crops could be grown by farmers, thereby impacting remuneration from agriculture.

Understanding the sources of salinization, and their relative contributions by different sources and seasonal variability has become priority for planning best practices in water management and suggesting remedial measures. For identifying the sources of salinization, the direct application of the relationship between $\delta^{18}O$ and δD is limited as it depends upon initial isotopic composition showing no isotopic variation in the mineral dissolution process. The present study advocates the use of deuterium excess which is independent of initial isotopic composition and extends this concept for identifying the relative contribution of different sources towards seasonal variability in salinization. Mineral dissolution found to be responsible for overall groundwater salinization (fig. 2).

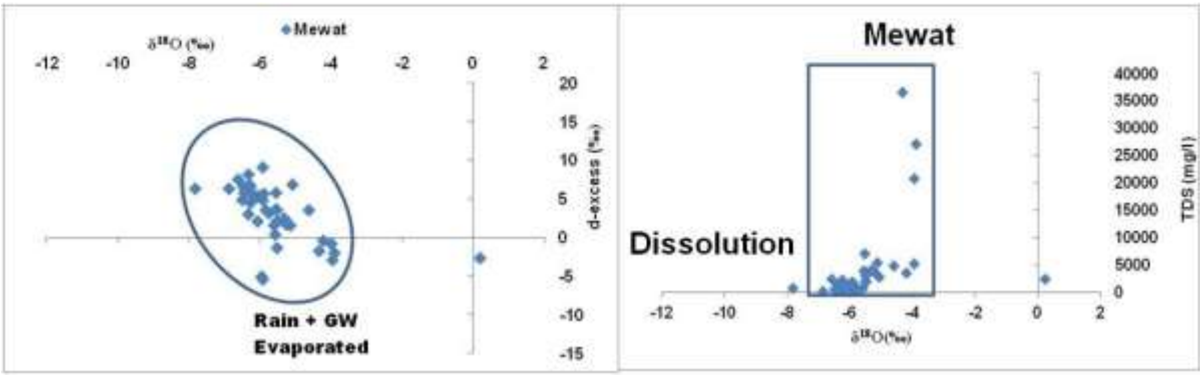


Fig: 2 Recharge source identification and salinity mechanism

In order to determine the dominant ions, multiple regression analysis was carried out. For all the seasons, three trails were carried out in accordance to the p-value with 95 percent of significance level. The dominant ions in the pre-monsoon were Cl^- & $SO_4^{2-}$from anions and Na^+& Ca^{2+} from cations. The dominant ions in the monsoon season were Cl^-& HCO_3^- from anions, Na^+ & Ca^{2+} from cations.

In order to understand the various processes responsible for the seasonal dominance of various ions modeling of precipitation and dissolution process is carried out using PHREEQC model. SI is obtained for $CaCO_3$, $CaSO_4$ and NaCl from the model as shown in (Fig. 3). The highest level of dissolution is encountered in case of NaCl, followed by $CaSO_4$, whereas $CaCO_3$ depicts precipitation.

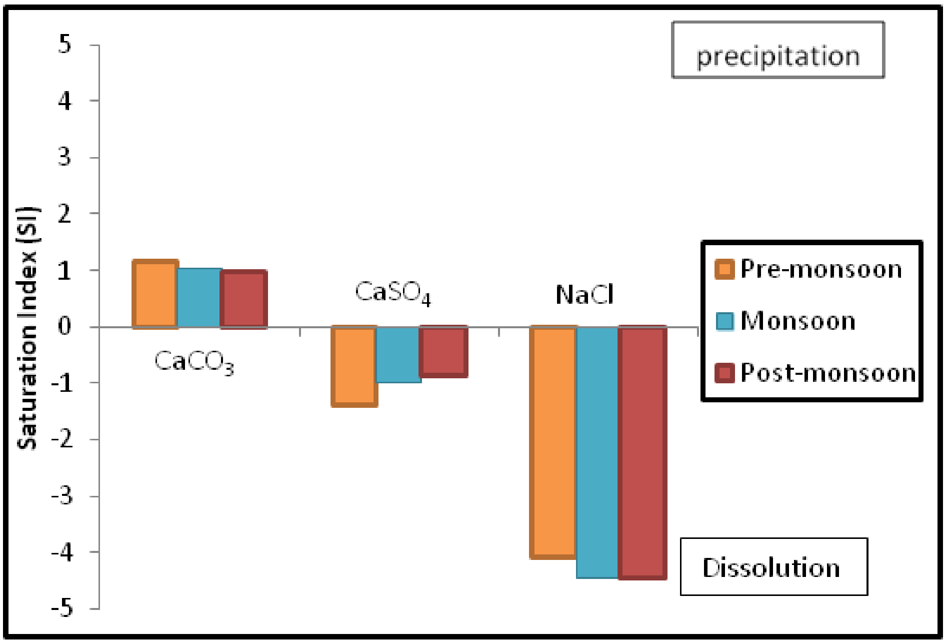


Fig: 3 Season wise trend of Saturation Index (SI) with respect to $CaCO_3$, $CaSO_4$ and NaCl in the groundwater of Mewat, Haryana, India.

A cluster of piezometers were developed to study the salinity variations under field conditions following top down approach. Depth wise salinity variations are observed. More salinity has been observed at the bottom than top part. In addition to the depth wise salinity variations, these were also observed with time. Maximum salinity was observed during the summer time.

Aquifer Storage and Recovery (ASR) system can prove to be important technique for seasonal, durable and future storage of this resource mainly at the time of its inaccessibility due to contamination, water losses, natural disaster and other unexpected conditions. ASR depends on hydro-geological feasibility determined by soil and sub-surface characteristics which are related to percolation rates, porosity, permeability, water quality and connecting recharge zones. Some of the important aquifer characteristics are: type, permeability, thickness, storage, pore type, uniformity, groundwater redox and chemistry. Keeping in view above issues, an experiment was carried out at National Institute of Hydrology Roorkee in an experimental model fabricated under World Bank funded, Mewat Purpose Driven Study (PDS) under National Hydrology Project with an aim to recover fresh water from injected saline water and to assess recovery efficiency.

Recovery efficiency of 63% was found with EC of recovered water equal to or less than 1000 µS/cm after 29 hours of experiment. Aquifer storage and recovery was found to be a significant, suitable tool for water resource management and might act as a hydraulic barrier in saline environments. Similar experiment was carried out in field condition (fig. 4).

Fig. 4 ASR experimental set up in field at Mewat

Description of work planned:

- Data analysis and interpretation work is in progress

Action plan:

Year	**Jan 2018 to Jul 2022**(Annexure 1)	Remark
2018 to 2022	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 (four months wise from Jan. 2018 to July 2022)

Item/Period quarterwise	**1-4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Data/literature collection	■	■	■	■							
Field Surveys	■	■									
Sample collection	■	■	■	■	■	■	■	■			
Analysis			■	■	■	■	■	■	■	■	
Data interpretation			■	■	■	■	■	■	■	■	
Suggestions/remedial measures			■	■	■	■	■	■	■	■	
Report writing/publications				■				■			■

Data requirement & Expected source:

Data will be downloaded from conductivity loggers.

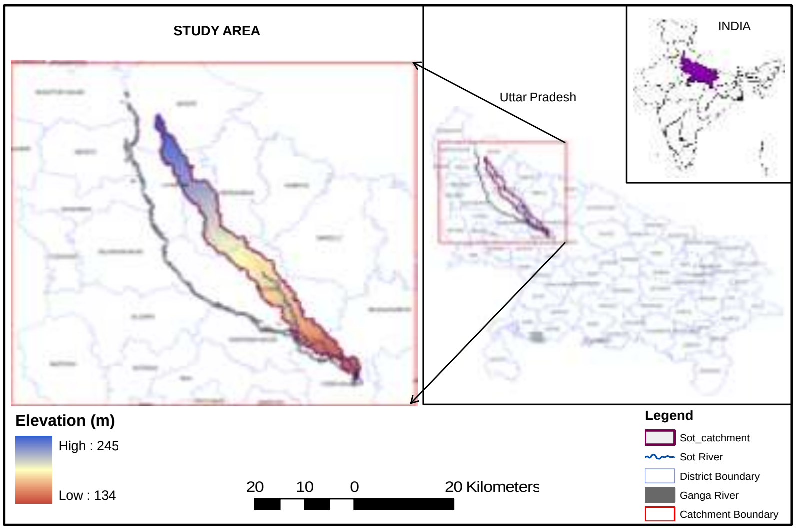
IPR potential and issues **:** Work is in progress

Major items of equipment: EC-probe for soil salinity and; water level and conductivity loggers, rain gauges and piezometers construction

6. PROJECT REFERENCE CODE: NIH/GWH/PDS/17-21

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) : December 2017
Scheduled date of completion: July 2022 (Four Years)
Location : Sot River Catchment (Uttar Pradesh)



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, and 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 is drying-up in recent years after monsoon season, and its 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 river and suggest rejuvenation measures.

Methodology:

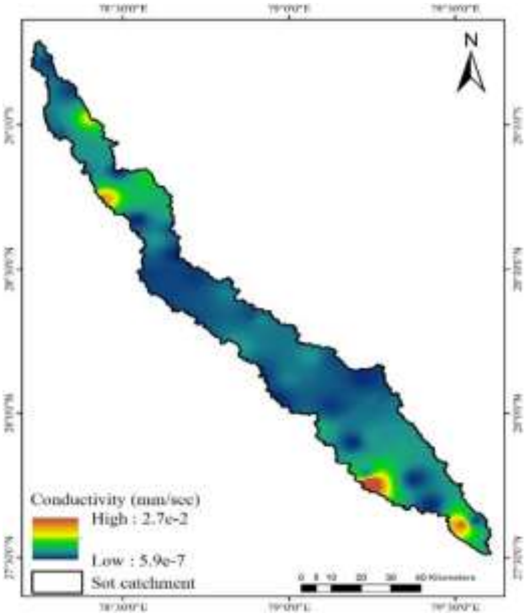
- Delineation of aquifers using litholog/ borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks software.
- Time series analysis by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river 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 Pettit technique 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.
- Estimation of surface water availability from river flow data using flow-duration curve and groundwater availability using GEC-2015 methodology.
- Vulnerability analysis using SAHP/DRASTIC approach.
- Catchment water balance using mass balance approach.
- Integrated surface water and groundwater modelling for river-aquifer interactions and future scenarios for river flows during lean seasons.
- Isotopic analysis to verify the reaches of recharge/discharge zones to/from the river.
- Development of plan for enhancement of surface and ground water resources.

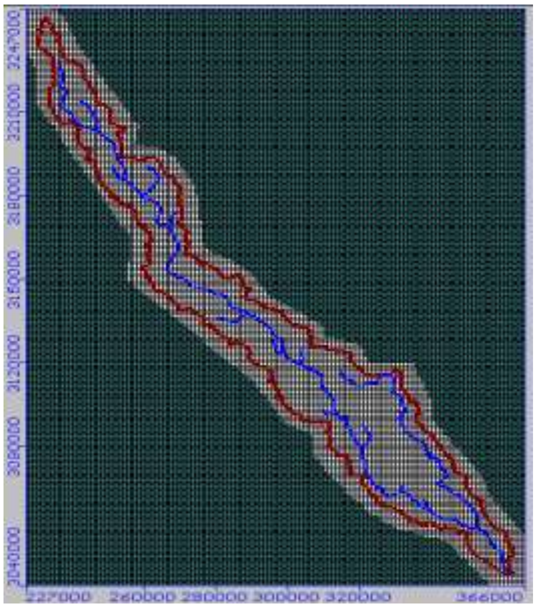
Objectives vis-à-vis Achievements:

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

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 was completed. The study area falls in the Uttar Pradesh state of India and covers an area of 3,027 sq.km. The elevation of the catchment varies from 138 to 245 m above mean sea level. Various thematic maps such as catchment boundary, catchment location, DEM, drainage, slope, soil, sub-basin, district/tehsil/road network, grid and land use have been prepared. Daily river flow data was collected and processed to analyze variations of river flow along with rainfall variation. Changes in land use and meteorological variables were also completed. Lithology data was processed and geological sections and fence diagram are prepared. Infiltration and hydraulic conductivity tests were conducted at 48 locations in the entire Sot river catchment for which infiltration and conductivity values were computed and infiltration equations were fitted. Disturbed and undisturbed soil samples were also collected from the same 48 locations of the catchment for the determination of soil properties.





(a) Variation of hydraulic conductivity, (b) Discretized catchment in the Modflow model

MODFLOW setup is in progress for the groundwater flow modelling. Litholog data is processed and hydro-stratigraphy is finalized. Import of aquifer layers in the model is completed including initial and boundary conditions. Groundwater recharge and withdrawals are being assigned to the model, then the model shall be calibrated and validated for the river aquifer interactions.

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.

Laboratory Facility used during the Study:

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

Data Procured/ Generated during the Study:

- Toposheets, DEM, Meteorological data, Soil information, Groundwater Levels, Landuse, River flows, Lithologs.

Study Benefits /Impact:

Increased surface water 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

7. PROJECT REFERENCE CODE: NIH/GWH/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 years (01/2018-01/2022)
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 University of Birmingham.

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;
- Recommendations for 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 research and water resource management institutions and projects.

Objectives vis-à-vis Achievements:

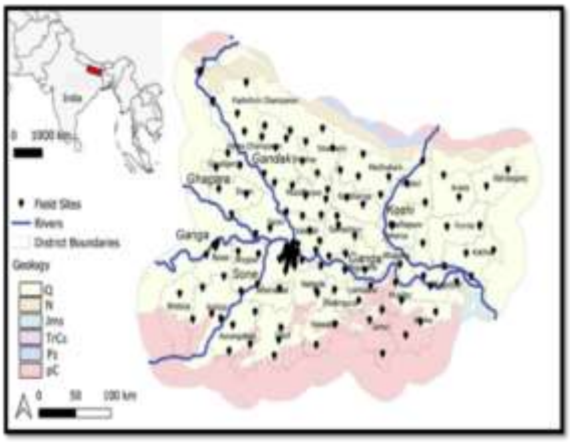
Objectives	Achievements
Produce a national risk assessment of shallow groundwater arsenic from carefully selected tectonic, geological, geo-morphological and climatic variables.	Completed
Produce recommendations for the remediation/ mitigation of human exposure and health risks arising from current and 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.	Completed

Progress

Review on various arsenic remediation technologies was done. The technical and socio-economic analysis of Arsenic removal technologies were based on the reliability, operational ease/simplicity, plant performance, affordability and social acceptability. Further, Life Cycle Analysis (LCA) was also conducted for assessment of environmental impacts associated with these arsenic treatment plants.

For arsenic remediation, nano material for injection was developed by IITR. For this, examined the 1D transport behaviour of synthesized Maghemite nanoparticles (NP) injected under partially saturated porous media. For pilot scale remediation practices using NPs, the strategies to find out the arsenic groundwater patches through geophysical technique and tracer experiments to indent the groundwater flow were worked out. For arsenic remediation using permeable reactive barrier (PRB), Pumice supported nZVI particles and maghemite (γ-Fe_2O_3) nanoparticles with 20 % iron loading were developed by IITR for PRB.

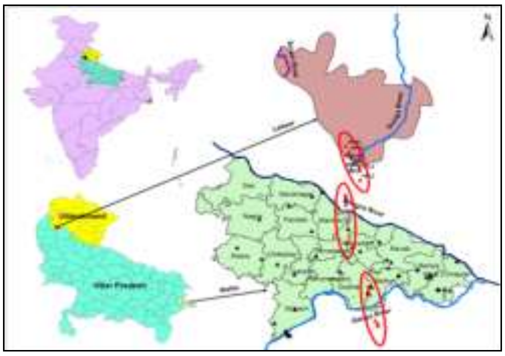
FAR- Ganga team discussing with villagers



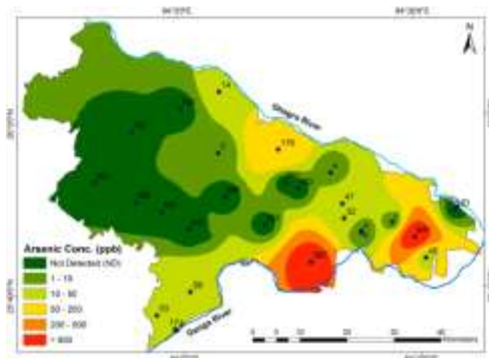
GW Sampling Sites in Bihar

For potential natural Hyporheic zone experimental sites, NIH carried-out GW and SW sampling in Bijnor and Moradabad area. Groundwater of both Bijnor and Moradabad area indicated arsenic concentration below permissible limit except few locations. Laksar (Uttarakhand) and Ballia (UP) were therefore identified as reference stretch for Hyporheic zone experimental sites. In Ballia, two sections were identified one on the Ganga River and another on the Ghagra river. Groundwater sampling being done from 8 locations on each section including one sample from river on quarterly basis. Sediments samples from river bed in Ballia and Laksar show As conc. above the equivalent acceptable limit for water (10 ppb). UoM in collaboration with MCS, UoB, NIH & IIT Kharagpur, with equipment provided by UoB (PROTEUS and TriOS), undertook cross-sectional boat surveys of organics in River Ganga in/around Patna (2018 & 2019 – seasonal comparison), Varanasi (2018) & Ballia (2019).

Sampling of 24 sites of Ganga and key tributaries by UoM-MCS-UoB team (Nov 2019) from Begusarai to Varanasi as part of wider Ganga survey along with groundwater sampling near selected SW sites throughout Begusarai to Varanasi corridor. Detailed groundwater sampling in Patna was done to better understand the extend and interactions within the hyporheic zone. These inputs were used for pollutant transport modelling.



Hyporheic zone experimental sites in Laksar (UK) and Ballia District, UP



Arsenic Concentration Map of Ballia District (UP)

For MAR analysis, water samples (77) collected from Ballia and Bahraich districts of UP and clusters of arsenic contaminated areas were identified. Maximum concentration of 641 ppb was found in Murli Chhapra block followed by Maniyar block of Ballia to select the MAR site to study positive/negative impacts of MAR. Continuous quarterly groundwater sampling at 32 locations in Murli Chhapra block of Ballia for chemical/isotopic analysis was done. Surface water quality was also monitored. 10 out of 32 samples (31%) were found above the acceptable limit of As. Arsenic occurred along the river Ghaghara and Ganga with no As contamination in central and upper part of Ballia District. Samples contaminated with As above acceptable limit were found contaminated with high Fe and Mn.

Mapping of arsenic was done and modelling was done using the machine learning models of 2-D spatial distribution of groundwater arsenic. First quantitative country-specific all India model of groundwater arsenic attributable cardiovascular disease mortality was developed. The project enhanced the understanding of the tectonic, sedimentological/ hydrogeological and mineralogical controls on the distribution of groundwater arsenic in India. Systematic randomised sampling survey of groundwater arsenic and uranium across Bihar provided improved representative hazard estimates. The ingress of organics from the River Ganga into the groundwater were characterized. Regional controls on hydro-geochemistry of arsenic prone aquifers identified. Importance of hyporheic zones and river-groundwater exchange to vulnerability of aquifers in the Ganga river basin was demonstrated and modelled. Vulnerability of some MAR systems on arsenic was also identified. Wheat and rice were identified as the major dietary sources of inorganic arsenic. Key factors controlling the effectiveness of remediation systems were identified. Novel patented materials were developed for remediation of groundwater arsenic were developed and patents have been filed.
The project outputs were dissemination through interaction with the stakeholders and contributed by focusing on arsenic-remediation approaches in Bihar through the Mahavir Cancer Sansthan Hospital and Research Centre, Patna. It was challenging to quantify the extent of arsenic to which this has arisen specifically from FAR-GANGA published papers or from related discussions and meetings made possible by the DST-NERC funding for FAR-GANGA project. Ongoing community science actions with colleges and schools in Bihar have resulted in extensive knowledge transfer and engagement leading to greater awareness of the scale and nature of the health impacts of chronic arsenic exposure.

24 research papers were published in Journals; 23 research papers were published in conferences/ seminars and 2 Patents were filed. Project Management Board Meetings (PMB) were successfully organized in India and UK through online platform.

8. PROJECT REFERENCE CODE: NIH/GWH/DST/18-21

Title of the study : Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micropollutants

Type of study (sponsored/consultancy/referred/internal): Sponsored Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund
Nature of study: Study components include technology development, technology dissemination, technology adaptation, capacity building
Duration: 01/2018 to 02/2022
India Project Partners: NIH Roorkee (India Lead); IIT Ropar; IIT Jodhpur
UK Project Partner: Cranfield University

Location Map

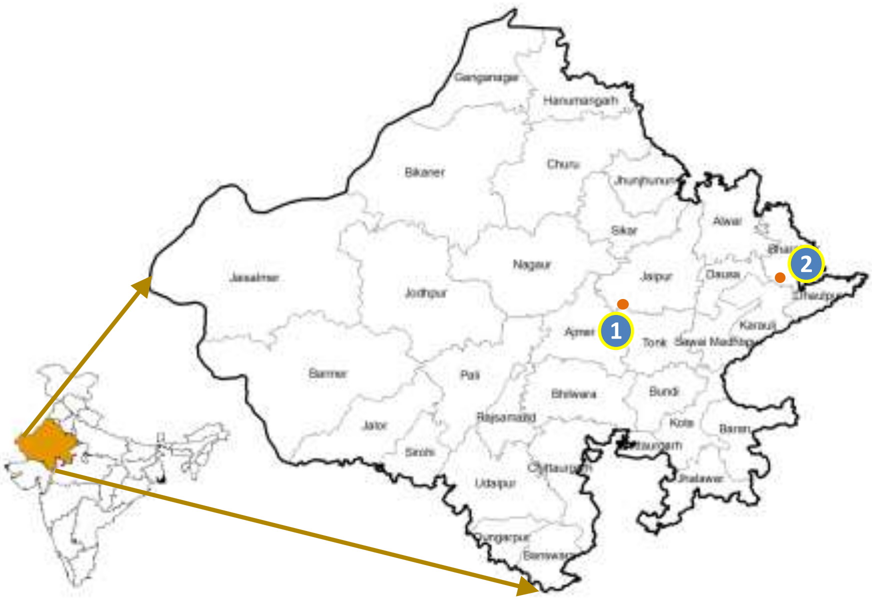


Fig. 1 Locations of study sites in Rajasthan

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 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
Evaluate water level and quality at selected MAR sites in Rajasthan.	Evaluation of water levels and chemical analyses of water samples at regular intervals completed.
Assess the proportion of recharged groundwater attributable to MAR systems at selected sites.	Groundwater recharge assessment for chauka system in Laporiya. Completed
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.	Work to be finalized.
Develop analytical protocols to facilitate the detection of micropollutants in water bodies	Work to be completed.
Understand the interactions of local users with the MAR structure and also their role in water management.	Completed.
Interaction with project partners and DST-NERC	Indo-UK Consortium Meeting (Sept 01, 2021), Indo-UK Consortium Workshop (Feb. 1 & 4, 2022), Indo-UK Consortium Brain Storming (Mar. 01, 2022), Project Presentation before DST-NERC (Mar. 4, 2022), Online meetings with Indian consortium.

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Water Quality Laboratory

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

9. PROJECT REFERENCE CODE: NIH/GWH/PDS/18-22

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

Type of study: Special Study under Centre of Excellence in Hydrological Modelling (NHP)
Date of start: April 2018
Duration of study: Six years
Location Map:

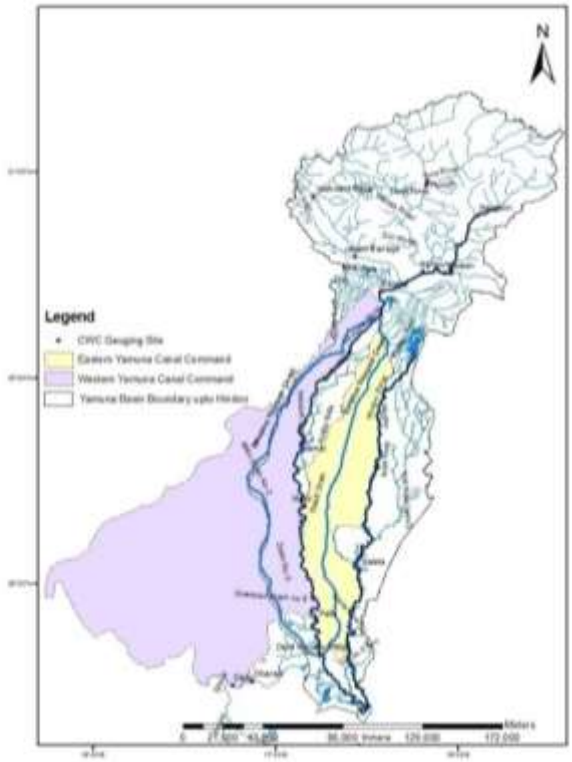


Fig. 1 Study area showing the Upper Yamuna Basin and command areas of EYC and WYC

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 modelling 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

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality	Application of hydrological models completed for SWAT, HEC-RAS, VIC, QUAL2K. Application ongoing for MODFLOW, MIKE HYDRO. Includes data collection from various agencies, field visits, data processing and analysis. In addition, equipment purchased under project.
Quantification of contribution of snow and glacier-melt through snowmelt modelling for Tons basin	Data processing and work on snowmelt runoff model WinSRM and SWAT in progress for Himalayan portion..
Assessment of changes in baseflow contribution to river Yamuna	Assessment of changes in baseflow contribution to river Yamuna completed.
Assessment of present and future water availability under Climate scenarios	Extracted data for study area, data processing, maps for climate change indicators
Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command	In progress using MODFLOW for Yamuna-Hindon Interbasin. Database buildup for WA+ tool to process spatial information on water depletion and net withdrawal using satellite measurements. GW related data collected for Eastern Yamuna Canal Command.
Formulation of adaptation measures in the context of climate change	To be taken up after assessment of future water availability
Flood frequency analysis and flood plain mapping of river Yamuna	River cross-section survey completed. Flood frequency analyses completed. Flood plain mapping for selected reach.
Assessment of anthropogenic activities on water quality	Field visits undertaken and data collected from central/ state agencies. Assessment of surface water quality of Yamuna river completed.
Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable gw resources	Modeling in progress using GIS based WetSpass distributed model. Field and lab experiments for soil parameters for selected sites completed.
Roll out of technical know-how through training workshops for partner organizations	One online training course organized for 24 officers of UP Ground Water Department.

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) Evaluation of impact of climate variability on renewable groundwater resources;
4) Training Workshops for State Department officials of UP and Haryana.

10. PROJECT REFERENCE CODE: NIH/GWH/DST/19-23

Title of the study Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water

Type of study (sponsored/consultancy/referred/internal): Sponsored by DST
Nature of study: Applied research
Duration: 02/2019 to 01/2024

Lead agency and project partners: CAZRI Jodhpur (Lead agency), NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur

Aims

- Enhancing water productivity at farming system as well as its components level
- Analyzing future demand and supply of water at regional and sub-regional level
- To develop improved methods for reusing industrial effluents in agriculture
- Capacity building of stakeholders in enhancing water productivity and developing policy guidelines

Objectives

I. To enhance water productivity in farming systems/regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
II. To develop improved methods for reusing industrial effluents in agriculture
III. To analyze future demand and supply of water at regional and sub-regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
IV. To develop policy guidelines and capacity building of stakeholders

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Enhancing water productivity at farming system as well as its components level	Field experiments undertaken with CAZRI to study the impacts of different irrigation schedules on the water balance components. Data being used in developing numerical model to study various irrigation management scenarios. Equipment purchase completed.
Analyzing future demand and supply of water at regional and sub-regional level	To be taken up with project partners
To develop improved methods for reusing industrial effluents in agriculture	Work by project partners
Capacity building of stakeholders in enhancing water productivity and developing policy guidelines	To be taken up with project partners

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Water Quality Laboratory

Deliverables & Beneficiaries: Beneficiaries will include farming communities in arid regions of Rajasthan. Deliverables include research papers, reports, software, manuals, brochures, flyers, users' interaction workshops.

11. PROJECT REFERENCE CODE: NIH/GWH/CCRBF/20-23

Title of the study:		Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF
Name of PI and members	:	**NIH, Roorkee, India** Dr. Gopal Krishan (PI and co-coordinator) **University of Applied Sciences Dresden (HTW Dresden/HTWD), Germany** Prof. T. Grischek (Project Leader) Dr. C Sandhu (Project Coordinator)
Type of study	:	**Sponsored,** Federal Ministry of Education and Research, Germany (BMBF)
Date of start (DOS)	:	**01** July 2020 (**Approval received in Feb, 22 Ministry of Jal Shakti & DEA**)
Scheduled date of completion	:	**30** June 2023
Location	:	Agra, Uttar Pradesh and others if necessary

S. No.	Study objectives	Achievements
1	Determination of the upper limit for removal of "emerging pollutants" by RBF	**30%** – Past data has been collected and plotted
2	Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra	**10%-** RBF technique has been proposed as an master plan for the nation and is being conceptualized for selected sites including one at Agra
3	Synthesis of information for inclusion in the RBF Master Plan and guidelines	20%- Literature on RBF techniques used in India has been collected from various sources

Statement of the problem:

Background

The floodplain of the Yamuna river between the National Capital Region of Delhi and the city of Agra (located approximately 200 km south of Delhi) is one of the most densely populated urban and rural regions in India (COI, 2011). Large quantities of untreated to partially treated domestic and industrial wastewater are discharged into the Yamuna between these two cities resulting in a critical river water quality (Agarwal and Trivedi, 1995; CSE, 2002; Seth and Babu, 2007). Despite the Yamuna's poor water quality, the river is a major source of raw water for domestic purposes for towns and cities located by it, including Agra city and for irrigation in the rural and semi-urban areas (GONCTD, 2013). After direct pumping from the river, the water is conventionally treated. However most of these conventional drinking water treatment plants are technically unable to remove the high concentrations of micro-biological, organic and inorganic parameters present in the river water thereby either resulting in deliberate interruptions in drinking water production or in widespread consumer dissatisfaction due to noticeable and unacceptable organoleptic quality of the supplied water (CSE, 2002; Sandhu et al., 2011). Furthermore there is a widespread perception amongst the consumers that the water supplied in the taps is unsafe for consumption without prior treatment at the household level. That is why many households typically use reverse osmosis filters. There are also many areas that are not connected to the piped water supply. These areas have to rely either on groundwater (vertical wells, handpumps) or water delivered in tankers that is expensive and is not affordable by many people.

By using wells installed on the banks of flowing rivers, river bank filtration (RBF) combines the advantage of easy access to large volumes of induced surface water (SW) with the benefit of an improvement in water quality due to natural treatment processes occurring during aquifer passage. Field investigations at various locations across India including in Uttarakhand and the Yamuna floodplain (Delhi and Mathura) have confirmed that there is a large potential to use RBF as an alternative to directly abstracted SW for drinking water production, primarily because it provides an ecosystem service by effectively removing pathogens and turbidity even in monsoon (Sandhu et al. 2011, 2016).

Proposed solution, technological intervention and demonstration up to 2018

In light of the previously described background and scientific investigations conducted on RBF at locations in Uttarakhand, NCR Delhi and other parts of India within the framework of the Saph Pani project (2011 – 2014) accompanied with construction of pilot RBF schemes in Uttarakhand, NIH was motivated to demonstrate RBF technology at six sites across India, including Agra, that have diverse environmental conditions within the project Peya Jal Suraksha (PJS, 2015–2018) funded by the Ministry of Jal Shakti (NIH, 2019). Consequently, the site in Agra was first investigated with standard geophysical, geotechnical and water quality investigations. Accordingly, the site was found feasible for the construction of a vertical exploratory well. The well was constructed on the riverbank in the premises of the Agra waterworks at Jeevani Mandi in February 2018. Due to the scheduled termination of PJS in 2018, only one water sample could be analysed during development of the well in 02/2018. Further investigations, including geohydraulic measurements (water levels monitored for at least one hydrological year) and water quality, could not be conducted. So it was not possible to evaluate the purification efficiency of the RBF system at Jeevani Mandi, because the system only became operational when the PJS project concluded.

Nevertheless, water quality investigations conducted at an existing high capacity horizontal RBF well in Mathura by collaborators from IIT Roorkee in 2007/2008 and subsequently by NIH Roorkee, HTW Dresden and TU Dresden at the same RBF well in Mathura and Yamuna river and near-bank groundwater from 2013 onwards in Agra and Mathura within the framework of the Saph Pani project and Indo-German Competence Centre for Riverbank Filtration (MoU NIH & HTWD, 2011) showed a high potential for RBF as a pre-treatment step for drinking water production. The main advantages of RBF in Agra-Mathura region are an improvement of organoleptic parameters (taste, odor and aesthetic appearance) and a substantial lowering of concentrations of organic compounds including dissolved organic carbon (DOC), turbidity and pathogens and a low risk of formation of disinfection by-products. The main positive observation is that while river water DOC concentrations are high and show a large seasonal fluctuation of around 9 mg/L (3 mg/L in monsoon – 12 mg/L in non-monsoon), the concentration of DOC in the RBF wells was found to be substantially lower at 3 mg/L and 6 mg/L in monsoon and non-monsoon respectively. Removal of total and fecal coliform of 1.3–1.7 and 2.3–3.2 $\log_{10}$ units respectively was observed at the high capacity RBF well in Mathura. Thus RBF can serve as an important pre-treatment step and provide cost-savings for post-treatment.

Validation, demonstration and exploitation of RBF technological intervention post 2018

With the impending conclusion of project PJS in 2018, NIH and HTWD endeavored to exploit the infrastructure created in PJS (pumping well), in a new collaborative project. The rationale for this is given below. None of the following were possible to investigate in the predecessor project PJS:

1. Validation of RBF process:
    a. Possibility to investigate the upper limit of the purification capacity for RBF w.r.t. organic micropollutants and pathogens because the Yamuna river is one of the most polluted rivers worldwide
    b. Comparison of RBF water quality with directly abstracted and conventionally treated surface water treated at the same location
    c. Investigation of the effects of aquifer anisotropy (hydraulic conductivity changes in vertical/z-direction due to intermittent low and high conductivity layers) because the subsurface stratification found in the Yamuna floodplain in Agra is similar to many locations in the Ganga-Yamuna basin
    d. Estimation of the portion of bank filtrate in pumped water from well and travel time of bank

filtrate from river to well

2. Demonstration of RBF scheme:
   a. Development of existing well into a demonstration site for RBF to show how a RBF site should be made and to display the benefits of RBF
   b. Creation of infrastructure to monitor the RBF site by construction of at least 1 monitoring well
   c. Demonstration of the purification capacity of RBF for conditions typical of extremely polluted rivers with complex subsurface geology

3. Exploitation of above by:
   a. Development of a science-based masterplan for RBF water supply in India using above scientific results
   b. Revision of existing guidelines on RBF into a second edition that will incorporate scientific / technical experiences of above
   c. Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra

Whether Study is a New Study/Extension of Previous Studies: New study

Methodology:

NIH has already established the abstraction well infrastructure at the site at Agra in PJS project (2015-2018) including vertical borewell with submersible pump, provision of electricity supply to pump and construction of pump house. Samples will be collected from river, RBF exploratory well, adjoining drainages and groundwater to assess the removal of emerging pollutants and pathogens. So the main focus of this project will cover validation, demonstration and exploitation aspects (discussed above), especially:

- Determination of the upper limit of removal of "emerging pollutants" by RBF
- Equipping the site with water quality monitoring infrastructure
- To equip site with promotional/information materials on research done at site

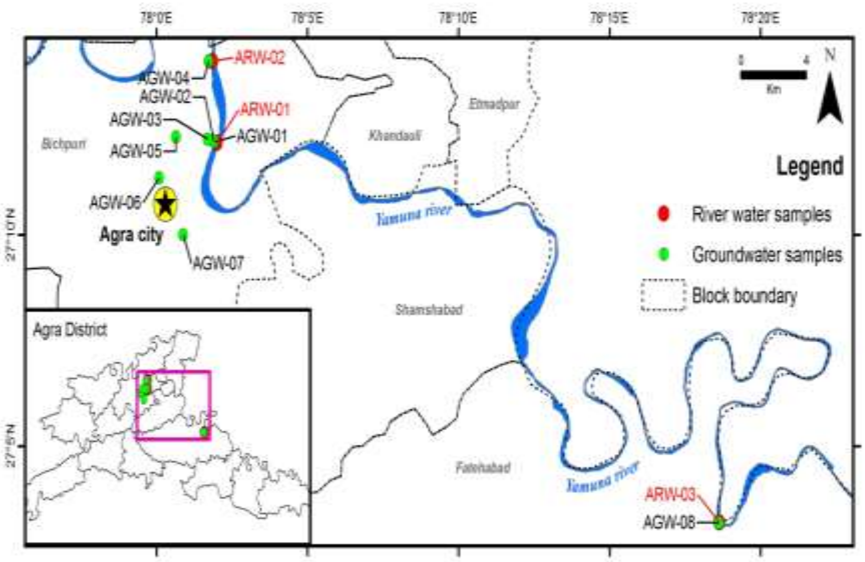


Fig. 1. Study site

Progress

1. Work package/WP 1: Strengthening of network/collaboration

   a. Completion of administrative formalities by signing Cooperation Agreement with 7 other Indian partners and 7 German partners in CCRBF consortium (total 15 partners).
   b. Obtaining permission from Ministry of Jal Shakti and Department of Economic Affairs, Govt.

of India, for NIH to be a partner of CCRBF consortium and to participate in CCRBF project activities.

c. Signing of Transfer Contract with HTWD (CCRBF project coordinator) to receive funds from the funding agency BMBF, Govt. of Germany.
d. Application to MoJS to extend the existing MoU between NIH and HTWD on "Indo-German Competence Centre for Riverbank Filtration" (IGCCRBF) for third phase from 2021 to 2026.
e. Participation in 3 project/consortium meetings (online due to Covid-19 pandemic) on 21 July 2020, 03 February 2021 and 08 July 2021
f. Participation in online CONNECT programme meeting organized by BMBF on 18 November 2021

2. WP2: Development of RBF demonstration site Agra

Due to the Covid-19 pandemic, especially the critical second wave from March to May 2021 and subsequent monsoon season, it was only possible to commence field work in Agra from

a. Scientific-technical support to CCRBF German partners HTWD & TUD for field investigations in Agra, liaison with stakeholder UP JAL Nigam (Oct. – Dec. 2021 & Mar. 2022)
b. Collection and analyses of water samples for Oxygen-18 and Deuterium isotope analyses
c. Scientific and logistic support to Mr. J. Nainan, student (Indian national) of TU Dresden who is doing hydrogeological investigations for Agra site for his master thesis
d. Field work comprising water sampling, shallow drilling with auger/tripod to determine groundwater level at site (planned 3rd week March)

3. WP3 to WP5: Guideline for RBF in India (WP3), Education & Training (WP4) and RBF masterplan (WP5)

In progress. Results from WP2 will be synthesized into these WPs and accordingly disseminated/exploited.

4. WP6: Dissemination and exploitation of results

NIH contributed/disseminated for the period 01 July 2020 to 31 March 2022 as follows (details in annexure 2):

- 7 conference presentations (annexure 2, s.no. 1 to 7)
- 1 ad hoc presentation at meeting with Ministry of Jal Shakti, New Delhi, on 29.11.2021 (annexure 2, s.no. 8)
- 1 brainstorming session organized by Uttarakhand State Council for Science & Technology (UCOST), Dehradun, 31.07.2021 (annexure 2, s.no. 9)
- 2 peer-reviewed book chapters (1 submitted & 1 published)
- 3 conference proceedings

1 article in India's leading water industry publication "Everything About Water"

Action plan:

Period	**July 2020 to June, 2023** (Annexure 1)	**Remark**
July 2020 to June 2023	Monitoring of the site regularly Establishing the site with monitoring infrastructure Project works as listed in section "Validation, demonstration and exploitation of RBF technological intervention post 2018" Preparation of revised RBF guidelines and masterplan on RBF for India Prepare a status report	Report preparation as per Annexure 1 and dissemination activities as per Annexure 2

Study Benefits /Impact:

- The result will be the creation of a road map within framework of RBF masterplan to increase contribution of RBF to total drinking water supply from currently less than 1% to at least 5% by 2030.
- Strengthening Indo-German/European scientific collaboration on managed aquifer recharge/RBF
- The project has a high socio-economic relevance for the underprivileged households living in Jeevani Mandi area of Agra because before implementation of the action they had no access to safe drinking water and after implementation of action they have access to safe drinking water.
- informing and collating experiences/knowledge; capacity development and strengthening competence on MAR/RBF.
- evaluating existing work bases and sharing or making them known within the network synergies with other Indo-European projects (e.g. DST–EU-Horizon2020 funded projects)Keeping in mind the title of the CCRBF project, viz. “Expansion of the Indo-German Competence Centre for RBF”, the inclusion of an additional and potential RBF site by the Sutlej river in Punjab is being considered (Phillaur town in Ludhiana urban area). It is hoped to thereby transfer RBF experiences and to expand the RBF network to Punjab that is affected by aquifer depletion and deteriorating groundwater quality due to groundwater over abstraction. Thereby the thematic topic of RBF within the “food-water-energy” nexus can be investigated in North India. This topic has been studied in South India under different hydro-climatic and environmental conditions.

Specific linkages with Institutions:

- German partners: TZWD, TUD, FHP, AUT, AKUT
- Indian partners: UJS, BHU, CSIR_CMERI, BBEC, AU, IITM, TERI, UPJN

Activity schedule for expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF (quarter-wise wise from July 2020 to June 2023)

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Data Collection	♦		♦		♦		♦		♦			♦
Sample collection and analysis			♦			♦			♦			
Equip the site with modern infrastructure				♦	♦	♦	♦	♦				
Organization of trainings/knowledge dissemination				♦				♦				
Final Report/Publication(NIH-HTWD)											♦	♦

Progress

- One introductory meeting is held online with all partners
- See previous section “Progress”

Future plan

- Use of synergies from the competence-pool of RBF/CW/MAR through training and thematic cooperation between partners and stake holders
- See previous section “Action plan”

12. PROJECT REFERENCE CODE: NIH/GWH/DST-SERB/21-24

Title of the study Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen

Name of PI and members : **NIH, Roorkee, India**
Dr. Gopal Krishan (PI)
Dr. M.S. Rao (co-PI)
IIT-Kanpur
Dr. Shivam Tripathi (PI)
Dr. Richa Ojha (Co-PI)
Dr. Rajesh Srivastava (Co-PI)
Dr. Saumen Guha (Co-PI)

Type of study : **Sponsored,** DST-SERB
Date of start (DOS) : April 2021
Scheduled date of completion : March 2024
Location : **NIH** Roorkee and IIT-Kanpur

S. No.	Study objectives	Achievements
1	Estimate evapo-transpiration (ET) flux at a study site in Kanpur	**20%** – Experiments has been set up at IIT Kanpur
2	Partition ET flux into soil evaporation (E) and plant transpiration (T) fluxes, and investigate ➢ diurnal fluctuations in the fluxes; ➢ variations in the fluxes during a cropping season; differences in fluxes between Rabi & Kharif seasons,	%- Work in this will start soon
3	Quantify uncertainties in the estimates of E, T and ET fluxes	**20%-** Experiments to finalize methodology are in progress

Statement of the problem

The irrigation water demand in the Ganga basin is among the highest in the world (more than 90% of the total freshwater used in the basin). A major portion of the applied irrigation water eventually evapotranspires. The transpiration (T) component of the evapotranspiration (ET) is associated with crop productivity, while the undesirable soil evaporation (E) component represents losses. The knowledge of the relative magnitude of E and T fluxes in ET is therefore essential to design efficient irrigation techniques. The knowledge of ET partitioning is also crucial to understand the mechanism of energy and moisture transfer in the soil-plant-atmosphere continuum. In spite of its importance, few, if any, studies have investigated ET partitioning over the Ganga basin. In this project, we propose to estimate E and T fractions of ET by conducting field experiments at a site in the Upper Ganga Plains. A method based on stable isotopes of oxygen and hydrogen will be used. The main outcome of the project will be an understanding of the diurnal, inter- and intra- cropping seasonal variations in ET partitioning over rice-wheat system at the study site.

Estimation of evaporation (E) and transpiration (T) components of evapotranspiration (ET) is critical for the closure of energy and water balance equations in a hydrological study. Traditional hydrological modelling approach of lumping different components of ET into a single term has many disadvantages because the processes governing different components of ET have different physical characteristics, time scales and responses to climate feedbacks. Partitioning of ET is important to improve irrigation practices, particularly in water limited environments. The T component of ET is associated with crop productivity, while the undesirable E component represents losses due to soil evaporation. Thus, knowledge of ET partitioning can help in designing irrigation techniques that increase the fraction of T in ET, thereby improving water use efficiency. The main objectives of the project are to understand the diurnal, inter- and intra- cropping seasonal variations in ET partitioning over rice-wheat system at the study site in Kanpur.

The methods developed for ET partitioning can be divided into two categories – (i) stable isotope based method and (ii) hydrometric method. The isotopic method partitions ET based on the differences in the isotopic signatures of evaporated and transpired water. When water evaporates from soil it fractionates, i.e. the concentration of heavier isotopes enriches in the soil water and depletes in the vapour formed. However, negligible fractionation occurs during transpiration. Thus, by knowing the isotopic compositions of E, T and ET, the relative contribution of individual components can be estimated. The hydrometric method partitions ET by directly measuring E, T, and ET fluxes. The reliability of this method depends on the quality of individual flux measurements.

Whether Study is a New Study/Extension of Previous Studies: New study

Methodology:

To achieve the objectives stated in the proposal, the work is divided into 4 tasks. The following describes the methodology for implementing each task.

Task 1: ET partitioning by using Isotopic method

The key concept behind the isotopic method is that the heavier isotopes of oxygen and hydrogen in water $\left({}^{18}\mathrm{O}\text{ and }{}^{2}\mathrm{H}\right)$ have different physical properties than the abundant isotopes $\left({}^{16}\mathrm{O}\text{ and }{}^{1}\mathrm{H}\right)$. The following methodology will be followed to estimated isotopic signatures of ET, T and E fluxes.

Estimation of δ_{ET} : The value of δ_{ET} will be estimated by *Keeling plot method* (Keeling, 1958). The method assumes that the atmospheric water vapour in the boundary layer is the combination of background vapour already present and ET flux added locally to it.

Estimation of δ_{T} : We propose to use two methods. In *the first method*, the value of δ_{T} will be obtained by measuring the isotopic composition of xylem water $\left(\delta_{\mathrm{x}}\right)$ in the plant. Under the assumption that there is no fractionation during the transpiration process, δ_{T} will be equal to δ_{x}. In *the second method*, the direct measurement approach proposed by Wang et al. (2012) and successfully applied by Wei et al. (2015) and Dubbert et al. (2014) will be used. This approach uses a customized leaf chamber filled with high purity nitrogen to collect vapour transpired by the leaves. Mass balance equation is then applied to water vapour and water vapour isotopes inside the leaf chambers to estimate δ_{T}.

(i) *Estimation of* δ_{E} : The value of δ_{E} will be obtained by applying the *Craig-Gordon model* (Craig and Gordon, 1965) that accounts for equilibrium and kinetic fractionation during phase change, and diffusion of water vapour from the soil surface to the atmospheric boundary layer.

Task 2: ET partitioning by using hydrometric method

The ET partitioning results obtained from the isotope based method in Task 1 will be corroborated by hydrometric method in Task 2. The hydrometric method partitions ET by estimating the magnitude of ET, and E and/or T fluxes. In this study, we propose to measure all the three fluxes independently

(i) *Estimation of* ET: The magnitude of ET flux will be obtained by *Bowen ratio method*.

(ii) *Estimation of* T: The magnitude of T will be estimated by measuring the rate of sapflow in the plant stem. In this *sapflow method*, a constant low grade source of heat will be attached to the plant stem, and the resulting heat fluxes in the vertical and radial directions will be measured. The rate of sapflow will then be estimated by applying the energy balance equation.

(iii) *Estimation of* E: We proposed to measure E by using *micro-lysimeter* (ML). The ML, also called mini-lysimeter, consists of a cylindrical tube of small diameter (generally between 0.1m to 0.3m). The tubes are inserted into the soil without disturbing the soil structure, particularly the upper soil structure is maintained.

Task 3: Estimation of interception losses

The interception losses will be determined by calculating the differences between the amount of rainfall collected by rain gauges outside the canopy (total rainfall) and the amount of rainfall collected by rain gauges (or catch cans) under the canopy (net rainfall). This method of finding the *difference between total and net rainfall* to estimate interception losses is the most common method for different kinds of vegetation including crops (Ward and Robinson 1999). As the method ignores stemflow, the estimated interception losses may have a positive bias. We propose to measure stemflow at a few randomly selected plants by placing collection cups sealed around the stem near the base of the plants. In addition, water wiping method (Wang et al., 2006) will be used for a few storms to account for the biases, if any, in the estimates of interception losses. The uncertainty in interception loss estimate can be due to uncertainties in rainfall measurement, sampling bias in determining net rainfall, and errors in stemflow measurements.

Task 4: Quantification of uncertainties

Uncertainties in the ET partitioning may arise from observational uncertainty, parameter uncertainty and model uncertainty. In this study, we propose to use the approach given in ISO Guide to the Expression of Uncertainty in Measurement (GUM, 2008). The uncertainty will be quantified at every step and will be propagated all the way to quantify uncertainties in the estimate of E and T fractions of ET. For the forward propagation of uncertainty, Mote Carlo method will be used where the tractable analytical expressions will not be feasible.

Progress

As part of project, the following work has been completed at the NIH-Roorkee to date:

a) Collection of Air moisture samples: Moisture in the form of vapour behaves similarly to any other gas. Even when it mixes with other gases in the air, it retains its identity and features. The conventional method to harvest moisture is cooling the ambient air below its dew point and collecting the condensate.

For our study, we used the cone-condensation technique to collect the air moisture samples. Depending on the prevalent relative humidity, the time taken to collect the air moisture sample varied (as shown in the table below).

Date of sampling	Average Relative Humidity (%)	Time taken to collect 15 ml sample (minutes)
27/12/2021	76	180
04/01/2022	97	30
15/02/2022	73	210

b) Collection of Plant transpiration samples: The physiological process by which excess water is lost from living tissues of plants in the form of vapours is known as transpiration. For our study, transpiration bags were used to collect the plant transpiration samples. The stomata disperse water into the atmosphere, which can be collected using transpiration bags.

To date, we've collected a large number of plant transpiration samples and studied their isotopic composition. Currently, we have set up transpiration bags at different elevations to determine the variance in sample volume collected.

c) Model development to collect soil evaporation and evapotranspiration samples: We used a cold trap set up to collect samples. In the previous set up, the air was pushed to the glass tube through connecting pipes. The glass tube was kept inside a cylindrical thermosteel flask containing ice as coolant (refilled twice a day) to condense the vapors that were pushed by the pump. The entire set-up was sealed using plastic sheets and weights on the border in order to avoid any leakage/contact with external environment. The vapors got condensed and were collected as liquid droplets in the glass tube. The problems associated with our previous set up were **(i)** Exposure of the outlet pipe to the surrounding atmosphere **(ii)** No provision for temperature and humidity measurement (**iii)** Presence of atmospheric moisture representation in collected soil moisture sample.

Our current model, which is made of transparent Acrylic Sheet (5 mm thickness) and measures 75x75x60 cm, includes an air compressor for suction and trapping the soil evaporated vapors in the glass tube. To control the suction and trap process, the compressor is linked to a rotameter and a nozzle valve. This model was designed to overcome the drawbacks of our previous experiment set up.

d) Miscellaneous: Apart from the above mentioned work, different literatures related to sampling of air moisture, plant transpiration, soil evaporation and evapotranspiration sampling are being continuously studied to achieve better results. Moreover, a paper entitled “Methodological considerations for the collection of Air moisture for Isotopic Analysis” would be presented in the Roorkee Water Conclave 2022.

Action plan

Period	**April 2021 to March, 2024** (Annexure 1)	**Remark**
April 2021 to March 2024	Installation of instruments Collection of waters samples, isotope analysis Data analysis and uncertainty quantification Data dissemination and report writing	Report preparation as per Annexure 1

Study Benefits /Impact:

1. Diurnal, inter- and intra- cropping seasonal variations in soil evaporation (E), plant transpiration (T) and evapotranspiration (ET) fluxes at the study sites. 2. A methodology to quantify uncertainty in ET partitioning. In addition, the results obtained and methodology developed during the proposed project will be useful for - (a) validating process based hydrological models that estimate E and T fluxes separately, and (b) improving irrigation efficiency by developing agricultural practices that reduce soil evaporation losses.

Specific linkages with Institutions:

- IIT Kanpur

Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen **(quarter-wise from April 2021 to March 2024)**

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Literature review	♦	♦										
Installation of instruments	♦	♦	♦	♦								
Collection of waters samples			♦	♦	♦	♦	♦	♦	♦	♦		
Isotope analysis			♦	♦	♦	♦	♦	♦	♦	♦		
Data analysis and uncertainty quantification						♦	♦	♦	♦	♦		
Data dissemination and report writing											♦	♦

Future plan

- Experiments will be continued to achieve the desired objectives

13. PROJECT REFERENCE CODE: NIH/GWH/APN/22

Title of the study	Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools
Name of PI and members	**NIH, Roorkee (**Partner organization**)** Nitesh Patidar (PI), Surjeet Singh, Gopal Krishan, *IIT Roorkee* (Lead organization): Basant Yadav (PI), Ashish Pandey, R D Singh, Bhaskar Jyoti Deka *KU, Japan* (In-kind support): Yutaka Matsuno, *PNU, South Korea*: Sanghyun Jeong
Type of study	**Sponsored,** Asia-Pacific Network (APN)
Date of start (DOS)	01 Jan 2022
Scheduled date of completion	31 Oct 2022

Objectives vis-à-vis Achievements

The project is aimed at finding and disseminating an integrated approach for site suitability mapping of MAR under changing climate that suits the most affected parts of India, including states of Rajasthan, Punjab, Haryana, and Delhi. This involves developing a knowledge base to bridge the gap between science and decision-making to ensure effective implementation of MAR schemes. Thereby alleviating water supply problems, even as a measure to mitigate climate change. The capacity building program will aim at enhancing the capacity of implementing agencies, NGOs, and communities in implementing Managed Aquifer Recharge (MAR) projects effectively.

S. No.	Study objectives	Achievements
1	Disseminate knowledge on MAR, climate variability, and emerging planning tools and techniques. This would primarily be aimed at forming a necessary base in the trainees to understand various groundwater processes, groundwater-climate interactions, and sustainable MAR planning	A five-day training is planned to be conducted during Jun 2022
2	Develop and disseminate an integrated approach, considering quantity and quality, for site suitability mapping for MAR under changing climate to support effective MAR planning in the identified Indian hot-spots. The integrated approach will utilize remote sensing and machine learning-based hydrological modeling tools	Development of web-portal and a web-application is under progress. A training will be organized in Jul 2022
3	Evaluating the MAR projects using available field observations and hydrological models	A workshop will be conducted during Aug 2022

Problem statement

In the states with inadequate surface water supplies and low rainfall, the major part of irrigation water is provided using the groundwater source. Under the threat of climate change, groundwater resources, therefore work as a cushion against climate variability. Managed aquifer recharge (MAR) has already been accepted as a reliable approach for groundwater recharge, however, the implications of such recharged water on groundwater quality are still not well understood. Nevertheless, to tackle the twin hazards, alarming decline in groundwater levels, and consequent deterioration of groundwater quality, artificial recharge has now been widely propagated in India. Central Ground Water Board (CGWB) in 2013 proposed the master plan for artificial recharge to groundwater in different states. Recently, a more detailed master plan for artificial recharge to groundwater (2020) is proposed identifying the total area for artificial recharge of 11.23 lakh sq. km. However, this large scale recharge project can only succeed if the implications of MAR on environment and health at the local, regional and global scale are well understood. Global knowledge sharing and capacity building at the local scale would make sure that the MAR projects are well planned and have the potential to tackle challenges in MAR development, operation, and management.

The capacity building trainings and workshops will attempt to address various issues relating to the MAR development, operation, and management at the local and regional scale. The site suitability mapping using Multi-Criteria Decision Analysis (MCDA), Google Earth Engine, machine learning, and hydrological models will help the scientists, policymakers and other relevant stakeholders in addressing the issues of water quantity/quality and climatic variability. The developed science-based knowledge platform along with theoretical documents and hands-on manuals will help various stakeholders (civil society and policymakers) in addressing the issues of MAR design, sustainable operation strategy and management at regional and global level as well.

Progress

The methodology for site suitability mapping for Managed aquifer recharge is being developed. Multi-criteria Decision Analysis (MCDA) is being used for identifying the potential sites considering various influencing factors, such hydrological, topographical, climatological and geological. The methodology is being tested for Jaipur district. A web-application is being developed for MCDA using Google Earth Engine (GEE) cloud-based platform and Python programming. The web-based toll will allow quick mapping of the suitable sites on the web wherein the outputs could be downloaded for further analysis. A web-portal is being developed for disseminating knowledge on MAR. The portal will be utilized for conducting the training and disseminating lecture, video tutorials, manuals and sample data sets for training. Two trainings and one workshop are being planned for the officers of Rajasthan, Haryana, Punjab and Delhi.

Action plan and timeline (month-wise from Apr 2022 to Oct 2022)

Work element	Apr 2022	May 2022	Jun 2022	Jul 2022	Aug 2022	Sep 2022	Oct 2022
Preparation of methodology for site suitability mapping for MAR							
Selection of trainees from the Indian hot-spots where MAR is required							
Preparation and dissemination of training modules, and documents							
Organization of training and workshops							
Report preparation and submission							

New Study Proposals

14. PROJECT REFERENCE CODE: NIH/GWH/NIH/22-25

Title of the Project: Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin

Study Team:
Dr. Sumant Kumar, Sc-D, GWHD & PI
Dr. Surjeet Singh, Sc.-F, GWHD
Dr. Rajesh Singh, Sc.-D, EHD
Dr. Gopal Krishan, Sc-D, GWHD
Dr. Soban Singh Rawat, Sc.-E, HID
Dr. M.K. Sharma, Sc.-E, EHD
Dr. Nitesh Patidar, Sc.-B, GWHD
Dr. P. K. Mishra, Sc.-D, WRSD
Dr. M.K. Goel, Sc.-G & Head, GWHD

Collaborator : CGWB, Dehradun and NIT, Patna
Type of study **:** Internal (New)
Date of start (DOS) **:** April, 2022
Scheduled date of completion: March, 2025 (3 Years)
Location **:** Ganga basin (From Gangotri to Patna)

Objectives:

(i) Mineralogical characteristic of sediments and water chemistry in the Indian Himalayan region to detect genesis of arsenic.
(ii) Demarcating safe aquifer for drinking water supply in arsenic affected areas
(iii) Performance evaluation of existing treatment units and their comparison in terms of cost, efficiency and ease of operation etc in the central Ganga basin.
(iv) Developing a new treatment technique with high removal efficiency in optimized cost.

Statement of the problem:

Chronic exposure to groundwater having an arsenic concentration of more than 10 μg/L leads to numerous adverse health impacts like lower intelligence quotients, type 2 diabetes, skin lesions, melanosis, keratosis, and cancer etc. Arsenic (As) contamination of water is producing the greatest impact on livelihoods in terms of public health and thus arsenic calamity in the Ganga river basin put millions of population in danger. Arsenic is a natural constituent in bedrock and soil. It usually occurs at low concentrations (average 1–2 mg/kg) in the Earth's crust, but may be concentrated in certain rock types and especially in gold and sulphide-bearing ore deposits and occurrences. Pyrite [FeS_2; or arsenian pyrite $Fe(AsS)_2$] and arsenopyrite [FeAsS] are typical sulphide minerals containing As. Weathering processes of rocks and minerals appears to be a major source of arsenic found in soils. Because it accumulates due to weathering and translocation in colloid fractions, the arsenic concentration is usually higher in soils than in parent rocks. Under typical soil forming conditions, the nature of arsenic in soil is controlled by the lithology of parent rock materials, volcanic activity, bioactivity, weathering history, transport, sorption, and precipitation. The river Ganga and its major tributaries originate from the Himalaya and carry lots of sediment and these sediments determine the chemistry of water. In the mid Holocene period, the river Ganga likely to transport metals from Himalaya to the plains by erosion and sedimentation. The rivers originating from the Siwalik Hills are reported to release more arsenic and heavy metals from their sediments in comparison to those major rivers originating from the Higher Himalaya. In order to study the causes of arsenic occurrence in Ganga basin and its mobilization from solid to water phase, it is planned to carry out mineralogical, geochemical and mobilization study. The significance of the study is to help in demarcating safe aquifer, improved monitoring and mitigation measures at regional level.

With the grave problems of arsenic in India, Inter-Ministerial Group (IMG) on Arsenic Mitigation was constituted on the directions of Cabinet Secretariat by erstwhile Ministry of water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR) vide order No. 11014/1/2014-GW Desk (Part-V) dated 22 Dec. 2014 under the Chairmanship of Mission Director (MD), National Water Mission (NWM). The IMG desired that National Institute of Hydrology (NIH), Roorkee should take lead role on R & D activities related to "Arsenic Mitigation" as per the areas suggested by the 'Core Committee' on "Mitigation & Remedy of Arsenic Menace in India". The DoWR, RD & GR, Govt. of India (letter no. 50013/177/2020-E.II dated 20/07/2020) advised NIH to seek funding under the subcomponent “Sponsoring and Co-coordinating research in water sector” and accordingly may submit a project proposal to INCGW. A project proposal with budgetary requirement of 1259.50 Lakhs was submitted to INCGW with detailed work component and budget of multi-institutions. Now, INCGW provided their comments/suggestions for submitting the project proposal. The NIH is under process for incorporating the comments/suggestions and the project proposal would be submitted again to INCGW for their considerations. The GWHD wish to start working on project components pertaining to NIH under internal funding till receive the funds from INCGW considering national importance of project.

Proposed Methodology:

The study will cover the detailed hydrogeology and geochemistry of the As-contaminated aquifer of the Ganga basin. A Pre-monsoon and post-monsoon grid-wise sampling would be done in upper and middle Ganga basin to study the spatio-temporal variation of water quality parameters including arsenic. The sediment samples at different location would be collected from upper and middle Ganga basin focusing on Himalayan sediments for sediment characterization using XRD & XRF techniques. The mineralogical study would help in identifying the minerals of arsenic present in the Ganga basin.

Integrated hydrological survey of As concentrations would be carried out in the Ganga basin by using field test kits and collecting preserved samples for further analyses by more precise analytical instruments in laboratory. Groundwater and surface water samples will be collected during multiple field campaigns (pre-monsoon and post-monsoon season) from both deep and shallow aquifers. In addition to that, sediment samples (from hilly and plain region along with river bed material) would be brought out to lab for further analyses. The locations of the wells will be marked using a hand-held global positioning system (GPS). Unstable parameters and indicators of the oxidation state of ground water will be measured in the field. Field measurements will include temperature, electrical conductivity (EC), pH, oxidation-reduction potential (ORP) and dissolved O_2. The measured stable value of these water quality parameters will be representative of *in-situ* conditions. Samples will be filtered in the field with disposable 0.45-micron filters and will be collected for all major anions, cations and trace elements for further laboratory level analysis. Different analytical instruments would be used for analyses of ions and metals. Performance of existing treatment technology available and which are being used in arsenic affected areas would be evaluated. The influent and effluent of treatment unit would be tested and then removal efficiencies may be ascertained. It is also planned to develop cost effective treatment units in Lab and it may be upscaled at later stage.

Action Plan& Timeline:

Work Element	**1st Year**	**2nd Year**	**3rd Year**
Sediment and water sampling			
Sediment and water characterization			
Performance evaluation of existing treatment units			
Development of cost effective arsenic removal technology			

Preparation and submission of reports and publications			▬▬▬

Data Requirements:

- Geological map and bore logs of various location
- Groundwater levels
- Surface water and groundwater quality etc.

List of Deliverables:

- Reports
- Research papers

Study Benefits /Impact:

A project report will be prepared highlighting the genesis of arsenic and its mobilization from solid to liquid phase. The research output and development of new technique for arsenic removal may help stakeholders for deciding the water supply management strategies in arsenic affected areas. The findings of the study will be presented in conferences/workshops and published in journals. Stakeholder (Public Health Engineering Department, Jal Nigam, Water Resources Department, Department of Drinking Water and Sanitation, Ministry of Jal Shakti etc.) engagement would be done for improving their knowledge and application of various mitigation options.

15. PROJECT REFERENCE CODE: NIH/GWH/NIH/22-24

Title of the Project: *Conjunctive Management of Water Resources in IGNP Command*

Study team:	PI	Dr. Nitesh Patidar, Scientist-B
	Co-PIs	Dr. MK Goel, Scientist-G
		Dr. Anupma Sharma, Scientist-F
		Dr. Surjeet Singh, Scientist "F"
		Ms. Nidhi Kalyani, Scientist-B

Type of study: Internal (New study)

Duration: Two years (April 2022 – March 2024)

Objectives

1. Analysis of present groundwater scenario in enroute command of IGNP
2. Mapping of water-logged area in IGNP command using GW observations
3. Estimation of GW recharge from rainfall, canal and irrigation under present and future climatic scenarios
4. Conjunctive management of water resources in enroute command area of IGNP canal

Problem statement

Conjunctive management of surface water and groundwater for irrigation is recognized as an effective solution to water logging and root zone salinity. The conjunctive utilization of water resources also ensures consistent water availability for irrigation and support sustainable water management. However, despite these advantages the conjunctive management of water resources is scant in canal commands. The Indira Gandhi Nahar Pariyojana (IGNP) provides irrigation to an area of 1.963 million hectare (CCA) in Rajasthan. The project also provides domestic water supply to most of thar dessert of Rajasthan and is therefore the most important water source in the arid Rajasthan. Since the inception of the project, there has been various issues related to rising water table and increasing soil salinity. Several studies were conducted to assess the impact of canal on groundwater levels and water logging. It was observed that before the canal construction (before 1952) the depth to groundwater used to vary between 40 and 50 m. After the inception of irrigation through stage-I of IGNP groundwater level started rising. In 1972-82 the rise in groundwater level was observed to be 1.17 m/year. Later in 1995, an area of around 10% of CCA of stage-I was waterlogged and around 25% area was under critical condition (depth to GW in range 1-6 m). Such rise in groundwater level transports the salts from deeper soil layers to surface and impact the agricultural productivity in the area.

The present scenario of groundwater and mapping of water-logged area is essential in the IGNP command for effective management of land and water resources. Such analysis would help in quantifying the current potential of groundwater in conjunction with canal water to maximize the irrigation potential in command and to contain salt mobilization in root zone.

Study area

The IGNP project was initiated in the late 50's and is situated in the districts of Sriganganagar, Hanumangarh, Bikaner, Churu, Jaiselmer, Barmer, and Jodhpur. It has a CCA of 1.963 million hectares. The project was completed in two stage, Stage-I having a 204 km long feeder which originates from Harike Barrage, Punjab, to reach Masitawali, Rajsthan, and a 189 km long main canal from Masitawali to Chattergarh in Bikaner district. Stage-II is having a 256 km long main canal from Chattergarh to Mohangarh in Jaiselmer.

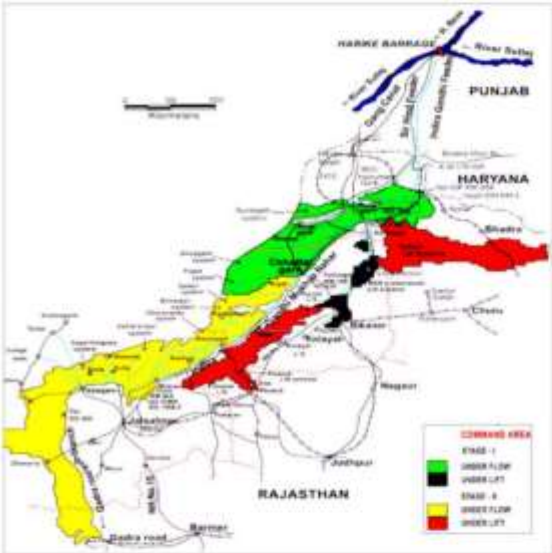


Image source: Gupta et al. (2002)

Fig. 1 Indira Gandhi Nahar Pariyojna (IGNP) command area under stage-I and stage-II

Methodology

The assessment of the present groundwater scenario will be done utilizing the groundwater observation of Central Ground Water Board (CGWB). Trend analysis will be performed on groundwater levels to identify the trend in groundwater. The mapping of water-logged area will be performed using the groundwater data. The conjunctive management of surface water and groundwater requires an integrated simulation-optimization model. A model developed at NIH which integrated Google Earth Engine (GEE), an surface water module and MODFLOW, will be utilized for estimating recharge to groundwater. A system model was developed at NIH which will be used to simulate the demand-supply and recharge due to canal percolation and irrigation. Iterative simulation runs will be performed to optimize the groundwater extraction so as to contain the rising water level and increase irrigation intensity. The Effect of climate variability will be considered using the most recent data of climate projections under different emission scenarios.

Action plan and timeline (quarter-wise from Apr 2022 to Mar 2024)

Work element	Apr-Jul 2022	Aug-Nov 2022	Dec 2022-Mar 2023	Apr-Jul 2023	Aug-Nov 2023	Dec 2023-Mar 2024	Apr-Jul 2024	Aug-Nov 2024	Dec 2024-Mar 2024
Collection of data and preliminary analysis	■	■							
Field investigations		■		■		■			
GW trend analysis and mapping of water-logged area			■						
Model simulations for quantifying GW recharge				■	■	■			
Simulation for conjunctive water management						■	■	■	
Project report and research paper									■

16. PROJECT REFERENCE CODE: NIH/GWH/NIH/22-24

Title of the Project: Study of groundwater dynamics with numerical modelling and machine learning in the Yamuna River Basin

Study team:

a. Nidhi Kalyani (PI)

b. Anupama Sharma, Nitesh Patidar, Sumant Kumar

Objectives:

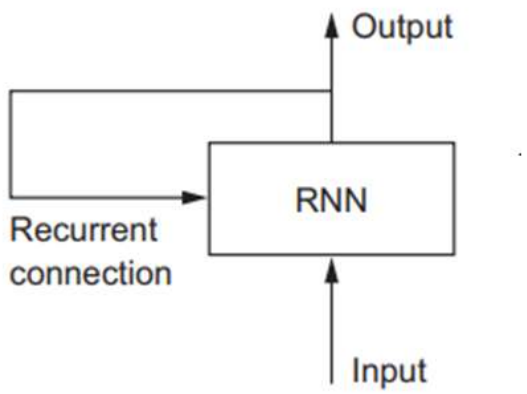
a) Review of AI/ML techniques and their application in Groundwater studies

b) Application of AI/ML techniques for analysis of groundwater dynamics in a part of the Yamuna-Hindon inter-basin and its comparison with numerical modeling techniques.

Methodology

MODFLOW is a physically based numerical model of groundwater flow. It uses the equation of groundwater flow to simulate groundwater dynamics. Solution of the groundwater flow equation is achieved by finite-difference method in which the groundwater flow system and simulation time are discretized into grids and stress periods, respectively. Each stress period is a period of simulation within which specified stress data are constant.

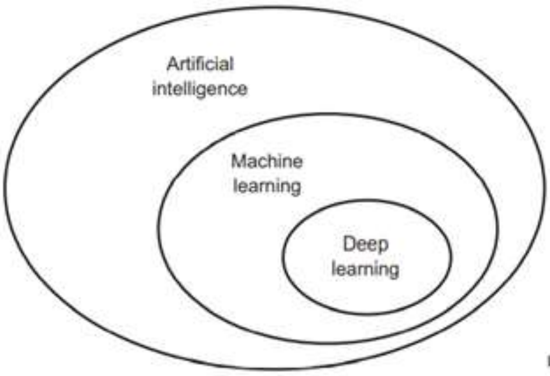
A recurrent neural network (RNN) processes sequences by iterating through the sequence elements and maintaining a state containing information relative to what it has seen so far. In effect, an RNN is a type of neural network that has an internal loop. The state of the RNN is reset between processing two different, independent sequences. What changes is that this data point is no longer processed in a single step; rather, the network internally loops over sequence elements.



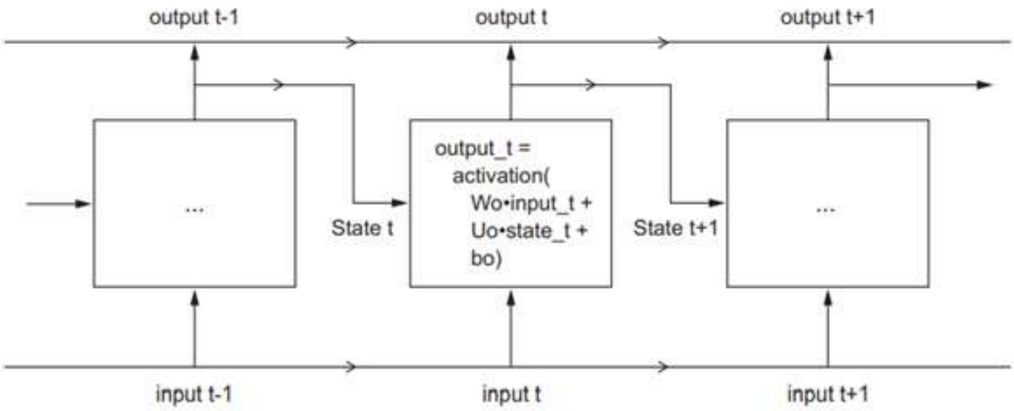
A recurrent network: a network with a loop

Deep learning is a specific subfield of machine learning that puts an emphasis on learning successive layers of increasingly meaningful representations. How many layers contribute to a model of the data is called the depth of the model. Modern deep learning often involves tens or even hundreds of successive layers of representations and they're all learned automatically from exposure to training data. These layered representations are learned via models called neural networks, structured in layers stacked on top of each other.

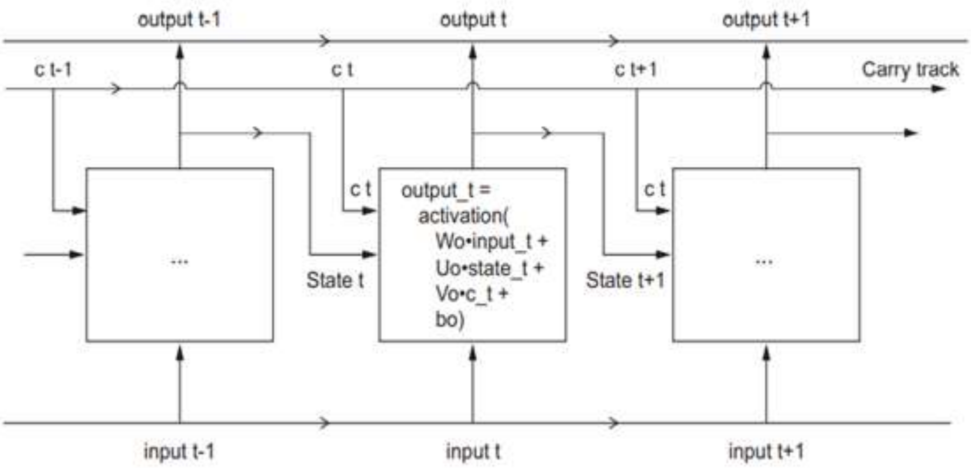
The model can be evaluated using three data sets: training, validation, and test. The model is trained on the training dataset and evaluated on the validation data. Once the model is ready, it can be tested on the test data.



Artificial intelligence, machine learning, and deep learning



The starting point of an LSTM layer: a SimpleRNN



Going from a SimpleRNN to an LSTM: adding a carry track

Research outcome from the project

The output of the study would be in the form of a comprehensive report.

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sudhir Kumar	Scientist G & Head
2	Dr. S D Khobragade	Scientist G
3	Dr. M S Rao	Scientist F
4	Dr. Soban S. Rawat	Scientist D
5	Dr. Santosh M. Pingale	Scientist C
6	Sri Hukam Singh	Scientist B
7	Sri Rajeev Gupta	PRA
8	Sri V K Agarwal	PRA
9	Sri Vishal Gupta	SRA

APPROVED WORK PROGRAMME FOR THE YEAR 2021-2022

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Hydrological investigations of selected springs in Tehri Garhwal District, Uttarakhand	**S M Pingale** (PI), Sudhir Kumar S. D. Khobragade Soban Singh Rawat Er. Padam Singh, (UUHF, Ranichauri) Rajeev Gupta	3 years (04/19-03/22)	**Completed** (Report to be finalized)
2.	Assessment of impact of land use and land cover change on groundwater conditions in parts of Sabarmati river Basin, Gujarat	**M. Someshwar Rao** (PI) Sudhir Kumar Vipin Aggarwal	2 years (04/20 – 03/22)	Continuing Study
3.	Integrated Hydrological Investigations of Renuka lake, Himachal Pradesh, for its Conservation and Management	**SD Khobragade (PI)** Sudhir Kumar Hukam Singh Rajiv Gupta Vipin Agarwal Scientist from GoH.P.	3 years (07/20-06/23)	Continuing Study
4.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	**Hukam Singh (PI),** M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal	1 ¾ years (04/21-12/22)	New Study
SPONSORED PROJECTS:				
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	5 Years (04/16-09/21)	**Completed** (NMSHE Sub-Project_09)
2.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	**M. Someshwar Rao** (PI) Sudhir Kumar	3 Years (06/16 -12/22)	Continuing Study IAEA under CRP
3.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	**Sudhir Kumar (PI)** M. Someshwar Rao Vipin Aggarwal	3 ½ year (01/18 – 06/22)	Continuing Study NHP (PDS)
4.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	**M. Someshwar Rao** (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan	3 ½year (01/18 – 06/22)	Continuing Study NHP (PDS)
5.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	**Suhas Khobragade** (PI) Sudhir Kumar	3 Years (1/18 – 12/20) Extended upto 06/22	Continuing Study NHP (PDS)
6.	Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study	**Sudhir Kumar (PI)** SM Pingale BK Purandara YRS Rao	1 year (04/19 – 12/21)	**Completed** (Study under NCESS, MoES)

S. N.	Project Title	Study Team	Duration	Status
7.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	**Sudhir Kumar (PI)** M. Someshwar Rao SM Pingale	2 years (06/19 – 9/22)	Continuing Study (IIT Bombay, Mumbai)
8.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh	**S S Rawat (PI)** Sudhir Kumar P G Jose, Suman Gurjar, D S Bisht	4 Years (08/17 – 09/22)	Continuing Study NHP (PDS)
9.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	**S S Rawat (PI)** P G Jose, Suman Gurjar, D S Bisht	3 Years (1/19 – 06/22)	Continuing Study (NMHS)

PROPOSED WORK PROGRAMME FOR THE YEAR 2022-2023

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Assessment of impact of land use and land cover change on groundwater conditions in parts of Sabarmati river Basin, Gujarat	**M. Someshwar Rao** (PI) Sudhir Kumar Vipin Aggarwal	2 years (04/21– 03/23)	Continuing Study (proposed to be dropped)
2.	Integrated Hydrological Investigations of Renuka lake, Himachal Pradesh, for its Conservation and Management	**SD Khobragade (PI)** Sudhir Kumar Hukam Singh Rajiv Gupta Vipin Agarwal Scientist from GoH.P.	3 years (07/20-06/23)	Continuing Study
3.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	**Hukam Singh (PI),** M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal	1 ¾ years (04/21-12/22)	Continuing Study
4.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	**SD Khobragade (PI),** Dr. Vishal Singh, Sudhir Kumar	3 years (04/22-03/25)	**New Study**
SPONSORED PROJECTS:				
1.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	**M. Someshwar Rao (PI)** Sudhir Kumar	3 Years (06/16 -12/22)	Continuing Study IAEA under CRP
2.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	**Sudhir Kumar (PI)** M. Someshwar Rao Vipin Aggarwal	3 ½ year (01/18 – 06/22)	Continuing Study NHP (PDS)
3.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	**M. Someshwar Rao (PI),** Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan	3 ½year (01/18 – 06/22)	Continuing Study NHP (PDS)
4.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	**Suhas Khobragade** (PI) Sudhir Kumar	3 Years (01/18 – 06/22)	Continuing Study NHP (PDS)
5.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	**Sudhir Kumar (PI)** M. Someshwar Rao SM Pingale	2 years (06/19 – 09/22)	Continuing Study (IIT Bombay, Mumbai)
6.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water	**S S Rawat (PI)** Sudhir Kumar P G Jose, Suman Gurjar,	4 Years (08/17 – 09/22)	Continuing Study NHP (PDS)

S. N.	Project Title	Study Team	Duration	Status
	Demand in Ravi Catchment of Himachal Pradesh	D S Bisht		
7.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	**S S Rawat (PI)** P G Jose, Suman Gurjar, D S Bisht	3 Years (01/19 – 09/22)	Continuing Study (NMHS)

ITEM NO. 52.2 ACTIONS TAKEN ON THE ADVICE / DECISIONS OF THE 51st MEETING

The specific action taken on the advice/decision of the 51st meeting of Working Group of NIH are as follows:

SN	Project	Status & Comments/ suggestions	Action Taken
INSTITUTE FUNDED R & D STUDIES			
1.	Hydrological Investigations of Selected Springs in Tehri-Garhwal District of Uttarakhand	iii) Dr. Bhishm Kumar suggested to contact Uttarakhand Government and get funding for this study. iv) Director, NIH suggested to take this study outcome to the logical end and show utility of this study to the end users.	Efforts were made to get the study financed from Forest Department, Uttarakhand. Now Forest department is collaborating in the study but without any financial support. Noted
2.	Assessment of Impact of Land Use and Land Cover Change on Groundwater Recharge in Parts of Sabarmati River Basin, Gujarat	Dr. Bhishm Kumar advised to use tritium tagging technique only at places where estimation of vertical recharge to groundwater is of utmost necessity.	The study could not be started due to covid-19. The collaborator from CU, Gujarat is now not willing to participate in the study.
3.	Integrated Hydrological Investigations of Renuka Lake, Himachal Pradesh, for Its Conservation and Management	Dr. Khobragade informed that lake catchment is a protected reserved forest hence permission of the Dept. of Forests & Wildlife, Govt. of HP is necessary for carrying out the study. He further informed that communication in this regard has been made with the Forest Department but response is still awaited. Dr. Bhishm Kumar suggested that efforts be continued to get the response from the department	Telephonic communication was made and reminder email has also been sent to Forest Department of Himachal Pradesh., but response is still awaited.
SPONSORED PROJECTS			
1.	Understanding hydrological processes in Upper Ganga basin using isotopic techniques	Dr. Bhishm Kumar commented that different studies have given different contribution show/ice, GW etc. to river Ganga. The final report should include a review of these studies and possible reasons for variation in reported contribution	Review of studies has been included in the final report.

ITEM NO. 52.3 PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2021-22

As per the approved work program, the status of studies carried out in HI Division during 2021-22 is given below:

Type of study/Project	*Completed during 2021-22*	*Continuing in 2022-23*	*Total*
Internal R & D Studies	01	03	04
Sponsored Projects	02	07	09
Total	03	10	13

Details of training Courses/Workshops organised by the Division during 2021-22:

S. N.	Topic	Duration	Coordinator	Venue	No. of Participants
1.	Scientific data collection and processing techniques for springshed management and rejuvenation	05 Days (13-17 Dec 2021)	Dr S S Rawat	Guwahati	25
2.	Tools and techniques for springshed management	Two Days (06-07.01.2022)	Dr SS Rawat	Jammu	39
3	Stakeholder Consultation Workshop on “GRACERS Project”	March 22, 2022 (01 day)	Dr. SM Pingale	Haldia, West Bengal	50

Mass Awareness activity organised

S.N.	Name and Details of Outreach Activity	Date	Participants
i.	"आजादी का अमृत महोत्सव अभियान" के अंतर्गत "आत्मनिर्भर भारत हेतु जल संरक्षण एवं जल प्रवंधन की वैज्ञानिक तकनीकें" विषय पर एक दिवसीय ई-संगोष्ठी का आयोजन रा.ज.वि., रुड़की किया गया|	05/07/2021	27
ii.	"आजादी का अमृत महोत्सव” अभियान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा” विषय पर स्कूली बच्चों के लिए सूचना, शिक्षा और संचार (आईईसी) कार्यक्रम का आयोजन जलविहार कॉलोनी रुड़की में किया गया|	28/05/2021	20
iii.	"आजादी का अमृत महोत्सव” अभियान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा” विषय पर ग्राम बेलड़ी-साल्हापुर, रुड़की में जागरूकता कार्यक्रम का आयोजन किया गया|	02/09/2021	50
iv.	"आजादी का अमृत महोत्सव” अभियान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा” विषय पर स्कूली बच्चों के लिए सूचना, शिक्षा और संचार (आईईसी) कार्यक्रम का आयोजन राजकीय उच्चत्तर माध्यमिक विद्यालय, बेलडी (हरिद्वार) में किया गया|	29/10/2021	50
v.	"आजादी का अमृत महोत्सव’’ अभियान के अंतर्गत "जल संरक्षण	29/12/2021	50

	एवं जल सुरक्षा" विषय पर ग्राम **Dhanderi Khwazgipur** (ढंन्डेरी ख्वाज़्गीपुर) **village, District: Haridwar** में जागरूकता कार्यक्रम का आयोजन किया गया|		
vi	"आजादी का अमृत महोत्सव" अभियान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा" विषय पर स्कूली बच्चों के लिए सूचना, शिक्षा और संचार (आईईसी) कार्यक्रम का आयोजन **Government Inter-College** रुड़की में किया गया|	18/02/2022	40

Details of samples analysed by the Division Laboratories during 2021-22:

S.N.	Parameter analysed	No. of samples
1.	δ^2H on DI-IRMS	4078
2.	δ^{18}O on DI-IRMS / CF-IRMS	4776
3.	C-13 on CF-IRMS	185
	Tritium	243
4.	WQ samples on IC	900

Details of Research Publications by the Division during 2021-22:

	Published	Accepted	Communicated
Books/Book Chapter	01	-	-
International Journals	10	-	06
National Journals	01	01	01
International Conferences	06	02	08
National Conferences	02	-	-

Details of important instruments purchased by the Division during 2021-22:

S.N.	Name of Instrument	Qty.	Cost (Rs.)
1	DGPS	01 No.	Rs. 15.50 Lakhs
2	Imaging System	01 No.	Rs. 36.75 Lakhs

The progress of the various studies undertaken during 2021-22 is given below:

A. Internal R & D Studies

1.0 PROJECT CODE: NIH/HID/INT/19-22

Title of the Study:	**HYDROLOGICAL INVESTIGATIONS OF SELECTED SPRINGS IN TEHRI-GARHWAL DISTRICT OF UTTARAKHAND**
Study Team:	Santosh M. Pingale (PI), Sudhir Kumar, S.D. Khobragade, Soban Singh Rawat, Rajeev Gupta,
Collaborator:	Padam Singh, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri
Type of Study:	R & D Study
Funding Agency:	NIH
Study Duration:	03 Years (April 2019 to March 2022)
Budget:	Rs. 31.82 Lakh

Objectives:

1. To inventorize, characterize and evaluate the sustainability of the springs in Tehri Garhwal district.
2. To assess the impact of anthropogenic activities/climate variability on hydrologic responses of springs and develop the adaptive measures to sustain the livelihoods.

Statement of the Problem:

The watershed/springshed are dynamic and complex systems involving a range of physical processes, which may operate simultaneously and have different spatial and temporal influences. Understanding these processes is essential for managing the quality as well as quantity of water available from both surface runoff and natural springs flow under the changing LULC and climatic conditions. Protection and management of the springs cannot be facilitated unless one has basic understanding physical and climatic characteristics of the watershed/springshed. Otherwise, spring rejuvenation measures cannot be successful in the adverse climatic conditions. Therefore, this study has been undertaken with an objective to conduct systematic investigations on the selected springs of Tehri-Garhwal district of Uttarakhand. The output of the study is expected to go as an input for planning augmentation measures for theses springs and to rejuvenate the drying springs in the district.

Study area:

The present study is being carried out for the selected springs in the Tehri-Garhwal district of Uttarakhand (***Fig. 1.1***).

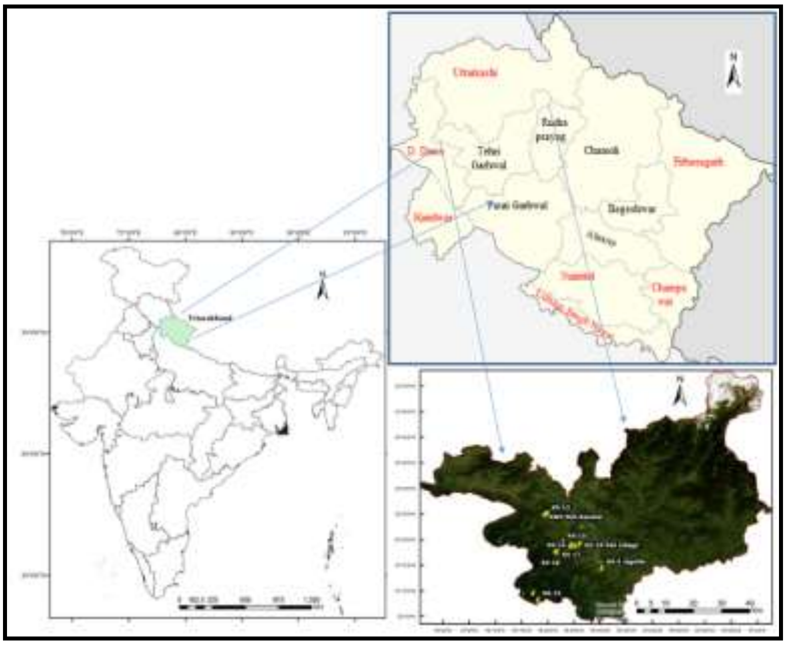


Fig. 1.1 Location of the study area.

Methodology:

The methodology adopted in the present study is described here:

a. Preparing comprehensive inventory of available springs in the study area.
b. Creating geo-database for the springs, which can be updated from time to time.
c. The representative springs from different lithological units selected for continuous monitoring hydro-chemical, physical and social parameters (e.g. Discharge, pH, EC, TDS, major anion and cation), dependent population, use of water and land use conditions around the spring's source / springshed / watershed.
d. The characterization of spring in different lithological units is being carried out using hydrological investigation techniques.
e. The trends and shifts in hydro-climatic variables using different statistical techniques and LULC change have been taken up for the selected study area.
f. The characterization and development of IDF curves for rainfall and FD curves of the springs flow is under process.
g. The impacts of anthropogenic activities/climate variability on selected springs flow in different lithological units within the study area is under process.
h. Finally, suitable interventions and scaling out plan will be suggested based on hydrological investigations.

Achievement vis-à-vis Objectives

Objectives	Achievements
To inventorize, characterize and evaluate the sustainability of the springs in Tehri Garhwal district.	• Springs inventory and geo-tagging have been prepared based on field visits. About 40 springs have been inventoried. • Local Meteoric Water Line (LMWL) has been established using $\delta^{18}O$ and $\delta^{2}H$ of identified springs water. In addition, temporal plots of the isotopic composition of spring water ($\delta^{18}O$ and $\delta^{2}H$) have been prepared. • The spring water and rainwater samples for isotopic composition at different locations/altitude have

	been collected within study area and tritium analysis is in progress. • The hydrometeorological analysis have been carried out at different temporal scales. • The IDF curves for rainfall and FDC for spring flow have been constructed.
To assess the impact of anthropogenic activities/climate variability on hydrologic responses of springs and develop the adaptive measures to sustain the livelihoods.	• The impact of anthropogenic activities/climate variability on hydrologic responses of the selected springs in the study area is in progress.

Progress of Work

Archival data collection: The historical hydro-climatic data for Ranichauri & Fakua springs were obtained from College of Forestry, Ranichauri. These two perennial springs are being monitored for their spring flow on daily basis.

Springs Inventory: During the field visits, more than 40 natural springs have been identified in the selected blocks of Tehri-Garhwal district (Fig.1). The spring related data have been collected (e.g. discharge, pH, EC, location, elevation). It was found that all spring water are slightly in alkaline nature (pH: 6.8 to 8.5; EC: 40 to 1440 µs/cm).

Hydro-geological investigation of study area: In the present study, aquifer and lithological formation maps of Tehri Garhwal district have been used for detail hydrogeological investigations of the study springs. It has been found that district comes under Schist, Gneiss, Quartzite, Phyllite and Shale with limestone aquifer formations. Of the twenty springs, two springs fall in older alluvium and Pebble/gravel/Bazada/Kandi formation, while remaining springs lie in the Phyllite, Quartzite, Shale with limestone, and Schist group.

Establishment of spring monitoring sites: The monitoring stations have been identified to collect the water samples from rain and spring water for isotopes analysis. In addition to Ranichauri & Fakua springs, two more spring sites have been identified for monitoring and details hydrological investigations in the area, where spring monitoring can be started to understand the spring's responses in different lithological and geographic settings.

GIS database creation & statistical analysis: The base maps have been prepared for the study area such as DEM, Slope, stream network etc. Trends and shifts detection analysis have been carried out for the archival data of springs and meteorological parameters using different statistical techniques for the Ranichauri campus and Fakua springs in the study area.

Characterization and development of IDF and FD curves: The IDF curves for rainfall and FD curves of the springs flow is prepared for the selected springs. Tritium dating of the collected spring water and rainwater is under progress.

Future work plan: As per activity schedule

- Additional field visits are required for spring inventory in the study area.
- The springs location map along with isotopic values of spring water and rainwater will be prepared for the identified selected springs in the study area. Further, results of tritium dating of the collected spring water will be analyzed.
- The impact assessment of anthropogenic activities/climate variability on hydrologic responses of the selected springs.
- Development of adaptive measures to sustain the springs.

2.0 PROJECT CODE: NIH/HID/INT/19-22

Title of the Study:	**ASSESSMENT OF IMPACT OF LAND USE AND LAND COVER CHANGE ON GROUNDWATER RECHARGE IN PARTS OF SABARMATI RIVER BASIN, GUJARAT.**
Study Team:	M S Rao (PI), Sudhir Kumar, Hukum Singh, V. K. Agarwal, Vishal Gupta and S.L. Srivastava
Collaborating agencies:	(Mrs.) Rina Kumari, Asstt. Prof., Sch. of Env. & Sustainable Develop, Central University, Gujara
Type of Study:	R & D Study
Funding Agency:	NIH
Study Duration:	2 Years [1/4/2021 to 31/3/2023]
	(Work could not be initiated from 1/8/2020 due to COVID -19 pandemic. As per the discussion held with Dr. Rina Kumar, the fieldwork will be initiated from May 2021)
Budget:	Rs. 15.00 Lakh

Objectives:

The specific objectives of the project are as given below:

i. Decadal change in LULC
ii. Groundwater mapping (flow, fluctuation & availability)
iii. Stable isotope characterization of groundwater and surface water sources
iv. ^{3}H dating of groundwater
v. Identification of surface water groundwater interaction zones
vi. Analysis of change in groundwater recharge rates over the last 4 decades due to the change in LULC pattern and groundwater demand

Origin of the Proposal & Problem Definition:

Groundwater is a valuable natural resource. Depletion of groundwater resources and deterioration of its quality can have a serious impact on both the socio-economic growth and the eco-environment. Factors like urbanization, changing land use land cover patterns, increasing water demand for food production to support the growing population growth, etc., affect the groundwater recharge conditions, groundwater resource, and its quality. In the present study, change in land-use and land cover and its impact on the groundwater recharge will be assessed.

Study Area:

The study will be conducted in the Sabarmati river basin near the city of Ahmedabad. Groundwater samples will be analyzed from the locations where the previous study on groundwater recharge estimate (Gupta et al., 1980) was conducted.

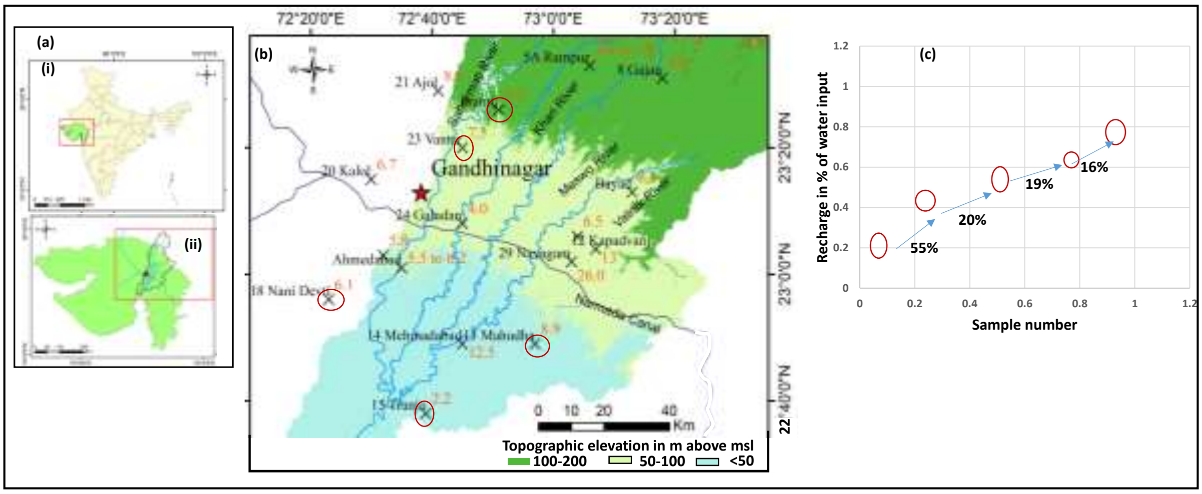


Fig 2.1: Study area. (a) (i) The state Gujarat in India (ii) Sabarmati river basin in Gujarat (b) Rivers and canal in the study area. The values shown in orange colour are the groundwater recharge rates as estimated in the previous study (Gupta et al., 1980). Red circles are the proposed sites for groundwater recharge experiments, (c) Groundwater recharge rate as observed in the previous study (Gupta et al., 1980). The red circles indicate the recharge values that will be re-estimated in the present study (as marked in the fig (b)

Methodology:

Changes in LULC over the last 4 decades will be analyzed using the remote sensing data. Decadal scale fluctuation in groundwater level will be analyzed by using archival data. To identify the change in groundwater recharge rates, the published data on groundwater recharge rates for the year 1977 (Datta et al., 1980) will be compared with the recharge rates to be estimated during the present study. In the previous study, recharge rates of 2.2% to 10% were observed in the study area. In the present study, experiments will be conducted to estimates the recharge rates once again at 5 locations, where recharge rates were observed to be 2.2%, 4.9%, 6.1%, 7.5%, and 8.9% of the input water. The difference in the recharge rates observed between the present and the past study will be interpreted in terms of the change in LULC and any other parameters that have influenced the recharge rate. It is also important to notice that during the previous study, the Narmada canal did not exist and hence its impact on the change in groundwater isotopic composition and water quality will also be assessed. Environmental tritium in groundwater will also be analyzed to estimate the average turnover time of the groundwater.

Time Line

Work components	**May-Oct, 2021**	**Nov-Apr, 2022**	**May-Oct 2022**	**Nov-Apr 2023**
Data collection (LULC, rainfall, irrigation data, archival water quality & ground water level data etc.)	✓	✓		
Preparation of various thematic layers	✓	✓	✓	
Collection and analysis of water sampling for water quality & isotopic (^{2}H, ^{18}O, ^{3}H) characteristics	✓	✓	✓	

Soil analysis (grain size, soil moisture stable isotopic composition of soil moisture)	✓	✓	✓	
Estimation of vertical recharge to groundwater		✓	✓	
^{3}H dating of groundwater		✓	✓	
Data interpretation			✓	✓
Report and publication			✓	✓

Progress of Study:

No progress was made as the field investigations could not be started due to covid-19. In addition, the Collaborator from CU, Gujarat is no more interested in the study.

Working Group may consider dropping the study.

3.0 ***PROJECT CODE: NIH/HID/R&D/2021/1***

Title of Project:	**INTEGRATED HYDROLOGICAL INVESTIGATIONS OF RENUKA LAKE, HIMACHAL PRADESH, FOR ITS CONSERVATION AND MANAGEMENT**
Project team:	SD Khobragade (PI), Sudhir Kumar, Sc-G; Hukam Singh, Sc-B,; Rajiv Gupta, PRA, Vipin Agarwal, SRA and Scientist from H.P. State Council for Science Technology & Environment.
Type of Study:	Institute Funded R & D Study
Duration:	3 years
Date of Start:	1st July, 2020
Date of Completion:	30th June, 2023
Budget:	46.5 Lakh

Statement of Problem:

The Renuka lake in Himachal Pradesh is facing some serious environmental problem such as pollution, growth of weeds and, reduction in water spread area and capacity due to siltation, etc. However, there is no proper conservation plan for the lake based on systematic scientific investigations. The National Institute of Hydrology, Roorkee carried out some preliminary investigations on the lake and it was felt that further detailed investigations are required on various aspects such as water balance, ground water–lake interaction, water quality, sedimentation etc for understanding the hydrological regime of the lake so that a comprehensive conservation and management plan for the lake can be developed. The matter has been discussed with the authorities of the Himachal Pradesh and it was agreed upon that systematic and detailed scientific investigations need to be carried out on the Renuka Lake. So, the present study is proposed to carry out detailed and integrated hydrological investigations on the lake to develop a conservation plan for its long term conservation.

Objectives:

The major objectives of the proposed study are: ·

- i) To assess the environmental health of the lake through assessment of its water quality
- ii) To understand the hydrological regime of the lake through analysis of its water balance
- iii) To estimate sedimentation rate and expected life of the lake ·
- iv) To determine the causes of quantitative and qualitative degradation of the lake, and
- v) To develop a Conservation Plan for conservation and management of the lake

Brief Methodology

For detailed hydrological investigations following methodology would be employed:

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

For the assessment of the water balance components, the inflow and outflow would be monitored. Water levels 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. 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.

Study Area

Renuka lake, is located at a distance of about 37 km from Nahan in district Sirmaur.in Himachal Pradesh at 30°36′36″N 77°27′30″E at an altitude of 672 m above mean sea level.

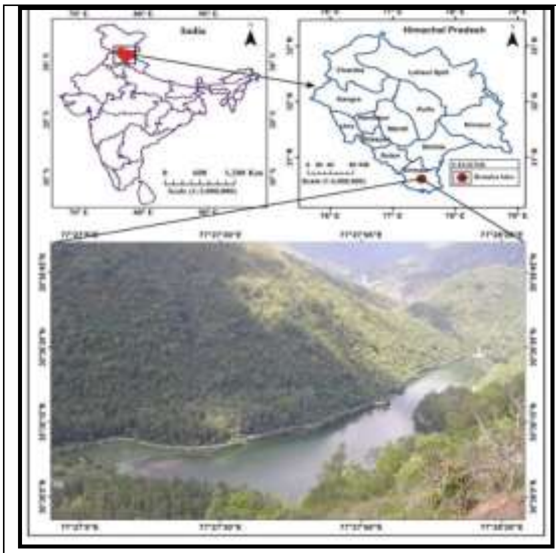


Figure 1: Location map of study area

It has a circumference of 3,200 meters, with a maximum depth of about 13m. There are two views regarding the origin of the lake. According to one view it is of glacial origin while the other view considers that the lake basin is a part of a former river valley. Besides being the largest lake of Himachal Pradesh, it is one of the most sacred lakes of northern India and a great tourist attraction for its picturesque location and biodiversity. It is the site of an annual fair held in the month of November. The lake is known to be home to at least 443 species of fauna. The Ministry of Environment and Forests, Government of India has recognized it as Wetland of National Importance in 2005. The lake was included in the list of Ramsar Sites in India during 2005 attaining international importance under the declaration of Ramsar Convention. The State Government has also declared 402 ha. in and around the lake as Wild Life Sanctuary.

Work Plan: As per activity schedule

Achèvements vis-à-vis Objectives

Objectives	Achievements
To assess the environmental health of the lake through assessment of its water quality	Water quality samples have been collected and results of laboratory analysis awaited
To understand the hydrological regime of the lake through analysis of its water balance	Isotopic samples have been collected for post monsoon 2020, water levels of existing hand pumps monitored for post monsoon 2020
To estimate sedimentation rate and expected life of the lake ·	---
To determine the causes of quantitative and qualitative degradation of the lake	--
To develop a Conservation Plan for conservation and management of the lake	To be done after all analysis are completed

Progress of work

A field visit of Renuka lake and catchment was undertaken during December 2020. Following works were carried out:

i) Reconnaissance survey of the lake & catchment and finalization of sampling locations & locations for installation of equipment
ii) Collection of samples for water quality and isotopes analysis & in-situ measurement of EC, pH and temperature
iii) Measurement of water levels from the available 4 hand pumps
iv) Discussion with local officers of Forest Department

During the discussion with the local officials of the forest Department it was informed that since the lake catchment area is a protected forest, no study can be taken up on the lake without prior permission from the Principal Chief Conservator of Forest & Wildlife Warden, Govt. of Himachal Pradesh. Accordingly, the Principal Chief Conservator of Forest & Wildlife Warden, has been contacted and necessary permission has been sought. The response is still awaited. The study shall be initiated only after the permission is officially received.

Some photographs of fieldwork carried out during December 2020

ACTIVITY SCHEDULE

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	Review of all available data/information & Identification of Data Gaps	√	√	√									
1.3	Procurement of meteorological Data	√	√	√									
1.4	Installation of equipment in field	√	√										
1.5	Preparation of basic maps of lake and catchment	√	√										
1.6	Arrangement for discharge measurement		√	√									
2.0	**FIELD WORK**												
2.1	Generation of hydro-meteorological data		√	√	√	√	√	√	√	√			
2.2	Collection of water samples for water quality & isotope analysis		√	√	√	√	√	√	√	√			
2.3	Infiltration tests to determine Infiltration rates			√	√								
2.4	Monitoring of discharge		√	√	√	√	√	√	√	√			
2.5	Bathymetric Survey of lake		√										
2.6	Monitoring of lake & 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**												
5.1	Preparation of Interim Project Report				√				√				
5.2	Preparation of Final Project Report												√
6.0	**ORGANIZATION OF TRAINING WORKSHOP**	Post-Project											

4.0 ***PROJECT REFERENCE CODE: NIH/HID/R&D/2021/2***

Title of the Study:	**ASSESSMENT OF DISSOLVED RADON CONCENTRATION IN GROUNDWATER OF UTTARAKHAND**
Project team:	Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal
Collaborating agencies:	CGWB, Dehradun
Type of Study:	MoU with CGWB
Funding Agency:	Internal Funding
Budget:	Rs. 4.00 Lakh
Duration:	One Year Nine Months (April 2021 to December 2022)

Objectives:

Mapping the spatial distribution of radon levels in groundwater in Uttarakhand.

Present state-of-art:

Radon in groundwater originates due to decay of parent radioactive member radon-226, which is derived from the decay of the ultimate parent source uranium-238. The uranium-238 is present in groundwater as uranyl complex or is present in the host aquifer matrix as radioactive contaminant. Solubility of parent members of radon (radium and uranium) in groundwater depends upon geochemical conditions and temperature of groundwater. Radon-222 concentration in groundwater is a function of radioactivity concentration of radium (and hence uranium) in aquifer matrix, aquifer porosity (dry pores may lead to escape of radon) and physico-chemical condition of groundwater. During rainfall recharge, moisture filled pores in the vadose zone may slow down the escape rate of radon and also rise in groundwater levels due to rainfall induced groundwater recharge may dilute the radon levels in the groundwater. Thus, radon concentration in groundwater at a given location depends on the local hydrogeology, groundwater fluctuation and soil moisture conditions. Thus, a temporal variation in dissolved radon concentration in groundwater may provide a new way to look into the aquifer system and recharge conditions. Due to the short half-life of radium & radon isotopes compared to timescales at which groundwater levels and soil moisture fluctuation take place; the variation of these hydrological parameters may be recorded in the radon signals.

Study Area:

The study will be carried out in various districts of Uttarakhand.

Methodology:

In order to study the radon contamination in the study area at different locations, groundwater samples from shallow as well as deeper aquifers for pre and post monsoon seasons will be collected for in-situ radon measurement for studying the spatial and temporal variation of radon concentration. The hydro-geological data will also be collected for the study area in order to study the hydro-geological features to be linked with the radon concentration in pre and post monsoon season groundwater samples.

Progress of Work/Results and Analysis:

Samples have been collected from 29 locations in the Haridwar and Dehradun districts of Uttarakhand. These samples have been analyzed in the Institute Lab. The results will be presented in the WG meeting.

Sponsored Projects:

1. PROJECT REFERENCE CODE: NIH/HID/SPON/16-20

Title of the Study:	**UNDERSTANDING HYDROLOGICAL PROCESSES IN UPPER GANGA BASIN USING ISOTOPIC TECHNIQUES**
Study Team:	S. D. Khobragade (P.I.), Sudhir Kumar, Suneel Kumar Joshi (Res. Sc-C), Rajesh Singh, M. Arora and S. K. Verma
Collaborating agencies:	WIHG and HNB Garhwal University
Type of Study:	Sponsored (under NMSHE Project)
Funding Agency:	DST, Govt. of India
Budget:	Rs. 177.228 lakh
Date of Start:	April 2016
Date of Completion:	September 2021

Study area

The study area (Figure 1). covers the upper catchment of the Ganga River, and lies between latitudes of ~29°45’34’’N and 31°27’39’’ N, and longitudes of ~78°9’18’’E and 80°15’16’’ E Bhagirathi and Alaknanda Rivers are the two headwater streams that join at Devprayag to form Ganga River. The catchment area of the Ganga River, up to Rishikesh, is ~21,780 km^2. The topography in the upper catchment area (altitude: ~2000 to ~7500m) is very rugged and gentle to rugged in the lower valley region (altitude:332 to <2000 m). The variation in altitude and latitude has led to the prevalence of different climate types within the study area. The upper part of the catchment, extending between the elevation of ~4000 m to ~7000 m, experiences an alpine environment, while the region is lying below ~4000 m exhibits characteristics of the sub-humid tropical climate.

Study Objectives

- Isotopic characterization of precipitation and identification of sources of vapor
- Runoff generation processes in the headwater region of Ganga using isotope and modeling
- Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries.
- The contribution of transient groundwater and its role in the sustainable flow of Ganga.
- Groundwater dynamics in the mountainous area, including identification of recharge sources and zones of major springs

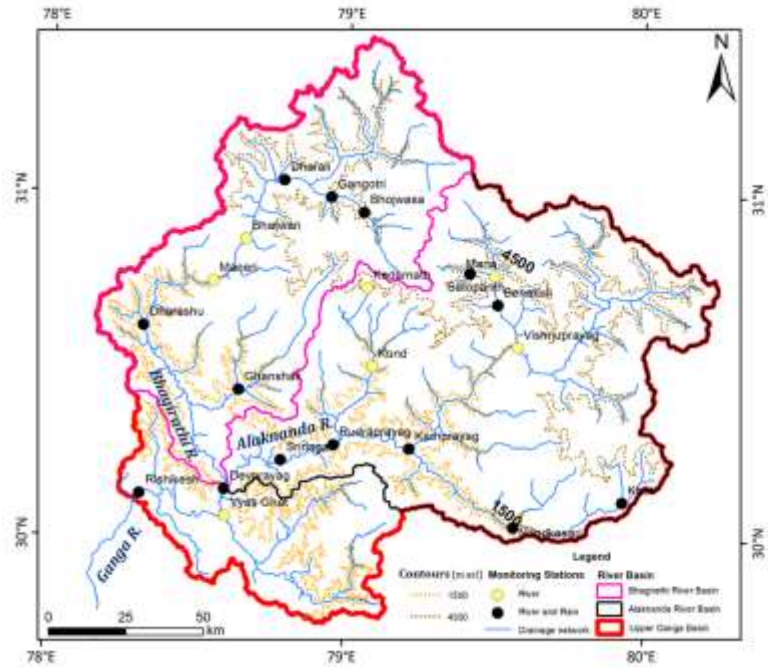


Figure 1 Study area map showing rain and river monitoring stations

Statement of the Problem

The Himalayan mountain system is the source of one of the world's most extensive supplies of freshwater. However, these sources are under threat due to severe environmental degradation and climate change. These changes are likely to dramatically impact the river flows, groundwater recharge, natural hazards, and the ecosystem, consequently affecting the people and their livelihoods, although the effects are not expected to be the same in terms of magnitude and intensity in all parts of the region. To understand the possible impacts of these changes on the water resources and hydrological regime of the Ganga basin, it is first essential to have a thorough understanding of the hydrological processes operating in the Ganga river basin. The present study has therefore been undertaken as part of the larger NMSHE project, sponsored by DST, Govt. of India, for the Upper Ganga basin up to Rishikesh. Considering the utility of the environmental isotopes to understand complex hydrological processes, isotope techniques are being used in the present investigations.

Brief Methodology

- Field survey and site selection for monitoring stations
- Sample collection from various water sources such as precipitation, river, groundwater, snow and ice melt and their laboratory analysis for stable isotopes, radioactive isotopes, and hydrochemistry
- Isotopic characterization, including altitude effect
- Application of two- and three-component isotope model for assessment of the relative contribution of tributaries at confluence points
- Modeling of snow and glacier melt

Action Plan: (2016-2021)

Activities	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Appointment of Project staff	√									
Procurement of instruments	√	√								

Literature Collection	√	√	√							
Sample collection and analysis for stable and radioisotopes		√	√	√	√	√	√	√		
Compilation of data, interpretation and analysis							√	√	√	√
Organization of training course and workshop						√		√		
Preparation of final report										√

Achievements vis-à-vis Objectives

Objectives	Achievements
Isotopic characterization of precipitation and identification of sources of vapor	Achieved
Runoff generation processes in headwater region of Ganga using isotope and modeling	Achieved
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	Achieved
The contribution of transient groundwater and its role in the sustainable flow of Ganga	Achieved
Groundwater dynamics in the mountainous area including identification of recharge sources and zones of major springs	Achieved

Outcome of the study

A total number of nine field visits have been made to the study area since 2016, including Satopanth and Gangotri glacier. Water samples were collected from springs, snow/ice melt, groundwater, river, and rainfall during the field visits for stable isotope and tritium analysis. Also, 21 monitoring stations were established to collect the water samples from precipitation and river for stable isotope and tritium analysis. A total of 6828 water samples from springs (n=333), groundwater (n=303), rain (n=1003), river (n=4999), and snow/ice (n=190) have been analyzed for stable isotopes. In comparison, a total of 191 water samples have been analyzed for tritium measurements.

Several analyses have been carried out which include spatio-temporal distribution of isotopic composition of different sources of water and their altitudinal variation, comparative analysis of isotopic characteristics of Alaknanda and Bhagirathi river basins, Back Wind Trajectory analysis of rain events for identification of vapor sources of precipitation, analysis of altitudinal variation in isotopic characteristics of groundwater and springs, isotopic characterization of Satopanth glacier, analysis of groundwater chemistry, linkages of hydrological processes with geomorphic and geologic features in the upper Ganges basin, the contribution of Alaknanda and Bhagirathi river system to river Ganga at Devprayag, long-term snow covers distribution in the study area, etc.

Enriched isotopic signature has been observed during pre-monsoon and winters showing local effects. The UGB-MWL and 13 separate LMWL line(s) have been established. The RMWL and 13 LMWL show seasonal variations in the isotopic composition of rainfall in the upper Ganga river basin. The isotopic composition of rainfall for all 13 rain gauge stations is close to the GMWL, suggesting no secondary evaporation in the study area during rainfall events. Also, there is no correlation between the isotopic composition of rainfall and the amount of rainfall. The temporal variation in the isotopic composition of precipitation depends on the seasonal dynamics of moisture source and transport pathways. Results of the study suggest that two distinct moisture sources are present in the upper Ganga river basin. The western disturbance brings moisture from the Mediterranean region during winters (November to March) and the vapor from the Arabian Sea, during the Indian Summer Monsoon (ISM).

Analysis of the relative contribution of the Bhagirathi and Alaknanda rivers to Ganga at Devprayag indicates monthly and seasonal variability. During the monsoon season (i.e., from July to September), the contribution of the Bhagirathi river to the Ganga river at Devprayag is about 15-20 %, which increases during the non-monsoon months. Using three-component isotope modeling, the groundwater, surface runoff, and glacier contributions to the river discharge have been estimated for the Bhagirathi river. It indicates that the groundwater contribution increases toward the downstream, whereas glacier contribution decreases toward the downstream. Results also show marked spatial variation in isotopic composition of springs and groundwater, suggesting different recharge sources and altitudes. The isotopic composition of spring water shows a wider variation than groundwater.

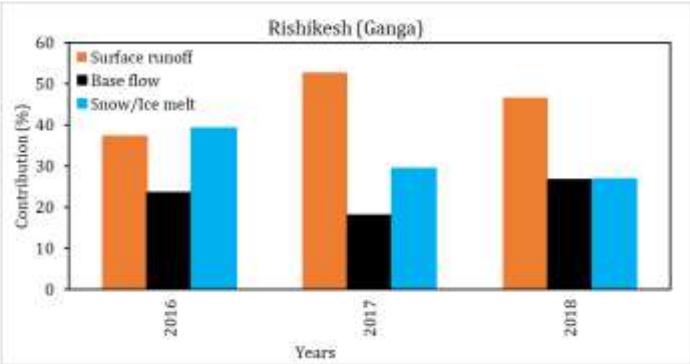


Figure 1: Annual average relative contribution from various sources to Ganga river discharge at Rishikesh.

2.0 ***PROJECT CODE: NIH-26_2017_62***

Title of the Study:	**CHEMICAL AND ISOTOPIC INVESTIGATION OF GROUNDWATER IN DEEP AQUIFERS OF MIDDLE GANGA BASIN, INDIA**
Study Team:	Sudhir Kumar (PI), M. Someshwar Rao
Study Duration:	03 Years **(**January 2018 to June, 2022)

Objectives:

i. To identify the source of recharge to deep aquifers
ii. To assess interaction of deep aquifer with the overlying aquifers.
iii. Water quality of deep & shallow groundwater
iv. Sustainability of deep aquifer for its exploration and future use

Statement of the Problem:

Uttar Pradesh is one of the most populous states in the country. The population of the state in the last two decades has increased from 16.62 crores to 23.5 crores, meaning an annual increase by 2.07% per year (or 2.07 lakhs per year). The state is striving towards increasing food productivity. The volume of food grain production in the state has increased from 42.75 Million metric Ton (Source: RBI, Govt of India) to 54.64 MT (Source: Statista during the period from 2001 to 2019), which means an increase in productivity by 14.69 thousand MT per year. To keep pace with the growing population and food production the water demand in the state is steeply increasing. Population growth, urbanization, runoff from the agri-zones is also increasing the solid and liquid waste, and causing contamination to the freshwater resources. As a result, per capita availability of freshwater resources is continuously reducing in the state. Therefore, the time demands to assess the availability of freshwater resources in the state and to identify the possible solutions to augment it for its sustainability.

Study Area:

The study area is part of the state Uttar Pradesh, and it is hydrologically bounded by three rivers; the river Ganga in the south, and the rivers Sharda, and Ghaghara in the north. The study area is well-drained by the tributary of the river Ganga viz., the rivers Ramgnga, Gomti, Ghaghara, and Sai; and the canal networks originating from these rivers (***Figure 2.1***). The total study area is spread over 95,600 sq. km and is divided into 28 administrative districts.

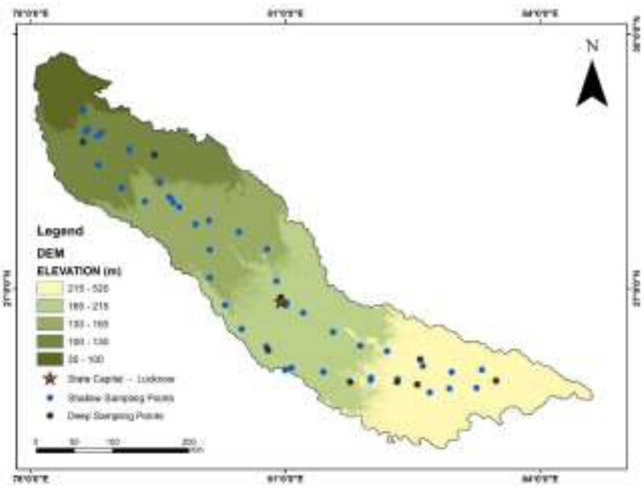


Figure 2.1: Study area, groundwater sampling points on DEM.

Methodology:

- Preparation of base map
- Field survey, groundwater sampling, and analysis of the collected samples (^{2}H, ^{18}O, ^{3}H, dissolved ion concentration and heavy metals)
- Watershed based analysis of decadal change in LULC, rainfall, demography, change in per capita water availability; and effect of these parameters on groundwater quality
- Rainfall-runoff modelling
- Data interpretation for groundwater availability, identification of potential groundwater recharge zones and the effective surface water recharge sources
- Developing the conceptual model for groundwater dynamics and augmentation measures

Work accomplished and work planned for the remaining period:

Work components	Work done till Feb 2021	Work programme for March –December, 2021
Preparation of thematic maps and data interpretation	Prepared the following maps: ➢ Study area outline map, district boundaries and block boundaries ➢ Rivers and watershed map ➢ DEM (ASTER data; 30m resol., year 2019; CARTOSAT data 2020; 2.5 m resol. March 2020) ➢ LULC (Source: Landsat, Resol.:30m; Year: 2005, 2020) ➢ Soil cover map ➢ Downloaded groundwater level, population, and rainfall data	Data interpretation for: ➢ LULC (urban sprawl, agriculture area, surface water bodies, etc.) change from 2005 to 2020 ➢ Change in rainfall pattern ➢ Groundwater fluctuation ➢ Per capita change in water availability ➢ Identification of water stressed area ➢ Impact of land use change on water resources and water availability ➢ Rainfall-runoff modelling ➢ Identification of potential ground recharge zones
Groundwater sampling, analysis and data interpretation	➢ 9 deep (depth > 200 m) and 49 shallow (depth: 30-40m) groundwater samples collected. 90% of the collected samples were analyzed for water quality and isotopic composition. The data interpretation, based on the analyzed data is completed.	➢ 2 more field works will be done for groundwater sampling. ➢ The results of these samples together with the previous fieldwork data will be integrated and interpreted in terms of contamination issues, groundwater recharge sources, and recharge zones.
End use		➢ Trainings, mass awareness, publication and preparation of final report will be done in the 2nd half of the year 2021

Progress shall be presented in the WG meeting.

3.0 PROJECT 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 Team:	M.S. Rao (PI), Sudhir Kumar, A.R. Senthil Kumar, V.S. Jeyakanthan.
Collaborating Agency:	Er.Subrata Halder, SWID, Govt. of West Bengal
Type of Study:	Sponsored Project (PDS-NHP)
Budget:	Rs 51.0 Lakhs
Nature of Study:	Applied Research
Study Duration:	03½ Years **(**March 2018 to June, 2022)

Study Area:

The study area is spread along the 5 coastal districts of West Bengal viz., West Midnapore, East Midnapore, Howrah N. 24 Parganas, and S. 24 Parganas; and Kolkata Municipal Corporation (KMC) (***Figure 3.1***). Groundwater in the study area exists in unconfined to confined conditions in the multi-layered aquifer system.

The quality of the groundwater varies in space, time and depth from fresh to saline conditions and, in some parts, it is arsenic contaminated. Approximately, 22.74 million people residing in the 59 blocks of the three coastal districts are in the range of seawater-groundwater interaction zone and under the threat of changing groundwater salinity.

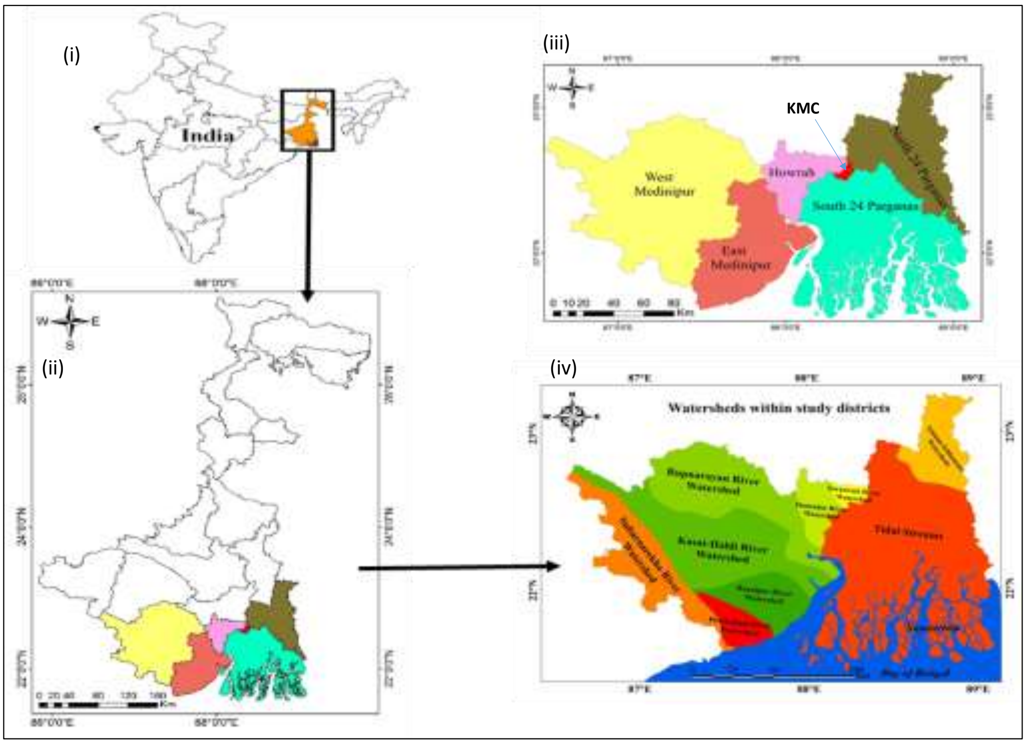


Figure 3.1: Study area. (i) Location of West Bengal in India map (ii) Coastal districts of West Bengal (iii) Map of the 5 coastal districts and the Kolkata Municipal Corporation (KMC) (iv) Watersheds in the study area

Statement of the problem

Due to the combined effect of climate change and anthropogenic activities, the coastal districts of West Bengal is now in danger position. As a result, its districts are now fragile. Therefore, a detailed hydrological study is a very much need. The detailed analysis will be watershed based which has never been done in this region.

Objectives:

- Mapping of seawater intrusion and fresh groundwater discharge to sea is a fundamental problem in the coastal zone groundwater dynamics. Specific to West Bengal, there exists little or no database on this aspect. Through this project, the un-answered question –how much fresh groundwater zone got invaded by seawater, how much area comes under vulnerability and from which area large quantity of fresh groundwater is getting lost to sea will be examined. The specific objectives of the project are:
- Assessment of spatio-temporal variables (sea level change, variation in groundwater levels, rainfall trend etc) influencing dynamics between seawater & groundwater interface using archival data
- Spatio-temporal variation map of fresh water – saline water interface from the present observations.
- Identification of source of salinity in groundwater
- 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
- Management measures for safe & sustainable coastal groundwater use

Methodology:

The adopted methodology involves field investigations and collection of hydrological, meteorological, groundwater quality, geological, topographic and land use data from different sources. The collected data will be analysed to prepare a situation analysis report, groundwater potential and recharge estimates. A conceptual model would be constructed to understand current water stress and future water stress. The changes in LULC shall be assessed to quantify the degree of anthropogenic impact on groundwater levels in the basin. Data related to aquifer characteristics will be procured from State and Central water related agencies.

Time Line of the Planned Activities and the Action Taken:

Planned Activities	Status till Dec 2020	Activities for 2020-21
Preparation of thematic maps: Index map DEM (ASTER 30m) Variation in population distribution from 2001 to 2011 LULC map of 2018 Hydrogeological Map Soil map (Source: NBSS LUP) Groundwater level & fluctuation (1995-2018) (source: India WRIS)	Completed	-----

LST (MODIS 2019 & 2020), Resol: 1km SST (2019 & 220)		
Rainfall pattern & change during (2000-2018) Sea level fluctuation (Daily data since Jan 2019) Litholog correlation (50% of the study area completed)	Data collected	Analysis to be done
Water sampling & analysis (Water quality and isotopic analysis)	Pre-monsoon (2 nos.) Sampling completed. 80% samples analyzed	Post monsoon analysis is to be done
Rainfall-runoff modelling	Data collected	Analysis is to be done
Data interpretation for: Mapping of salinity intrusion and fresh groundwater discharge zones Water scarcity hotspots Parameters influencing the water quality and water availability Identification of recharge areas & surface water storage zones Coastal hydrological processes Groundwater sustainability measures Conceptual framework		To be done
Training & mass awareness program		
Reports & publications		

Progress shall be presented in the WG meeting.

4.0 ***PROJECT 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 (Lead Organization for NHP PDS)
Type of Study:	PDS under NHP
Duration:	3 years
Date of Start:	1st January, 2018
Date of Completion:	30th June, 2022
Budget:	36 Lakh (NIH)

Statement of Problem:

The lake region of Kumaun Himalaya is known for its biodiversity and socio-economic value. The catchment areas of the Bhimtal and Naukuchiyatal lakes is are hot spots 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. Both Bhimtal and Naukuchiatal lakes have traditionally been used as primary sources of drinking and irrigation water for their regions. However, anthropogenic disturbances in the lake catchment over the last few decades, are threatening the existence of these 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.

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) Field surveys and field investigations
ii) Bathymetric survey
iii) Collection, processing and analysis of the available data
iv) Generation of additional required data.
v) Preparation of base maps and morphometric characterization
vi) Sample collection and laboratory analysis
vii) Data interpretation and analysis
viii) Assessment of Water balance components, water quality status, sedimentation rates, isotopic characterization

Study Area

Bhimtal is largest lake of all the lakes of Kumaun lesser Himalayan lakes. The lake is situated at 29° 21' N and 79° 34' E at an altitude of 1345 m, amsl. The surface area of the lake is about 0.46 km^2, maximum depth is about 24.7 m and storage capacity is about 5.27 Mm^3. Naukuchiatal is deepest of all the lakes of Kumaun lesser Himalaya. It is situated at 29° 19' N and 79° 35' E at an altitude of about 1320 m, amsl. The surface area of the lake is about 0.30 km^2, the maximum depth is about 42.7 m and storage capacity is about 5.17 Mm^3.and perimeter of the lake is about 3.13 km. The maximum length is about 983 m and maximum width is about 693 m. Both the lakes are significant in terms of drinking water, irrigation requirements, fisheries, recreation and aesthetic values. Due to the various anthropogenic activities (intensive construction and increase in population), the lake and their respective catchments are suffering from various environmental problems, particularly since two decades. The study area is a sub-tropical climate region, with maximum temperature of 32°C during summer (May and June) and minimum temperature below 0°C during winter. The average annual rainfall of the study area is about 1600 mm.

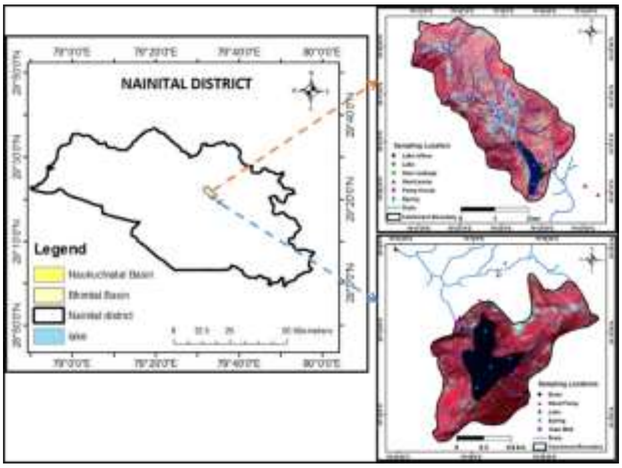


Figure 1: Study area map of Bhimtal and Naukuchiatal lakes

Action Plan: As per activity schedule

Achèvements vis-à-vis Objectives

Objectives	Achievements
To assess the seasonal water availability of the lakes and assess its adequacy in meeting future demands	Hydro-meteorological data required for the purpose is to be generated by IRI, Roorkee. Data are still awaited from IRI.
To assess the water quality of the lakes and possible causes of its degradation	Achieved
To estimate sedimentation rate and expected life of the lake	Achieved
To suggest a comprehensive plan for conservation and sustainable management of the lakes	To be prepared after all the analysis is completed.

Progress of work

Number of field visits were undertaken during 2018-2021 and samples were collected for water quality and isotope analysis. Water quality analysis has been completed for the study covering two pre-monsoon and two post monsoon seasons. Isotopic analysis of samples have been collected till October 2020. The analysis has been completed. The data required for water balance etc which was supposed to be provided by IRI, Roorkee, has not been provided so far. However, efforts have been made to estimate evaporation rates from available meteorological data. All other components of water balance shall be possible to be estimated only after the required data are provide by IRI, Roorkee.

Important results obtained:

(i) Bathymetric surveys of both the lakes have been carried out and depth-area-capacity curves have been developed.

(ii) There is no declining trend in rainfall at the study area during 2004-2018.

(iii) Lake water levels are significantly correlated with the rainfall. However, in case of Bhimtal lake the mean water level reached by the lake also shows some correlation with the dam leakage.

(iv) Average monthly evaporation rates have been estimated for the for the study area based on available meteorological data (Figure 2). Average monthly evaporation from the Bhimtal lake varies from 1.4 mm/d (Dec., Jan) to 4.4.mm/d (May). Total evaporation losses from the lake are insignificant relative to the change in storage. They vary in the range of 0.01 MCM to 0.06 MCM.

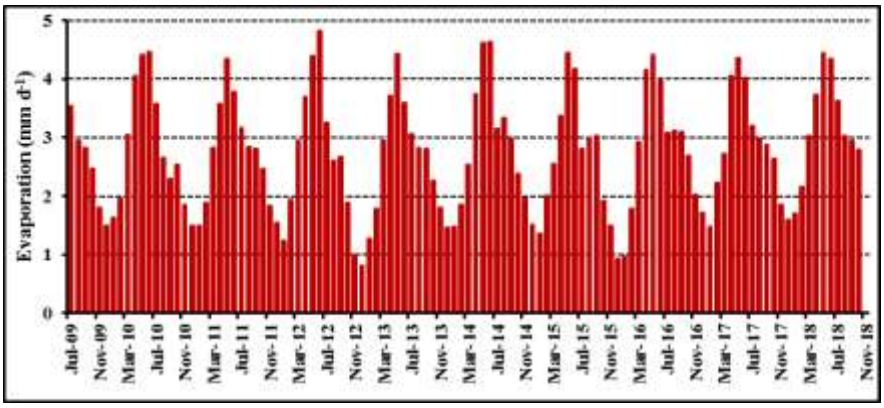
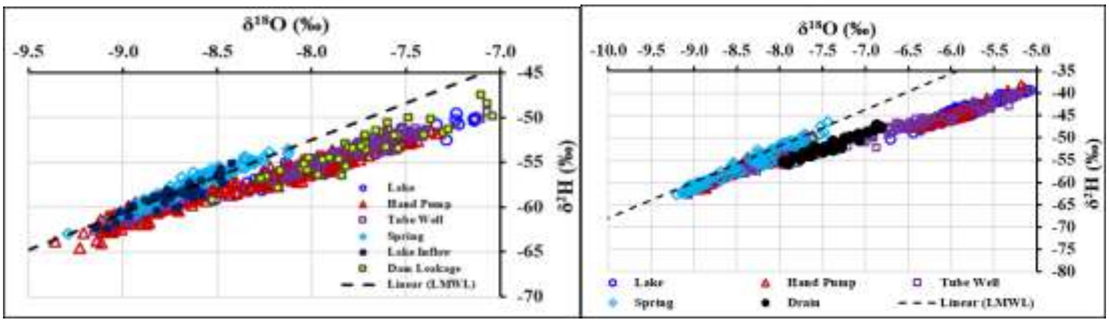


Figure2: Average monthly evaporation rates for the study area

(v) The major LULC in the study area are agriculture, open forest and dense forest. The statistics clearly indicate that the agriculture has reduced significantly in the Bhimtal lake catchment from 40% in 2002 to 29% during 2018 while the built-up area has significantly increased from 5% to 16% during this period. In the Naukuchiatal lake catchment agriculture has reduced significantly from 48% in 2002 to 32% while the built-up area has increased from 3% to 9% in the same period.

(vi) Analysis of d-excess for the study area indicates higher values during winter and lower values during the summer & monsoon periods. The higher d-excess during winter follows the reported pattern for the western Himalayas, due to moisture source from Mediterranean region.

(vii) The isotopic values of Bhimtal lake water do not show any variation from mid-September to mid-March after which they start showing enrichment till mid-July due to evaporation of the lake. In case of Naukuchiatal lake there is not much variation in the isotopic signatures throughout the year. This indicates different hydrological behaviour of the two lakes (Fig. 3).



(a) Bhimtal (b) Naukuchiatal

Figure 2: Isotopic variation of lake waters

(viii) Isotopic investigations also indicate that the groundwater at some locations downstream of both the lakes are almost completely recharged by the lake while at some locations they are recharged by the lake as well as by rainfall. The recharge source for all the springs in upstream of both lake catchments are observed to be precipitation.

(ix) Water quality analysis brings out that the quality of the lakes water is mainly determined by the geochemistry of the catchments. Ca^+ and Mg^+ dominate as major cations in both the lakes and surrounding groundwater, while HCO_3^- dominates as the major anions. The water type in both the lakes and catchments is basically calcium dominated because of the dominating limestone ($CaCo_3$) as a basement rock. Bhimtal lake also shows some organic pollution.

Future Plan: Water balance and conservation plan

Activity Schedule: 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, Recruitment of project staff, Review of all available data/information, Procurement of instruments and peripherals, Installation of equipment etc	√	√	√	√								
2.0	**FIELD WORK**												
2.1	Generation of hydro-meteorological		√	√	√	√	√	√	√	√			
2.2	Collection of water samples for water quality analysis & Isotopes		√	√	√	√	√	√	√	√			
2.3	Collection of sediment samples			√									
2.4	Infiltration tests to determine Infiltration rates			√	√								
2.5	Monitoring of discharge		√	√	√	√	√	√	√	√			
2.6	Bathymetric Survey of lake		√										
2.7	Monitoring of lake & GW levels		√	√	√	√	√	√	√	√			
3.0	**LABORATORY ANALYSIS**												
3.1	Analysis of samples for Water Quality & Isotopes		√	√	√	√	√	√	√	√			
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**												
5.1	Preparation of Interim Project Report				√				√				
5.2	Preparation of Final Project Report												√
6.0	**ORGANIZATION OF TRAINING WORKSHOP**	Post-Project											

1. PROJECT REFERENCE CODE: SP-35/2018-2020/HID

Title of the Study:	**UNRAVELLING SUBMARINE GROUNDWATER DISCHARGE (SGD) ZONES ALONG THE INDIAN SUBCONTINENTS AND ITS ISLANDS**
Study Group:	Sudhir Kumar (PI), SM Pingale, BK Purandara, YRS Rao
Collaborating Institutions:	RC Kakinada and Belagavi
Type of Study:	Sponsored Project, National Centre for Earth Science Studies, (Thiruvananthapuram), Ministry of Earth Sciences, Government of India
Budget:	Rs 46.44 Lakhs
Nature of Study:	Applied Research
Date of start:	March 2019
Scheduled date of completion:	Dec, 2021
Duration of the Study:	1 ¾ Year

Study area: The study area included the coastal districts of West Bengal (i.e. Purba Medinipur, North & South 24 Parganas) (Fig.1).

Objectives:

i. To collect archival data of groundwater (GW level, GW chemistry, aquifer properties, lithology etc.) in the potential SGD zones in the coastal aquifers.
ii. To investigate the SGD zones using Landsat 8 thermal infrared images.
iii. To collect water samples from open/bore wells at every average 1 km along the coast at selected intervals.
iv. To measure salinity and temperature of sediment pore water, groundwater and seawater
v. To collect data on water temperature, salinity, Alkalinity, DO, pH, DIC, DOC, Silicon and Nutrients, dissolved inorganic nutrients: Silica (Si); nitrate and nitrite (N+N); ammonium (NH_4); and phosphate (PO_4), Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging or hydrogeological surveys.

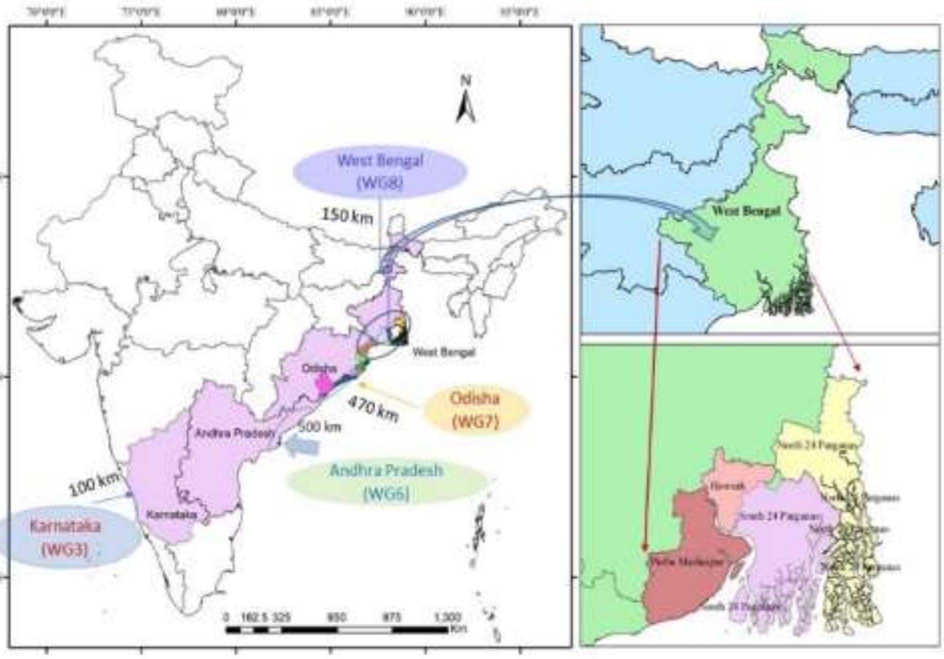


Fig. 1 Location of the study area.

Achievement vis-à-vis Objectives (as on date)

Objectives	Achievements
To collect archival data of groundwater (GW level & chemistry, aquifer properties, hydrogeology etc.) in the potential SGD zones	• Literature survey have been completed on SGD. • Collected archival data related with groundwater from different sources in the potential SGD zones located the coastal aquifers. • Detail analysis is completed.
To investigate the SGD zones using Landsat 8 thermal infrared images.	• Digital Elevation Model (DEM) (30m) was downloaded and Landsat 8 remote sensing data for the pre and post monsoon season (2017, 2018 & 2019) for the different time period have been obtained and processed (Fig. 2). • Detail analysis is completed.
To collect water samples from open/bore wells at every average 1 km along the coast at selected intervals.	• Water samples [groundwater (bore well/hand pump), pore water, seawater] for chemical and stable isotope analysis have been collected in the coastal district of Purba Medinipur. • Detail analysis is completed.
To measure salinity and temperature of sediment pore water, groundwater and seawater	• The in-situ salinity and temperature measurement of pore water, groundwater and seawater water have been carried out for the selected locations in the Purba Medinipur district. • Detail analysis is completed.
To collect data on water temperature, salinity, Alkalinity, DO, pH, DIC, DOC, Silicon and Nutrients, dissolved inorganic nutrients: Silica (Si); nitrate and nitrite (N+N); ammonium (NH4); and phosphate (PO4), Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging	• The some of the water quality data related with pore water, groundwater and seawater have been collected. The water quality parameters and Radon concentrations have been directly determined in the field. While water samples have been collected for $\delta^{18}O$ and $\delta^{2}H$ isotope for selected locations. • Temporal plots of the isotopic composition of water samples and Local Meteoric Water Line (LMWL) has been established using $\delta^{18}O$ and $\delta^{2}H$ of pore water, groundwater and seawater for the study region. • Detail analysis of $\delta^{18}O$, $\delta^{2}H$, Radon and water chemistry is

or hydrogeological surveys.	completed for the collected samples. • The linkages between the isotopic signature of water, its chemistry, and hydrogeological processes is established for the identification of possible SGD zones in the study area. • Signature SGD and SWI locations were identified (Fig.3).

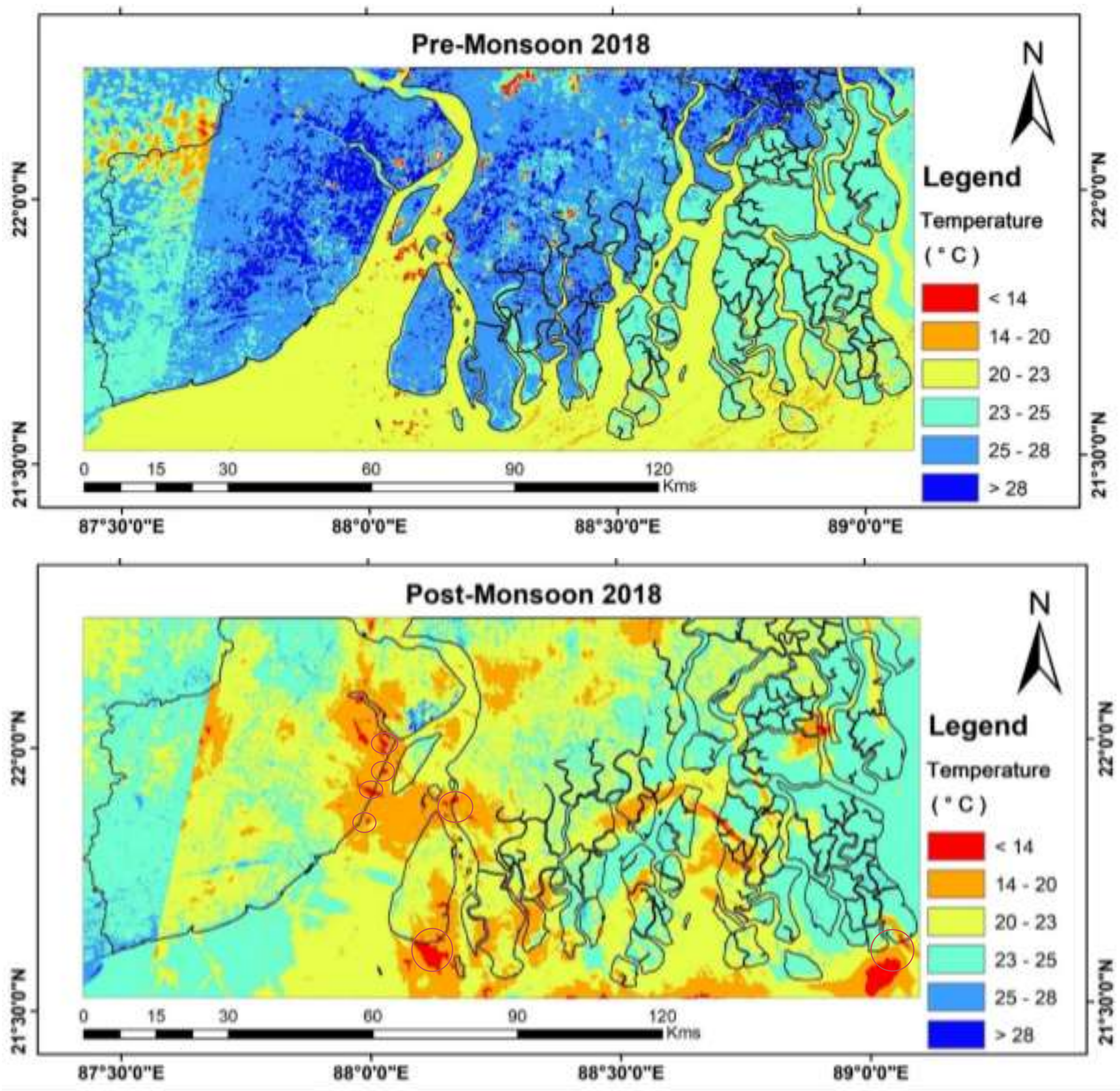


Fig. 2 Land surface temperature estimation using Landsat8 thermal infrared imageries over the coastal districts of West Bengal of the year 2018

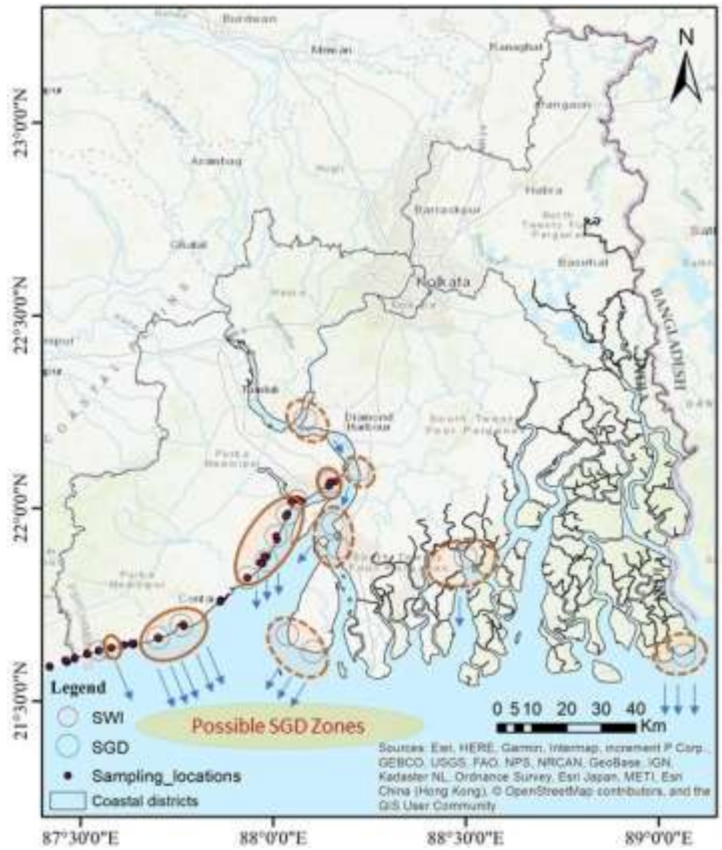


Fig. 3 Possible zones of SGD & SWI in the coastal regions of West Bengal.

Project has been completed and final report has been submitted to the sponsoring agency.

2. PROJECT REFERENCE CODE: SP-42/2019-2021/HID

Title of the Study:	**GROUNDWATER REJUVENATION AS CLIMATE CHANGE RESILIENCE FOR MARGINALIZED AND GENDER SENSITIVE GANGES (GRACERS)**
Study Group:	Sudhir Kumar (PI), S.M. Pingale
Collaborating Institutions:	IHE Delft through IIT Bombay
Type of Study:	Sponsored Project,
Budget:	Euro 18400
Nature of Study:	Applied Research
Date of start:	May 2019
Scheduled date of completion:	May 2021 extended project till September 2022
Duration of the Study:	2 Years

Statement of the problem

Due to the combined effect of climate change and anthropogenic activities, many tributaries of the Ganges River are changing from perennial to seasonal. As a result, the groundwater levels in the Ganges basin are also fast declining and are affecting the rural communities. Augmentation of groundwater recharge is very important to meet the water demands of the different users by increasing groundwater availability. A study in collaboration with IIT Bombay has been taken up to develop decentralized/distributed groundwater recharge scheme for a part of Purba Medinipur district in West Bengal. This site has witnessed unsustainable groundwater extractions, less natural groundwater recharge and groundwater pollution.

Objectives:
The main research objective is to identify hot-spots for decentralized and distributed groundwater recharge networks.

Specific Objectives for the NIH team

- To identify socio-economic stress due to poor groundwater quality and quantity.
- To identify limitations in groundwater recharge due to centralized water supply schemes.
- To develop conceptual groundwater model to understand current water stress and future water stress.
- To quantify the changes in Land Use/Land Cover (LULC) to assess the degree of anthropogenic impact on groundwater levels in the study area.
- To provide scientifically validated management plans for up-scaling distributed groundwater recharge networks.

Study area:
The study area is selected in the Nandigram and Haldia block of the Purba Medinipur district (Fig.1), highlighting the problem of groundwater table decline at alarming rate. Water Authority has notified the area and has imposed embargo on further exploitation of fresh water from the aquifer occurring within the depth of 120–300 metres below ground level (mbgl). Major Problems in the area are (i) Groundwater depletion, (ii) Water quality (salinity in the upper aquifers), and (iii) Lack of proper implementation of existing legislative acts for guiding the groundwater extraction.

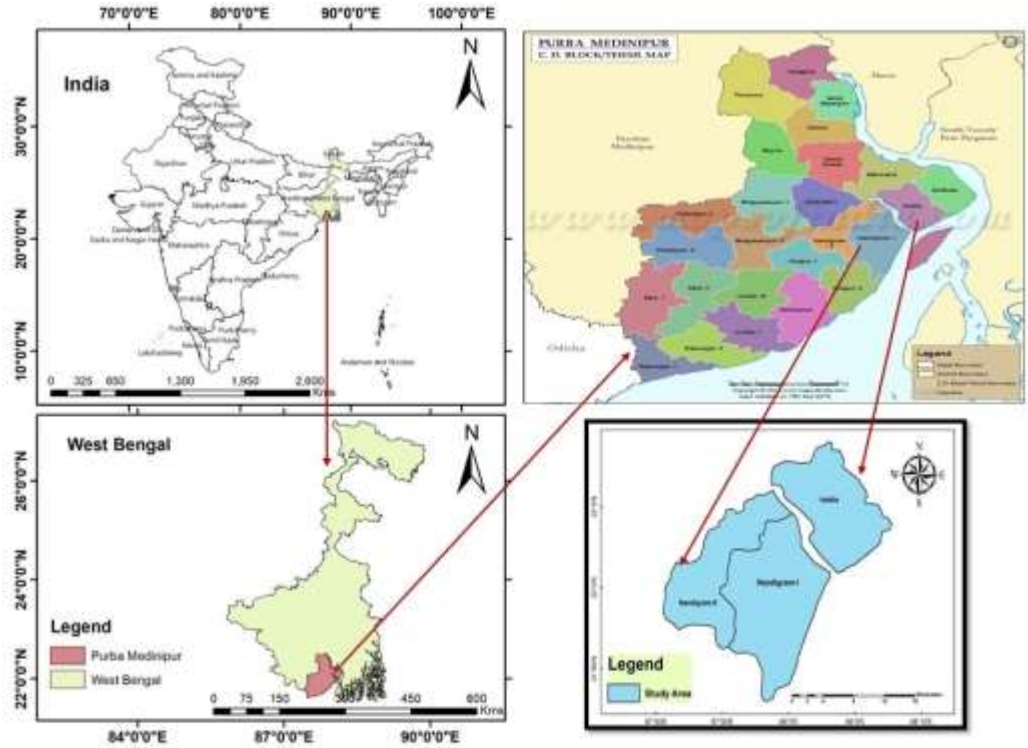


Fig. 1 Location of the study area (i.e. Nandigram & Haldia blocks)

Methodology: The adopted methodology involves field investigations and collection of hydrological, meteorological, groundwater quality, geological, topographic and LULC data from different sources. A social survey would be conducted to understand the water related health and social issues. The collected data will be analysed to prepare a situation analysis report, groundwater potential and recharge estimates. A conceptual model would be constructed to understand current water stress and future water stress. The changes in LULC shall be assessed to quantify the degree of anthropogenic impact on groundwater levels in the basin. Data related to aquifer characteristics will be procured from State and Central water related agencies.

Progress of the work:

- Literature survey have been completed related with study.
- Primary and secondary data from different sources have been collected.
- We have made field investigations in the Nandigram & Haldia blocks of Purba Medinipur district in West Bengal. Measured groundwater levels and collected groundwater samples for stable isotope analysis ($\delta^{18}O$ and $\delta^{2}H$). Also, performed in-situ measurement of groundwater quality parameters (e.g., salinity, temperature, EC, pH, TDS) using multi-parameter water quality analyser (Fig. 2).
- Some of the data related with groundwater, its chemistry, general aquifer properties and hydrogeology have been collected from CGWB & SWID.
- Historical groundwater level data of different groundwater observation wells in the selected blocks have been collected from CGWB and SWID and analyzed (e.g. Fig.3). This is prepared to understand the groundwater dynamics in the study area.
- We have conducted a one-day stakeholders consultation workshop on March 22, 2022 at Haldia in collaboration with IIT Bombay & local support of the State Water Investigation Directorate (SWID), Government of West Bengal (Fig.4). The workshop was focused on the groundwater depletion scenario in the Haldia and Nandigram blocks. The project findings are shared with local stakeholders and government officials.
- Obtained hydro-climatic data for groundwater analysis and detail analysis is in progress.

Fig. 2 Groundwater level measurement & groundwater quality analysis at Haldia & Nandigram blocks

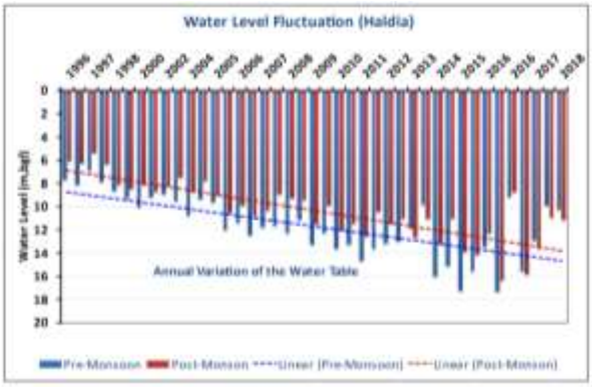


Fig. 3 Water table Fluctuation of Haldia block for Twenty Year (1996 to 2018) (CGWB, 2021)

Fig. 4 Stakeholders consultation workshop at Haldia

Future Plan:

- Additional field visits are required in the study area (Haldia and Nandigram Block) for data collection, survey and stakeholder's discussions.
- Hydro-stratigraphic cross section across the study area to understand the flow of groundwater system.
- Conceptual model based on data collected.
- Development of groundwater vulnerability maps and potential recharge zone map of the study area.

7.0 *PROJECT CODE:* NIH-21_2017_31

Title of the Study:	**WEB GIS BASED SPRING INVENTORY FOR VULNERABILITY ASSESSMENT AND HYDRO-GEOLOGICAL INVESTIGATION OF SELECTED SPRINGS FOR SUSTAINING LOCAL WATER DEMAND IN RAVI CATCHMENT OF HIMACHAL PRADESH**
Study Team:	S S Rawat (P.I.), Sudhir Kumar, P G Jose, Suman Gurjar, and D S Bisht
Collaborating agencies:	Himachal Pradesh Jal Shakti Vibhag
Type of Study:	Sponsored (under NHP-PDS)
Funding Agency:	World Bank
Budget:	Rs. 69.00 lakh
Duration of Study:	04 Years (August 2017 to March 2022) (to be extended up to Sept., 2022)

Study Area: Ravi River catchment of Himachal Pradesh having an area of about 5400 sq. km is the area selected for this study (Fig. 1). Hilly part of the Ravi River catchment completely falls in hill Chamba district and almost entire Chamba district drains into Ravi River. Geographically, Chamba is the second largest district of the Himachal Pradesh and significant part of the district is under scheduled tribes (highest ST population in the state). Topographically catchment having very rugged terrain and elevation varies from 467 m to 5872 m, amsl. All four agro-climatic zone of the state found only in this district i.e. Shivalik hill zone (350-650 amsl), Mid zone (650-1800 amsl), High hill zone (1800-2200 amsl), Cold dry zone (>2200 amsl, snowfall).

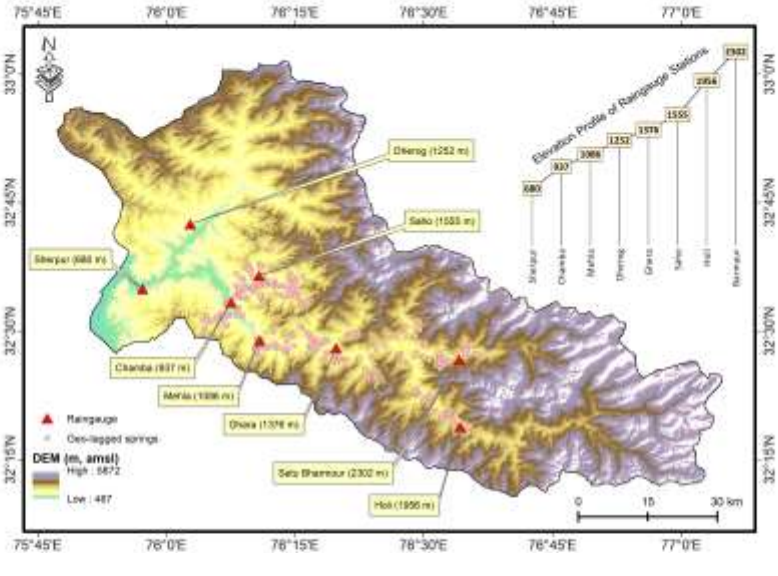


Fig. 1: Study area showing location of raingauges.

Objectives:

- Creation of web-enabled database of the springs emerging in the catchment based on extensive inventory of physical and hydro-chemical characteristics.
- Mapping of vulnerable springs using hot-spot analysis.
- Hydrogeological investigation of some selected springs, which are vulnerable and having high societal importance for identification of their spring-shed area and potential.
- To suggest adaptive strategies for selected hot-spot springs for spring sanctuary development to sustain the local water demand.
- To build capacity among the local stakeholders through creating para-hydrogeologists for conserving and managing the springs.

Statement of the Problem:

The demand for the water in the rural areas is much higher than in urban areas as a majority of the population of the Himachal Pradesh, a Himalayan state of India, lives in the rural areas. Furthermore, there is an imbalance between the supply and consumption of water, particularly by the poor and weaker section of society, the traditional sources (normally springs) of water play a significant role. There are 10512 traditional sources of water in the Himachal Pradesh for drinking water in rural habitats (Survey of status of drinking water in rural habitats, 1991-93). Chamba district has about 2598 traditional water sources, which are maximum among all the districts of the state. According to Himachal Pradesh Human Resource Development Report (2002), water demand for the population of Chamba district will increase from 36.53 mld (2001) to 58.04 mld (2021). About 85% of this total water demand is from the rural areas that are largely dependent on traditional water resources. HP State Council for Science, Technology and Environment has carried out a survey in 169 *Panchayats* of seven districts in the state of Himachal Pradesh on traditional water sources, which clearly showed that there were only 30% sources in good working condition and recharging properly throughout the year, while 70% sources were not in proper working condition and going to dry up in near future. In Chamba district, less than 1% sources were found working well, while more than 99% were in poor condition. It is worth noting that the entire Chamba district is part of Ravi River basin. Keeping in view of the importance of traditional water resources in sustaining the water demand of the state, a Purpose Driven Study (PDS) has been taken under National Hydrology Project (NHP) for investigations of the springs of Ravi River Catchment of Himachal Pradesh.

Brief Methodology:

- Conducting the Survey using handheld GPS
- Preparation of GIS layers and Base line data collection
- Development of Web-GIS Information System using open source technologies such as Geo-Server, Post-GIS, HTML, Java etc.
- Identify the vulnerable springs through Hot-spot analysis
- Identification of recharge area using the integration of Hydro-geo-chemical and isotopic analysis.

Progress of Work/Results and Analysis:

- Spring survey work for the entire Ravi River catchment of Himachal Pradesh (≈5400 sq. km) has completed. Total 925 springs have been geotagged, surveyed and water samples collected for water quality analysis.
- Samples for water quality analysis for all surveyed springs were collected and analysis in water quality lab at WHRC, Jammu. Total 14 water quality parameters viz. pH, EC, Ca^{+2}, NO_3^+, SO_4^-, F^-, SiO_2, K^+, Fe, Na^+, Cl^-, HCO_3^-, CO_3^{-2} and alkalinity have been quantified.
- Web-GIS based portal named, ISHVAR (**I**nformation **S**ystem of **H**imalayan springs for **V**ulnerability **A**ssessment and **R**ejuvenation) having the information of 925 surveyed springs on 35+ parameters have been created with all supporting GIS layers and geotagged spring photographs (Fig. 2). All springs data are also available in the form of infographics for easy to understand.

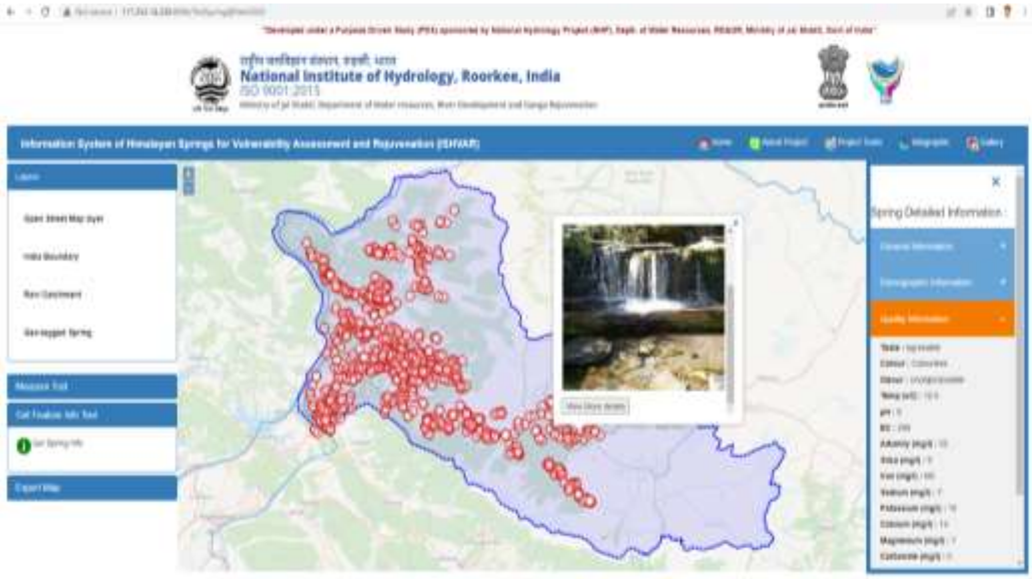


Fig. 2: Developed GIS based Web-Portal (ISHVAR) under NHP-PDS.

- Daily Rainfall data at 07 different locations (Sherpur, Dherog, Sahu, Mahela, Gera, Holi and Bharmaur) of the catchment are being observed and rainfall samples for isotopic analysis are being collected since July, 2021.
- Daily discharge of twelve springs of the catchment are being monitored and isotopic samples are also collected since July, 2021 for understanding the hydrological behaviour of the springs in different parts of the catchment.
- Field investigation was conducted during 18-24 November, 2021 with the geologist hired for geological investigation in Ravi river catchment. During the field visits in-situ water quality investigations of selected springs and nearby water bodies were performed (Fig. 3). Geological investigation was performed for identification of typology of 35 vulnerable springs in the area (Fig 4).

Fig 3: Field investigation for in-situ water quality analysis and geological investigation in Ravi River catchment.

Fig 4. Geological map with selected spring location map of the Ravi river basin. Modified after Webb, (2013); Thakur et al., 2019; Srikantia, and Bhargava, (2021).

Future Work:

- To identify the recharge area of selected springs.
- To develop the adaptive measures for revival of the springs.

9.0 *PROJECT* REFERENCE CODE*:* SP/38/2019-22/RCJ

Title of the Study:	**WEB-ENABLED INVENTORY OF NATURAL WATER SPRINGS OF TAWI RIVER CATCHMENT OF JAMMU AND KASHMIR STATE OF INDIA FOR VULNERABILITY ANALYSIS AND DEVELOPING ADAPTIVE MEASURES FOR SUSTAINING TAWI RIVER**
Study Team:	S S Rawat (P.I.), P G Jose, Suman Gurjar, and D S Bisht
Collaborating agencies:	Dept. of Soil and Water Conservation, Govt. of Jammu & Kashmir
Type of Study:	Sponsored (under NMHS)
Funding Agency:	Ministry of Environment, Forest & Climate Change, Govt. of India
Budget:	Rs. 38.04 lakh
Duration of Study:	03 Years **(**January 2019 to September 2022)

Study Area:

The present study is focused on the Tawi River Catchment (Fig. 1). Tawi River is a major river that flows from Jammu division of Jammu and Kashmir. Tawi River, also called the lifeline of the two major district (Jammu and Udhampur) of Jammu region, is the left bank tributary of river Chenab originating from the lapse of Kali Kundi spring area southwest of Bhadarwah in Doda district. After originating from the Doda district of Jammu region it enters into the Udhampur district where it flows for its maximum length and enters Jammu district and finally merges with river Chenab in Pakistan. The length of River from its originating point to Jammu is about 150 km. Total catchment area of the river Tawi is about 2168 km^2 up to Jammu region. Catchment area of the Tawi River lies in the four most populous districts of Jammu divison i.e. Jammu (21.56% area of Tawi catchment), Udhampur (71.6%), Reasi (4.8%) and Samba (1.7%). The Tawi River has a very high social impact as it is the only major source of water for drinking, agricultural and industrial needs, and it serves to the almost 20% population of the whole J&K state. About 250 villages of these four districts fall in the Tawi catchment directly depend on Tawi River or nearby springs for their drinking as well domestic water needs. Since, there is no glacier present in the Tawi catchment, springs are the only available sources that maintain the flow of the river Tawi in lean season. The average altitude of the catchment is about 2200 m above mean sea level (amsl). The catchment elevation varied from 4000 m amsl in the upstream to about 300 m amsl in the plains.

Objectives:

- Creation of GIS based web-enabled database of the springs emerging in Tawi River catchment based on extensive inventory of physical and hydro-chemical characteristics.
- Identification of vulnerable springs using hot-spot analysis.
- Hydro-geological investigation of some selected springs, which are vulnerable and having high societal importance for identification of their spring-shed area and potential.
- To suggest adaptive strategies for selected hot-spot springs for spring sanctuary development to sustain the local water demand.
- To build capacity among the local stakeholders through creating para-hydrogeologists.

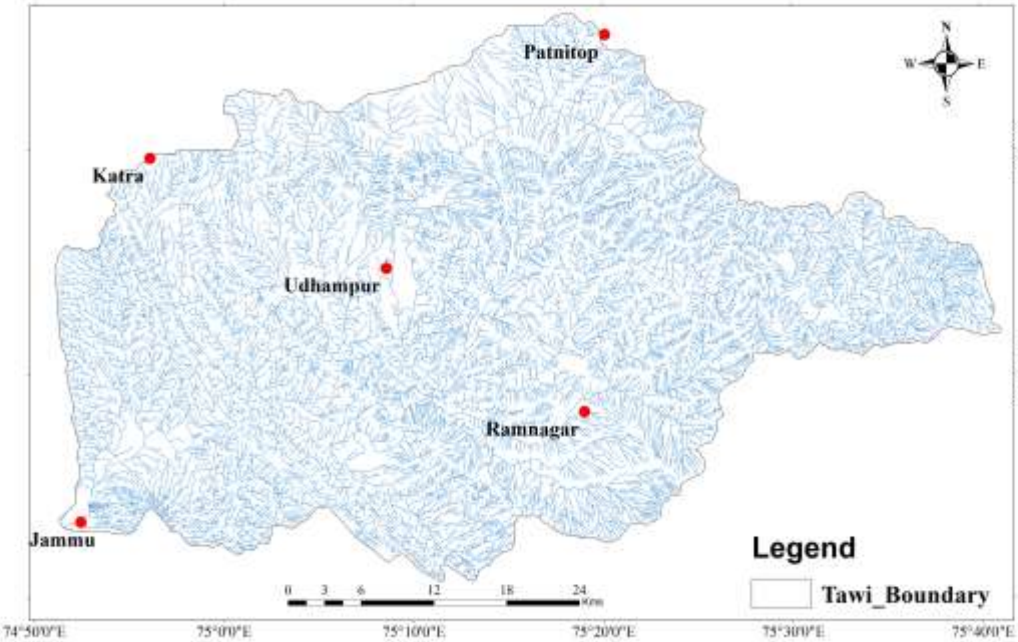


Fig. 1: Tawi River catchment of Jammu and Kashmir and its drainage network

Statement of the Problem:

River Tawi is the major river in Jammu region and its importance for sustaining the most populous cities in the region, Jammu and Udhampur, has been considered while selecting the basin. About 250 villages of four districts Jammu, Udhampur, Riasi and Samba fall in the Tawi catchment and depend upon Tawi River and springs in its catchment for their drinking as well domestic water demand. As per SOI toposheets more than 350 major springs are emerging from Tawi catchment and are responsible for maintaining the base flow of the River, which also is important for sustaining the artificial lake and Tawi Riverfront Development Project, which are under construction. There is hardly any water flowing in River Tawi during lean season and the people of the area face acute shortage of water impacting their very livelihoods. A previous study carried out by National Institute of Hydrology (NIH), Roorkee indicates that the discharge flux in Tawi is declining at the rate of 23 MCM per year. Water demand in the catchment is on the rise due to rapid urbanization and high population growth (20% per decade). In view of cultural, social and hydrological importance of Tawi catchment and lack of base data on springs, the proposed project has immense significance for the sustainable water resource management in the catchment wherein revival of drying springs will play a vital role.

Brief Methodology:

- Conducting the Survey using mobile app
- Preparation of GIS layers and Base line data collection
- Development of Web-GIS Information System using open source technologies such as Geo-Server, Post-GIS, HTML, Java etc.
- Identify the vulnerable springs through Hot-spot analysis
- Identification of recharge area using the integration of Hydro-geo-chemical and isotopic analysis.

Progress of Work/Results and Analysis:

- For collecting the data for creating spring inventory a survey form covering questionnaire to various parameters related to the springs has been created in KoBo tool box (Fig. 1). These parameters have been monitored during field visits and the spring photos have been geotagged. A total of 47 parameters have been recorded in the field which cover all the general, spatial, social and demographic factors related to the spring.

- Spring survey work for Tawi river catchment up to Jammu (2168 sq. km) has completed. Total of 500 springs have been geotagged and surveyed.

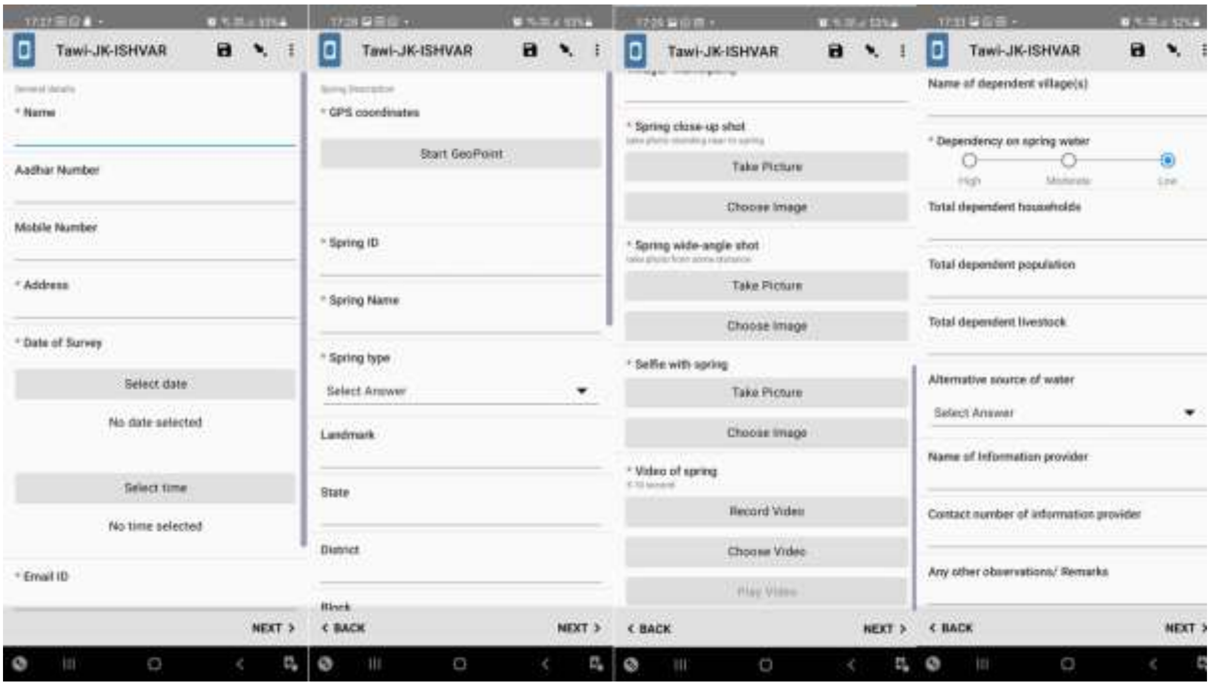


Fig. 1: Spring data collection app in KoBo tool box.

- Samples for water quality analysis for all surveyed springs are being conducted in the lab.
- Spring web-portal for Tawi catchment having the information of 300 surveyed springs on 47 parameters have been created with all supporting GIS layers and geotagged spring photographs (Fig 2). However, data compilation for the remaining springs are in progress.
- Seven raingauge stations i.e. Jammu (282 m, amsl), Udhampur (750 m, amsl), Pangara Jagir (766 m amsl) Chennani (1210 m, amsl), Jagir (1488 m amsl) and Mantalai (1650 m, amsl) have been established and daily rainfall data is being measured since July, 2021.
- 08 springs, representing the different parts of the catchment, have been selected for detailed study. Daily discharge data for these springs have been recorded since July 2021.
- Two days' online training workshop on 'Tools and Techniques for Springshed Management' was organized for the stakeholders of the Tawi catchment during 06-07. 01.2022 at WHRC, Jammu (Fig. 3)

Future Work:

- To compile the data of springs on the developed web-portal for complete inventory of springs of Tawi catchment.
- To prepare local geological maps and demarcation of recharge area of selected springs.
- To develop the adaptive measures for revival of the selected springs.

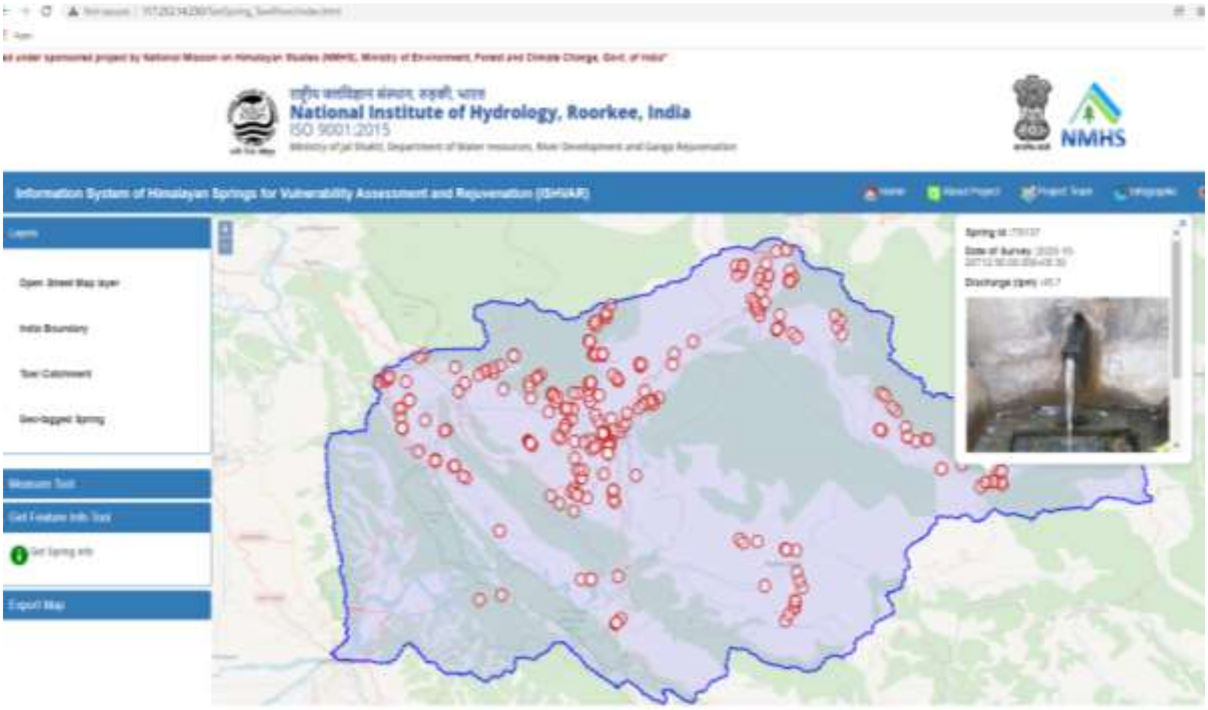


Fig. 2: Web-GIS based spring portal for Tawi catchment of Jammu & Kashmir.

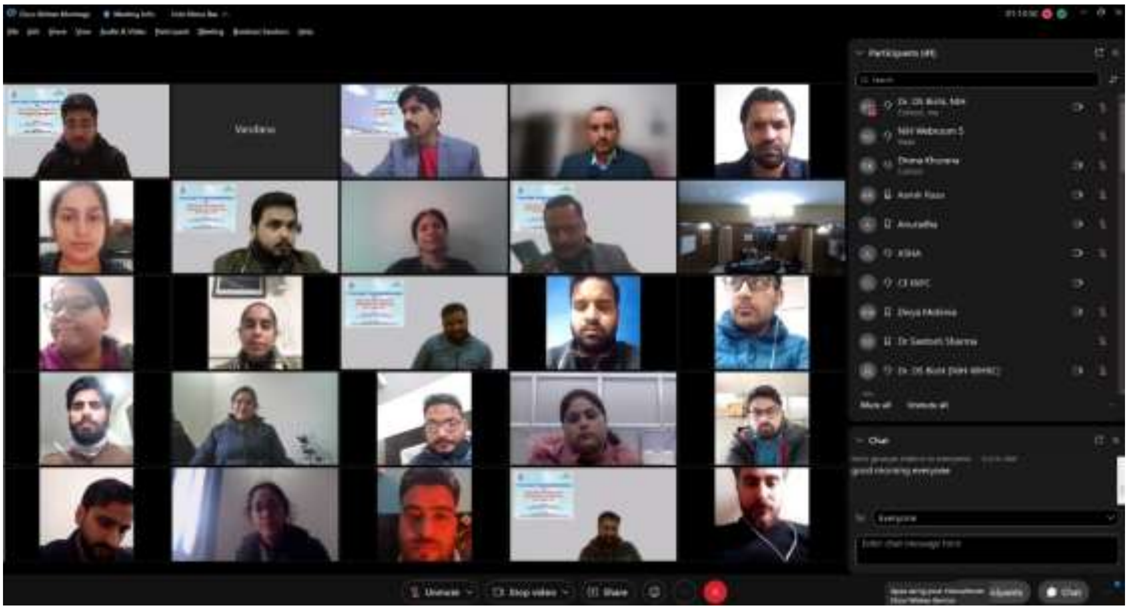


Fig. 3: Training workshop for the stakeholders of the Tawi catchment.

NEW STUDIES PROPOSED FOR 2022-23

INTERNAL STUDIES

1. PROJECT REFERENCE CODE: NIH/HID/R&D/2022/1

Study Title:	**ASSESSMENT OF THE POSSIBLE IMPACT OF CLIMATE CHANGE ON EVAPOTRANSPIRATION FOR DIFFERENT CLIMATIC REGIONS OF INDIA**
Study Team:	SD Khobragade (PI), Dr. Vishal Singh, Scientist-C, Dr. Sudhir Kumar, Sc-G;
Type of Study:	Institute Funded R & D Study
Duration:	3 years
Date of Start:	April, 2022
Date of Completion:	March, 2025
Budget:	10 Lakh

Statement of Problem:

Evapotranspiration is one of the key components of the hydrologic cycle. Precipitation which falls on the land is subjected to evaporation and evapotranspiration before it reaches back to the oceans, causing a significant loss of the available water. Increasing scarcity of water due to increased ET losses may lead to difficulties in meeting the various demands of the growing population and its development needs. Most of the water bodies in the warm tropical regions undergo heavy evaporation losses. As per the CWC (2006) report, average annual evaporation loss from reservoirs/water bodies in India is about 27,000 MCM. As such, any change in evapotranspiration is likely to significantly affect the global hydrologic as well as energy cycle (IPCC, 2013). Being a cause of significant water loss, evapotranspiration plays a major role in determining the stream flow regime. Therefore, understanding the impact of temperature rise or climate change on evapotranspiration is essential for a proper understanding of the impact of climate change on the hydrological regime of the stream and water availability in the basin or water body. It shall provide a proper assessment of how much more or less water shall be available and, if less water is available, then how much additional water shall be required to meet the various demands. Unfortunately, not many studies have been reported on assessment of impact of climate change on evaporation and Evapotranspiration, more so for India.

Objectives:

The major objectives of the proposed study are: ·

i) To assess the present ET regime of some selected climatic regions of India
ii) To assess the impact of rising temperature on various hydro-meteorological parameters used for ET assessment
iii) To predict and compare the possible impact of climate change on ET regimes of the selected climatic regions of India

Study Area

The study is proposed to be carried out for different climatic regions of India. About five areas shall be identified to represent different climatic regions. The selection of the study area shall be based on the availability of required data vis-à-vis the identified methodology.

Present state-of-art

A plethora of literature is available on the possible impacts of temperature rise and climate change on the hydrologic cycle. Unfortunately, only a limited number of these studies are related to the assessment of the impact specifically on the process of evapotranspiration. It can be illustrated from 5th assessment report of IPCC also. Many of the reported studies related to climate change impact are based on trend analysis of the evaporation data, particularly the pan evaporation data. These studies report mixed findings with increase predicted for some regions and decrease for some other. Few studies have also been reported using the output from the global or regional circulation models and coupling it with the hydrological models. As far as India is concerned, although one of the initial studies on climate change impact on evaporation using GCM simulations was reported in the last decade of the previous millennium by Chattopadhyay and Hulme (1997), which projected a decrease in the potential evapotranspiration, not may studies using GCM or RCM data have been reported since then. Most impact studies related to evaporation or evapotranspiration for different regions of India deal with analysis of trends in pan evaporation or reference evaporation data (Verma et al.,2008; Jaswal et al., Jhajharia et al.,2009; Bandopadhyay et al., 2009, Padmakumari et al.,2013; ; Annu priya et al., 2014, Goroshi et al. , 2017). The reported studies clearly indicate that evaporation paradox has been observed in most parts of India. However, more and more studies using the projected outputs from the atmospheric circulation models and using them as input in the Penman-Monteith model are required for the picture to become clearer.

Justification for the study

Climate change and the associated temperature rise is expected to significantly affect the hydrologic cycle in general and its various components in particular, necessarily including evapotranspiration. The knowledge of the possible impact of climate change on evaporation and evapotranspiration is particularly important because in water stressed regions of the world, like India, any increase in future ET losses may play a significant or even a deciding role in the water availability and management of such regions. As such, knowledge about the impact of climate change on ET is one of the most essential aspect of preparedness for future water management in view of climate change. Unfortunately, not many studies have been reported on assessment of possible impact of climate change on evaporation or ET in India. The proposed study intends to fill the gap.

Brief Methodology

i) The present average ET rates for selected climatic regions of India shall be estimated from the present hydro-meteorological data of last few decades, using the Penman-Monteith model
ii) All temperature dependent hydro-meteorological paramours shall be identified.
iii) Projected climatic data variables such as minimum and maximum temperature from the latest GCMs developed under CMIP6 project shall be obtained to analyze the impact of climate change on ET factors.
iv) For this purpose, the evaluation of four best GCMs with SSP245 and SSP585 scenarios
v) (total eight scenarios) will be done for selected climatic regions and then the bias correction and spatial downscaling of the GCM variables will be performed for selected climatic regions of India.
vi) The downscaled and bias corrected GCM variables shall be used as input to the Penman-Monteith model and future changes in ET rates will be estimated by performing probabilistic linear and non-linear trends analysis (e.g. Quantile regression, Q-Q plots, and CDF).
vii) The present and projected ET rates shall be compared to assess the impact of climate change on ET variability (in terms of magnitude of change) for different regions.
viii) The present and predicted rates of different climatic regions shall be compared and factors responsible variation shall be identified

Research outcome/Deliverable from the project

i) Comprehensive Project Report including all data, maps, information, analysis and results. The report would contain comparative impact of climate change on ET for different climatic regions of India.
ii) Research Publications

Beneficiary/End User

The outcome of the study shall be useful for all the state and central government agencies dealing with water management. It would also be useful for the researchers working in the area of impact of climate change on hydrology and water resources.

Budget Justification:

The budget is required for procurement/collection of data.

Work Plan/Activity Chart:

As given in activity schedule below. :

ACTIVITY SCHEDULE

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	Collection & Review of all available data/information/literature	√	√	√	√	√	√						
1.2	Selection of study area representing different climatic regions of India	√	√										
1.3	Preparation of study area maps		√	√									
1.4	Procurement & compilation of meteorological data of different selected climatic regions of India	√	√	√									
1.4	Downloading and processing of meteorological and GCM datasets	√	√	√	√	√							
2.0	**DATA PROCESSING & ANALYSIS**												
2.1	Estimation of present ET rates for selected climatic regions of India					√	√						
2.2	Assessment of the impact of temperature rise on different temperature dependent hydro-meteorological parameters & their inter-comparison for the selected climatic regions			√	√	√	√	√	√				
2.3	Prediction of the possible impact of climate change on future ET using GCMs for the selected climatic regions of India & their inter-comparison				√	√	√	√	√	√	√		
3.0	**PREPERATION OF REPORT**												
3.1	Interim report -1					√							
3.2	Interim Report-2									√			
3.3	Draft final report												√

2. *PROJECT REFERENCE CODE: NIH/HID/R&D/2022/2*

Thrust Area: Sustainable water systems management: Adaptation of hydro-system to climate change

Title of the Project: Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions

Study group

Dr. Soban Singh Rawat, Scientist 'E' **(Project Investigator)**
Dr. Sudhir Kumar, Scientist 'G', and Head, HID
Dr. Santosh M. Pingale, Scientist 'C', HID
Dr. P K Mishra, Scientist 'D', WRS
Dr. D. S. Bisht, Scientist 'B', WHRC, Jammu
Dr Rajesh Singh, Scientist 'D', EHD

Type of Study: Internal funding

Objectives: The present study will be carried out with the following objectives:

1. To physically validate the springs identified by SOI using state of the art technologies in Bilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district,
2. To create web-based spring database & its regular updation,
3. To conduct water quality analysis of the surveyed springs to understand the qualitative status of the springs in the area,
4. To identify the vulnerable springs which needs to be revived, and
5. To develop the capacity of local stakeholders and implementing agencies for effective development and management of springshed programme.

Study area

The present study will be carried out Bilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district of Uttarakhand state of India (Fig. 1).

Fig. 1 Location of the proposed study area.

Present state-of-art

The springshed project was taken up at the instance of a decision taken in the meeting of Secretary, MoWR on 20.03.2019 that CGWB & Survey of India (SoI) may prepare a proposal for pilot project in some districts of Uttarakhand through which Ganga is flowing. CGWB, UR recommended that the pilot project can be taken up in one of the three districts Uttarkashi, Tehri Garhwal & Almora. Survey of India has submitted the timeline & cost estimate for drone based systematic mapping of spring, 100% inventory of all springs & their ground-truthing, delineating springsheds, creation of 3-D model of springsheds and preparation of Atlas for Tehri Garhwal District under the guidance of CGWB. As NMCG was already carrying out project with SoI, another project was also taken up for drone study in Tehri Garhwal District & CGWB was advised to take up a pilot study in one area in the district. Accordingly, Pratpnagar Block (about 439 Sq Km), Tehri Garhwal District was identified for pilot study. Due to various procurement related issues, there has been a delay in 3 the drone survey of Tehri Garhwal district by SoI. Consequently, Ministry has accorded approval for taking up management & restorative initiatives for spring rejuvenation activity in Bhilangana C.D block of Tehri Garhwal (about 1093 sq Km.) & Ukhimath C.D. block (about 1081 sqkm), of Rudraprayag district for which the LiDAR DEM is already available with SoI. By using DEM, point cloud and ORI of Manu Project in Bilangana CD block of Tehri Garhwal District and Ukhimath CD block of Rudraprayag District & drone mounted LiDAR data of Pratpnagar Block, Tehri Garhwal District, spring identification and demarcation of spring shed will be carried out by SoI and shared with CGWB. District Administrations will be approached for carrying out the preparation of DPR for spring rejuvenation structures by MGNREGS & execution of DPR through MGNREGS fund in Bhilangana & Pratapnagar blocks of Tehri Garhwal district & Ukhimath block of Rudraprayag district. In view of the man power constraints, it was decided to take up the study through outsourcing work. As NIH has already completed spring study in parts of Himachal Pradesh & has also prepared a web based application for spring data storage (ISHVAR - Information System of Himalayan Springs for Vulnerability Assessment and Rejuvenation), it was felt prudent to utilize the expertise of NIH in springshed work.

Scope of Work

In order to achieve the objective, the scope of work for the project in three blocks with timeline is detailed as under:

- SoI will provide spring inventory, i.e. Spatial attributes (lat long/ Easting Northing) of Springs, along with DEM and Topographical features such as Roads, Water bodies, Buildings, Contours etc. SoI will carry out springshed atlas and share it with CGWB.
- The initiation of the project duration will be considered from the day of receiving the information from SoI for each of the three blocks.
- The project will be taken up one block at a time with a broad time line as given below:

Project	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Bhilangana C.D block, Tehri Garhwal District												

Project	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Ukhimath C.D. block, Rudraprayag District												

Project	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
Pratapnagar block, Tehri Garhwal district												

Detailed month wise timeline for different activities in a block

- Detailed month wise timeline for each activity in a particular block is prepared and the entire duration for one block is kept one year. However, the duration of the activity "Validation of spring map, creation of spring inventory and updation of spring atlas" will vary for different blocks as geographical area and topography of three block as selected in this study are significantly differ and the spring population is yet not given by the SoI. However, total duration of the project will not be affected. Blocks selected for this study will be taken one by one and the activities and month wise timeline for one block is as follows:

Sl. No.	Activity	Agency-Responsible	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
1	Validation & Ground truthing of the spring maps prepared by SoI*	NIH												
2	Web-GIS Spring Inventory/Atlas creation and updation	NIH												
3	Identification of Vulnerable Spring & field validation based on the list provided by stakeholders & SoI**	NIH & CGWB												
4	Springshed mapping & identification of Recharge areas for springs	CGWB												
6	Identification of Type & No of AR Structures for sustainability of	CGWB												

Sl. No.	Activity	Agency-Responsible	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
	Spring													
7	Capacity Building of Stake Holders	NIH												
8	Preparation of DPR***	State Agency dealing with execution of MGNERGS												
9	Monitoring of work	CGWB												
10	Execution of Work through MGNREGS Fund by State Government***	District Administration												
11	Continued Monitoring for Impact assessment	CGWB												
12	Final Report on Project Outcome	CGWB & NIH												

Methodology

(i) **Validation/Geotagging of Springs**:

Springs identified by the SOI will validate through their geographical coordinates. In addition to this springs which are nearby settlement will be geotagged and surveyed through mobile App developed in KoBo tool.

(ii) Information collection through field survey:

The following information will be collected through mobile-app based survey:

(a) General information (latitude, longitude, elevation, village, gram panchayat, tehsil, district, Spring type & Nature, Purpose of use, discharge, people perception about discharge, lean and peak month of discharge, month of muddy water, name and telephone of information provider, name and mobile number of gram pradhan);

(b) Demographic information (dependent villages, household, population, livestock, dependency, land ownership at spring point and upstream side, land use at spring point and upstream side), and

(c) Water quality information (taste, colour, odour, pH, EC, TDS, ORP, DO)

(iii) Springs Water Quality Analysis

The spring water is the sole source of drinking water and other domestic applications inthe villages of the study area, therefore, necessitating the water quality evaluation of these springs, for identifying sources of contamination and implementation of corrective actions, to ensure the safety of drinking water and in turn the human health. In addition, a baseline water quality inventory will be developed for the policy makers. Department of Drinking Water & Sanitation, GOI has recommended monitoring of at least thirteen basic minimum parameters (pH, turbidity, TDS, Total Hardness, alkalinity, fluoride, chloride, sulphate, nitrate, arsenic, iron) in drinking water samples. Apart from these parameters, other parameters as per geology and localconditions (some heavy metals for some representative springs and some bacteriological parameters such as TC & FC) that may hamper the human health should be analyzed.

(iv) Development of Web-GIS Information System and Infographic tool

A Web-GIS application will be configured using ArcGIS Web App-builder. The Web-GIS application will be able to respond to Spatial and Attribute based queries, and generation of report, chart, summary etc. It will allow viewer to click on spatial feature to retrieve all information on screen. A configurable operation dashboard will also be developed using ESRI application. The dashboard will provide status of key performance indicator in the form of graphs/charts/maps to users and policy makers.

(v) Identification of vulnerable springs

Vulnerable springs will be identified based on “Hardship Ranking System” in which springs are ranked in term of the information collected during spring survey on their importance for users and their present status. A spring with high scores will be declared as vulnerable, while those with less scores will be treated as ‘sensitive’ which may become vulnerable in future. Identified vulnerable springs will be treated as priority for various rejuvenation or revival programme to be taken by concerned departments of the district.

(vi) Capacity building programme

Need base training programme will be organized for the personnel of Himachal Pradesh Jal Shakti Vibhag and local stakeholder for understanding the hydro-geology and chemistry of springs so that they can themselves formulate the Spring revival programme in future.

6. Final Outcome

- Efficacy of use of modern technologies for spring mapping.
- Identification of vulnerable springs and ensure the sustainability of these springs through construction of artificial recharge/water conservation structures.
- Creation of detailed spring map of Pratapnagar & Bhilangana blocks of Tehri Garhwal District & Ukhimath block of Rudraprayag district.
- Updation of database of springs of the project area, in web portal (ISHVAR) developed by NIH
- Impact assessment study would lead to formulation of guideline for future projects on spring rejuvenation.
- The capacity building program will make the stakeholders aware about the necessity of water conservation and artificial recharge for sustainability and management of springs/aquifers in hilly region.

Budget estimates

a. The total cost of the project (03 Years duration): **Rs 39.55 lakh**

b. Source of funding: Internal funding from NIH

c. Sub Head wise abstract of the cost

S. No.	Head	Amount (Rs)
1	Salary (01 JRF @31000/month + HRA and 01 Field Worker@ 18000/month + HRA)	19,05,120
2	Travelling expenditure	6,00,000
3	Infrastructure/Equipment (Multi parameter water quality kit)	1,00,000
4	Consumables (Chemicals and plastic wares)	9,00,000
5	Capacity building (training & Workshop for stakeholders & implementing agencies)	3,00,000
5	Contingency	1,50,000
	Total	**39,55,120**

SPONSORED PROJECT

Title of the Study:	**Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river**
Study Team:	Dr. Sudhir Kumar, (Project Coordinator), Dr. M. K. Sharma, (Principal Investigator), Dr. R. P. Pandey, Dr. Suhas Khobragade, Dr.Anupma Sharma, Ms. Anjali, Dr. Vishal Singh, Dr. SM Pingale, Dr.Pradeep Kumar, Dr.Nitesh Patidar, Dr.Surjeet Singh.
Collaborating agencies:	IIT Kanpur
Type of Study:	Sponsored by DST (under DST-NOW call)
Funding Agency:	Department of Science and Technology, GoI
Budget:	Rs. 240 lakh
Duration of Study:	05 Years **(**April 2022 to March 2027

Study Objectives

This research aims at providing scientific understanding on the hydrological functioning and the impact of agricultural water management of the Hindon subbasin of the Ganges river. Three areas of research are distinguished:

1) Integrated water systems analysis to understand the spatio-temporal relations between surface water and groundwater quantity and quality, and the impact of human activities and climate characteristics by setting up a monitoring network.
2) Interventions to improve agricultural water management and reduce negative impacts on water quantity and quality.
3) Develop recommendations for improvements in Hindon basin water quantity and quality, food production and economic revenues.

Statement of the Problem

River Hindon, an important tributary of river Yamuna flowing through the districts of Western Uttar Pradesh, is subjected to varying degree of pollution caused by numerous untreated and/or partially treated waste inputs of municipal and industrial effluents. The toxic pollutants from these wastes will ultimately reach the ground water and enter in the food chain posing a threat to human health because of their carcinogenic nature. The pollution matrix in some stretches of the river becomes so complicated that anaerobic and septic condition prevails during the lean period due to discharge of effluents to the river from various industries and municipal areas. Though a large number of studies, to understand the pollution aspects of river Hindon, have been carried out by different workers (Verma and Mathur, 1971; Verma and Dalela, 1975; Verma et al., 1980; Patel et al., 1985; Singhal et al., 1987; Joshi et al., 1987; Seth, 1991; Seth and Singhal, 1994; Khare, 1994; Kumar, 1994; Lokesh, 1996; Jain, 1996, 2000; Kumar, 1997; Jain and Ali, 2000; Jain and Ram, 1997a, 1997b; Jain and Sharma, 2001a, 2002, 2006; Jain et al., 1997, 1998a, 1998b, 2002, 2003, 2004a, 2004b, 2005, 2007; Sharma, 2001; Sharma et al., 2009a, 2009b), but no comprehensive and holistic plan for rejuvenation of river has been attempted. This requires monitoring of water resources and pollutants within the river basin through data collection, modeling of river water and groundwater interaction and interpretation. Further hydrological study of the basin is important to understand the surface and groundwater interaction. Water Balance in Hindon River Basin will provide water allocation for different sectors for better water management in the basin. Reach-wise recharge augmentation plan may be implemented by identification of affluent and effluent sections in the river.

10. Approved Action Plan/Methodology

i) Literature review and collection of data from published reports and papers.
ii) Procurement of secondary data required for the analysis from various govt. agencies (discharge, rainfall, landuse/landcover, lithology, ground water level, aquifer parameters, sediment concentration, other water quality parameters, soil map etc.)
iii) Monitoring of water quality of River Hindon monthly basis for one year
iv) Study the relationships between different hydrological parameters
v) An inventory of pollution sources contributing to the River will be prepared from the collected information and Major Contaminant zones will be identified.
vi) Identification of affluent and effluent sections of River Hindon.
vii) Water Balance of Hindon River Basin using SWAT-MODFLOW model
viii) Reach-wise Recharge augmentation plan will be suggested

11. Work schedule / Timeline

Year	Month	Consortium Activity	NIH action plan
2022-23	Apr - Jun, 2022	Preparatory activities like approvals etc.	• Hiring of Project staff • Meetings with IIT K for formulating plans for field Visits • Forwarding request to state govt. for data • Literature Review
	Jul - Sep, 2022	Start of the project Kick of Meeting Hiring of Staff, PhD Creation of Advisory Board	• Administrative Approval for Equipment • Kick off Meeting and formal introduction of the members involved, role and responsibilities allocation. • Combined field visit of IIT K and NIH for G&D site and piezo-site locations.
	Oct - Dec, 2022	• Designing Observational Network • Identification of farms, urban and industry locations	• Installation of Piezometers and G&D sites • Inventory of pollution sources • Survey for morphometric analysis of river Hindon • Health, Agricultural and drinking issues identification.
	Jan - Mar 2023	Stakeholders Identification Installation of Base network and bathymetry Measurement	• Creation of Pollution Inventory • Stakeholders Identification • Groundwater level trend analaysis • Water quality over years inventory
<u>Year-2</u> 2023-24	Apr - Jun, 2023	Field investigations	• Soil, Groundwater and river water quality sample collection and analysis

	Jul - Sep, 2023	Data preparation for IHE-FEWS	• Contribute to FEWS data platform
	Oct - Dec, 2023	• Stakeholders Meeting • Field investigations	• Stakeholders Meeting • River discharge and water quality, • Groundwater levels and water quality
	Jan - Mar 2024	Report writing	• Preparation of Interim report • Scientific paper writing
Year-3 2024-25	Apr - Jun, 2024	Data collection	• Groundwater and river water quality sample collection and analysis
	Jul - Sep, 2024	Groundwater Investigation	• Recharge Estimation for Hindon river Basin • Estimation of Parameters for Groundwater Model Development.
	Oct - Dec, 2024	Mid- Project stakeholders meetings	• Stakeholders Meeting
	Jan - Mar 2025	Data interpretation and Report writing	• Preparation of Interim report • Scientific paper writing
Year-4 2025-26	Apr - Jun, 2025	Data collection	Groundwater and river water quality sample collection
	Jul - Sep, 2025	Sample analysis	Groundwater and river water analysis
	Oct - Dec, 2025	Scientific Advisory Board Meetings	Final Groundwater-surface water interaction Model
	Jan - Mar 2026	Stakeholders Workshop Result sharing and analysis	Effluent and affluent zone identification. And integration of individual developed models
Year-5 2026-27	Apr - Jun, 2026	Development of GW Model	Development of GW Model
	Jul - Sep, 2026	Calibration and Validation of the model	Calibration and Validation of the model
	Oct - Dec, 2026	Data analysis and interpretation	Suggestions and measures for Hindon rejuvenation
	Jan – Mar, 2027	Advisory Board Meetings for project finalization	Working on finalization of results with Dutch Partners.

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. A K Lohani	Scientist G & Head
2	Dr. S K Singh	Scientist F
3	Dr. P C Nayak	Scientist F
4	Dr. Sanjay Kumar	Scientist E
5	Dr. Archana Sarkar	Scientist E
6	Dr. L N Thakural	Scientist D
7	Er. J P Patra	Scientist D
8	Dr. Ashwini A. Ranade	Scientist C
9	Dr. Sunil Gurrapu	Scientist C
10	Sri N K Bhatnagar	Scientist B
11	Sri Om Prakash	PRA
12	Sri Jatin Malhotra	SRA

APPROVED WORK PROGRAM FOR THE YEAR 2021-22

COMPLETED STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/16-21	Hydrological modelling in Alaknanda basin and assessment of climate change impact (NMSHE)	A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	Proposed for 5 years (April 2016 to March 2021) **Completed in time and report submitted**
2.NIH/SWHD/19-22	Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation (NHP)	A.K. Lohani R.K. Jaiswal Sushant Jain WRD Rajasthan Sanjay Agarwal Shailendra Kumar	Proposed for 2.5 years (Oct. 2019 to April 2022) **Completed in Time**

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/19-23	Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP)	P C Nayak Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas	3 year (Sept 2019 to April 2023)

COMPLETED STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/21-22	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Upper Narmada - 3e.	S.K. Singh	Proposed for One year (April 2021 to March 2022) **Completed in Time**
2.NIH/SWHD/18-20	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	Initially proposed for 2 years (Nov. 2018 to October 2020) **Further extended to 2.5 years more and report not yet submitted**

			i.e. total duration Oct 2018 to March 2022 (**4.5 Years**)
3.NIH/SWHD/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) Extended upto September 2021 **Completed in 3.5 Years**
4.NIH/SWHD/18-21	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent	Sunil Gurrapu Ashwini Ranade J.P. Patra	Proposed for 3 years (Nov 2018 to October 2021) **Completed in Time**

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/20-22	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.	J.P. Patra Rakesh Kumar Pankaj Mani Sunil Gurrapu	2 years (July 2020 to August 2022)
2.NIH/SWHD/21-23	Uncertainty in rating curves and discharge estimation	Sanjay Kumar L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra	2 Years **(**April 2021 to March 2023)

PROPOSED WORK PROGRAMME FOR THE YEAR 2022-23

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/19-23	Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP)	P C Nayak Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas	3 year (Sept 2019 to April 2023)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/20-22	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.	J.P. Patra Rakesh Kumar Pankaj Mani Sunil Gurrapu	2 years (July 2020 to August 2022
2.NIH/SWHD/21-23	Uncertainty in rating curves and discharge estimation	Sanjay Kumar L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra	2 Years (April 2021 to March 2023)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/22-22	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	Dr. A. K. Lohani, Sc-G (PI) Dr. R. K. Jaiswal, Sc-E (PI) Dr. J. C. Patra, Sc-E (Co-PI) Dr. P. C. Nayak, Sc-F (Co-PI) Dr. Vishal Singh, Sc-D (Co-PI)	Two Years April 2022 – March 2024
2.NIH/SWHD/22-23	Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A.	S.K. Singh	Six month (April 2022 to Sept. 2022)
3.NIH/SWHD/22-25	Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution	S.K. Singh	Six month (Oct. 2022 to March 2023)
4.NIH/SWHD/22-24	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak A. K. Lohani J. P. Patra	3 Year (July 2022 to June 2025)

		Sunil Gurrapu T. Thomas Om Prakash Jatin Malhotra	
5.NIH/SWHD/22-25	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	L. N. Thakural M. K. Shama R. K. Jaiswal J. P. Patra P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani	2 Year (July 2022 to June 2024)
6.NIH/SWHD/22-24	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P.Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar	3 Year (April 2022 to March 2025)
7.NIH/SWHD/22-25	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Sunil Gurrapu Y R S Rao Nitesh Patidar R Venkat Raman	2 Year (April 2022 to March 2024)
8.NIH/SWHD/22-23	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade P.K. Mishra Sunil Gurrapu	3 years (April 2022 to March 2025)
9.NIH/SWHD/22-23	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar Jyoti Patil Rohit Sambare Charu Pandey	1.5 Year (May 2022 to Oct 2023)

COMPLETED STUDIES (SPONSORED)

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

1. Project Title:
   Hydrological modelling in Alaknanda basin and assessment of climate change impact
   (DST Sanction No: SP-06)

2. PI (Name & Address):
   Dr. A.K. Lohani, Scientist-G, Surface Water Hydrology Division, NIH Roorkee

3. Co-PI (Name & Address): Dr Sanjay Kumar Jain, Scientist G, Head WRS Div. NIH Roorkee

4. Approved Objectives of the Proposal
   - 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.

Date of Start: January, 2016
Total cost of Project: 42.296 (Rs. in Lakh)

Date of completion: Sept 2021(**Completed**)

5. Brief Methodology/Work Plan etc :

The present sub-project proposes to focus on snowmelt runoff modelling in Alaknanda basin and study of impact of climate change. It is also envisaged to develop disseminate knowledge and results of the study in the concerned Central, State and other departments/agencies. The stepwise methodology to be adopted is as follows: a) Collection/procurement of available long-term hydro-meteorological and hydrological data for the study area from different Organizations (say, IMD, SASE, CWC, State Departments etc.). b) Procurement of satellite data of different dates for preparing snow cover area maps, collection of DEM data for preparation elevation area maps and drainage network. c) Development of seasonally varying Temperature Lapse Rate (TLR) using LST data estimated from thermal satellite image in Alaknanda basin. d) Processing and analysis of hydrological and hydro-meteorological data. Calibration and validation of snowmelt runoff model. e) Development of future climatic scenarios and investigation of the impact of likely future changes in climate on stream flow in the study area. f) Organization of workshops for the departments dealing with water resources planning and management.

Activity	**1st year**		**2nd year**		**3rd year**		**4th year**		**5th year**	
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Collection of hydrological and hydro-meteorological data from various agencies and entry in SWDES software	←	—	—	—	—	—	→			
Generation/import of spatial data layers for the study area and reference database from different sources	←	—	→							
Processing and analysis of data in SWDES and HYMOS software			←	—	—	→				

Evaluation of various components of hydrologic cycle in different spatial and temporal scales, trend and correlation analysis					←	—	—	—	→	
Analysis and design of observation network					←	—	—	—	→	
Development of project web site including linkage with web-based hydrological information system	←	—	—	—	—	—	—	—	—	→
Capacity building			←	—	—	—	—	→		

6. Salient Research Achievements (summary of progress):

Variable Infiltration Capacity Model (VIC) and WinSRM models have been applied for the study area. VIC is a grid-based macro-scale hydrological model with sub-grid variability in land surface vegetation classes and soil moisture storage capacity. In VIC model, drainage from the lower soil moisture zone (base flow) as a nonlinear recession. While, SRM is a degree-day based, conceptual and deterministic model and can simulate the runoff from snowmelt in basins. Further, it was decided to extend the study upto Rishikesh. Both VIC and WinSRM models were again setup for the extended study area i.e. upto Rishikesh. Both the models were calibrated and validated at Rishikesh gauging site. The INCCC (Model - CCCma_CanESM2) for climate change were applied under RCP 4.5 scenario, to examine climate influences on precipitation and temperature in the basin. Temperature and precipitation were determined for this scenario for three periods of 2006-2040, 2041-2070 and 2071-2099. After calibration and validation on the present time (2000-2015), the VIC and SRM models were used to study the impact of climate variability on the Upper Ganga basin runoff. The future climate scenario for mean temperature, precipitation and snow cover area were used to estimate the relative stream flow in the future for water resources management. Results of the VIC model are presented in Figure 1.

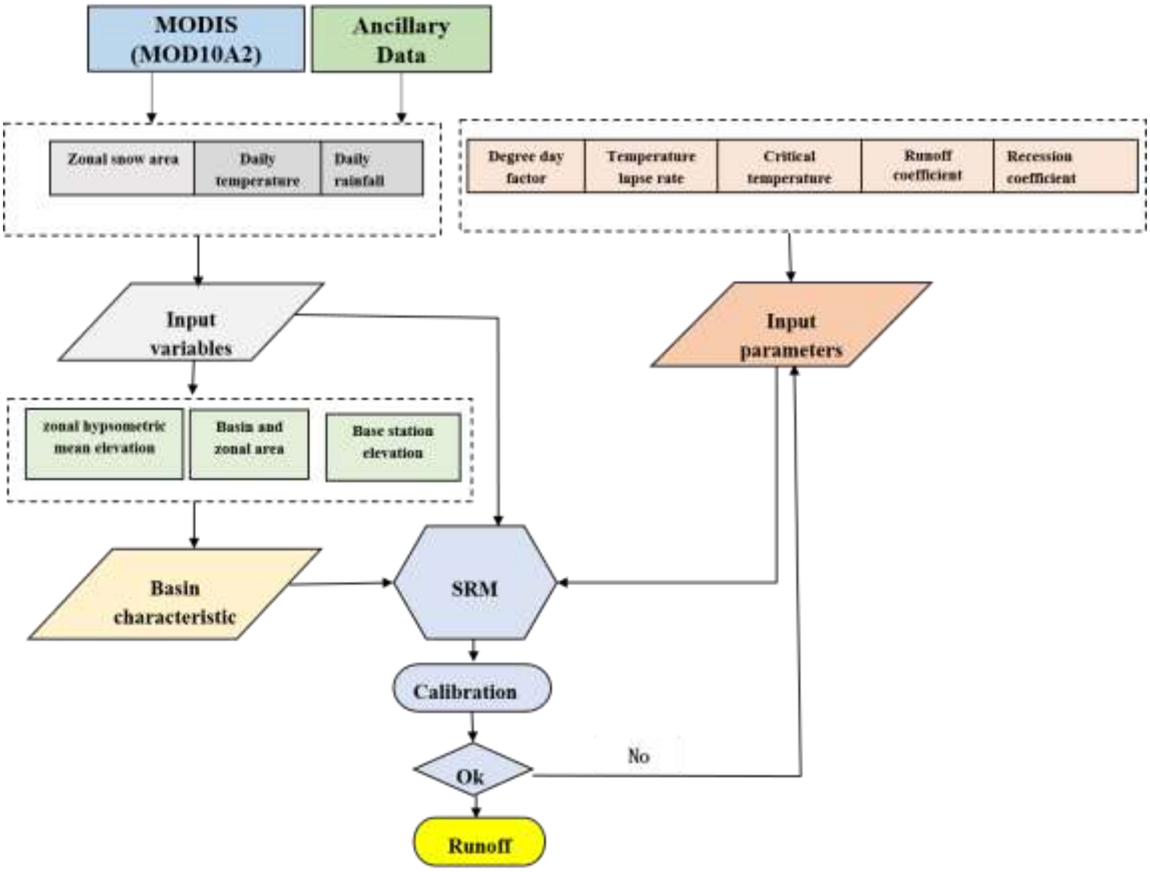


Figure 1: Workflow of SRM Model

Studying impact of climate variability

Climate change is an important environmental issue, as progression of melting glaciers and snow cover is sensitive to climate alteration. The snow depletion starts from March from zones 4 and moves to higher elevation zone. The analysis of snow-covered area depletion during 2000 to 2015, that in zone 1,2 and 3 the snow was almost free from snow cover, in zone 4, the snow was melted completely during July to Aug. After calibration and validation on the present time (2000-2015), the SRM and VIC models were used to study the impact of climate variability. The impact of climate variability on the Upper Ganga basin runoff was studied using the SRM and VIC models under the INCCC (Model - CCCma_CanESM2) rcp 4.5 future climate scenario and discharges simulated under different snow cover area scenarios are presented in Fig. 2

& 3. The future data from 2016 to 2099 is classified into three different time periods to represent the near future (2016-2040), middle future (2041-2070) and far future (2071-2099). From these above figures it can be observed that the monthly discharge during the monsoon period (July to August) are increasing from the near future to far future and for the non-monsoon months the monthly discharges are decreasing from near future to far future.

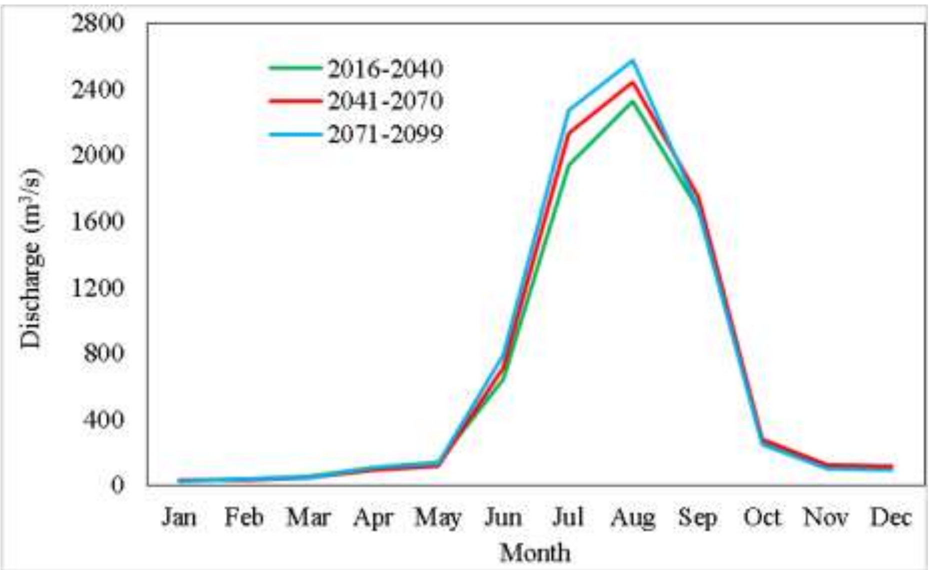


Figure 2: INCCC (Model - CCCma_CanESM2) rcp 4.5 Monthly Discharge at Rishikesh by SRM Model Data

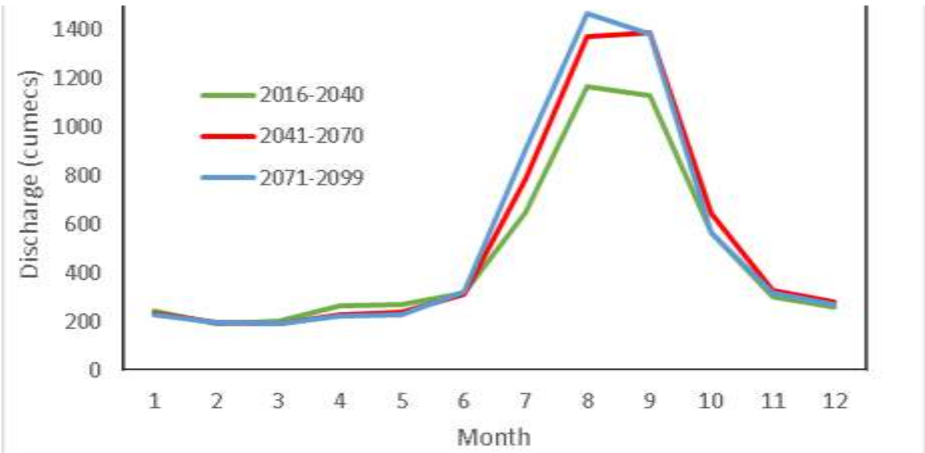


Fig 3: INCCC (Model - CCCma_CanESM2) rcp 4.5 Monthly Discharge at Rishikesh by VIC Model

COMPLETED STUDIES (SPONSORED)
2. PROJECT REFERENCE CODE: NIH/SWHD/19-22

Project Title:
Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation

Study Group

NIH
A.K. Lohani, Scientist G
R.K. Jaiswal, Scientist D
Sushant Jain, Research Scientist

WRD Rajasthan
Sanjay Agarwal, Executive Engineer
Shailendra Kumar, Executive Engineer

Sponsored Agency: NHP

Project Duration: Oct 2019-April 2022. (**Completed**)

Project Cost: Rs 15 Lakh (NIH:12 Lakh, WRD Rajasthan: 3 Lakh)

OBJECTIVES

- To understand the rainfall-runoff process by carrying out analysis of long-term hydrological data, land use/ land cover etc.
- Developing a rainfall-runoff model for the selected basin and to analysis the impact of land use/ land cover on runoff.
- To carryout sensitivity analysis of model parameters.

Progress:
The assessment of Land use and Landcover (LULC) changes on hydrological processes within the basin is conducive for optimal water resource management and assess the impact of extreme events like floods and drought. The modeling approach of basin enables us to understand the influence of each LULC class on hydrological components that greatly improve the predictability of hydrological consequences and thus can help water resource managers to make better and informed decisions. Water Resources Department, Rajasthan has requested for the rainfall-runoff modelling based on the LULC pattern for the selected basins under NHP. Out of 15 river river basins of Rajasthan, 5 basins are selected for this study namely Gambhiri, Parbati, Sabi, Shekhawati, and West Banas as sown in figure 1. Three decadal LULC were prepared for the years 1985, 1995, and 2005 and the year 2015, LULC map is going to be prepared. LULC of West Banas Basin is shown in Figure 2. SWAT model is being setup for the study basins. Further, request has been sent to WRD, Rajasthan for the supply of gauge & discharge data for the selected basins. In absence of G&D data for model calibration attempt were made to calibrate the model with satellite ET data.

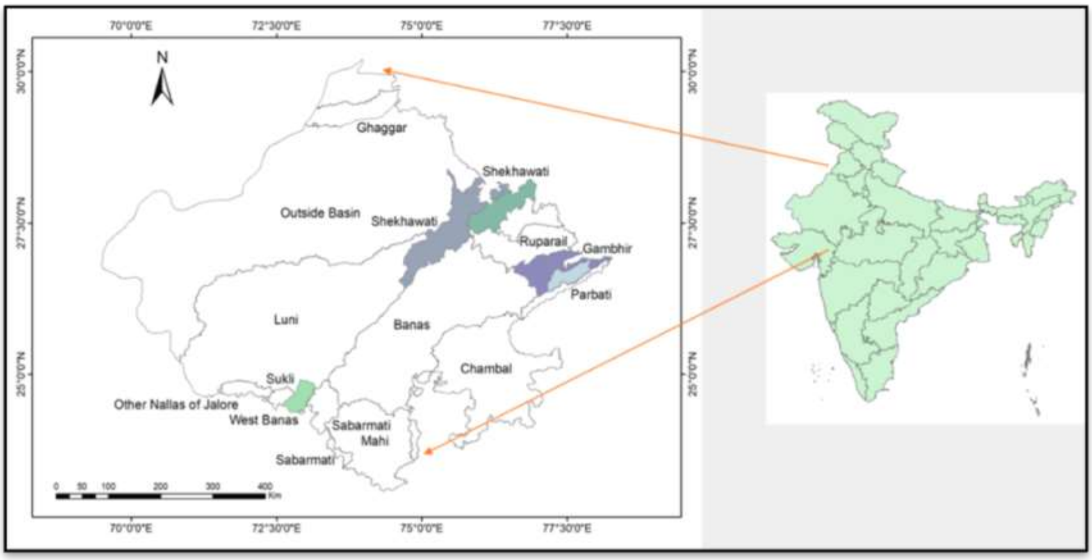


Figure 2 Selected Basin for the study

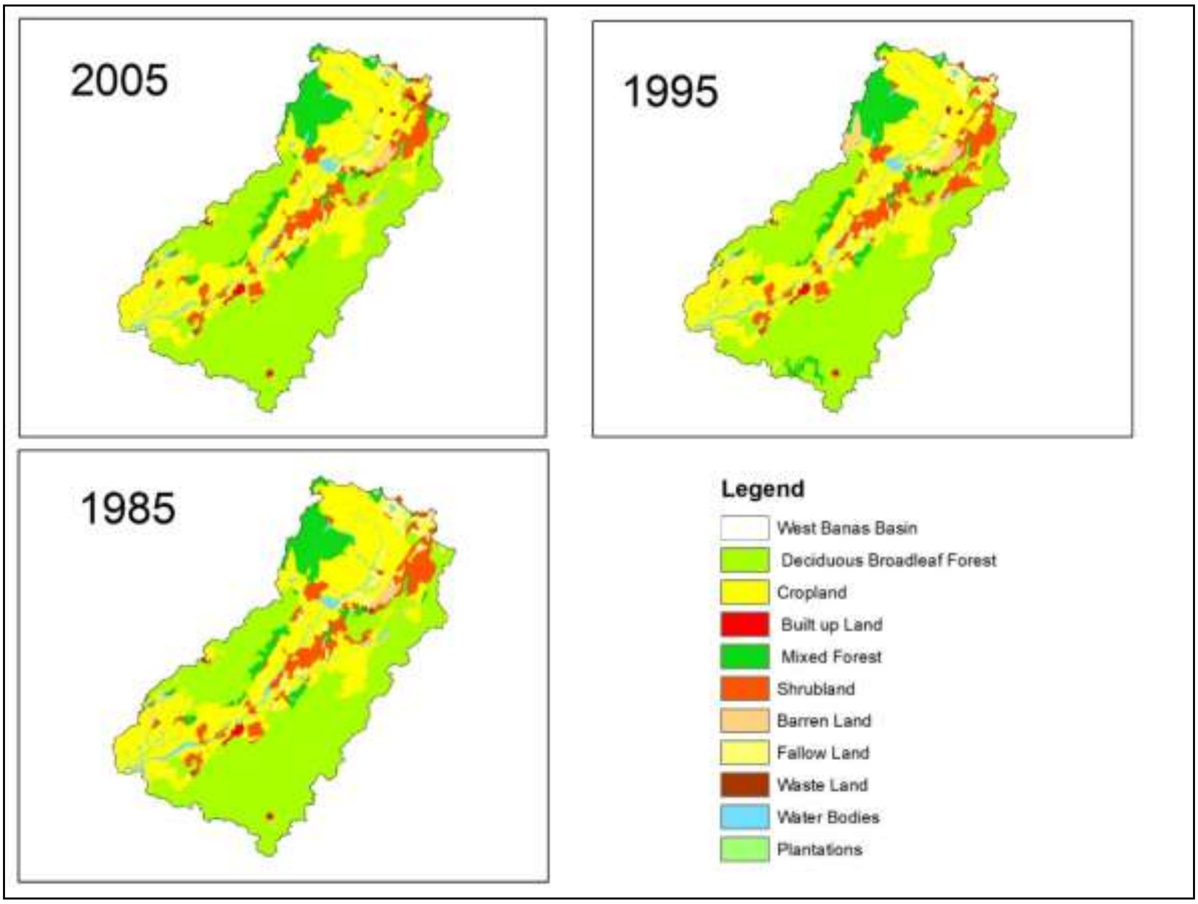


Fig 2.: LULC of West Banas

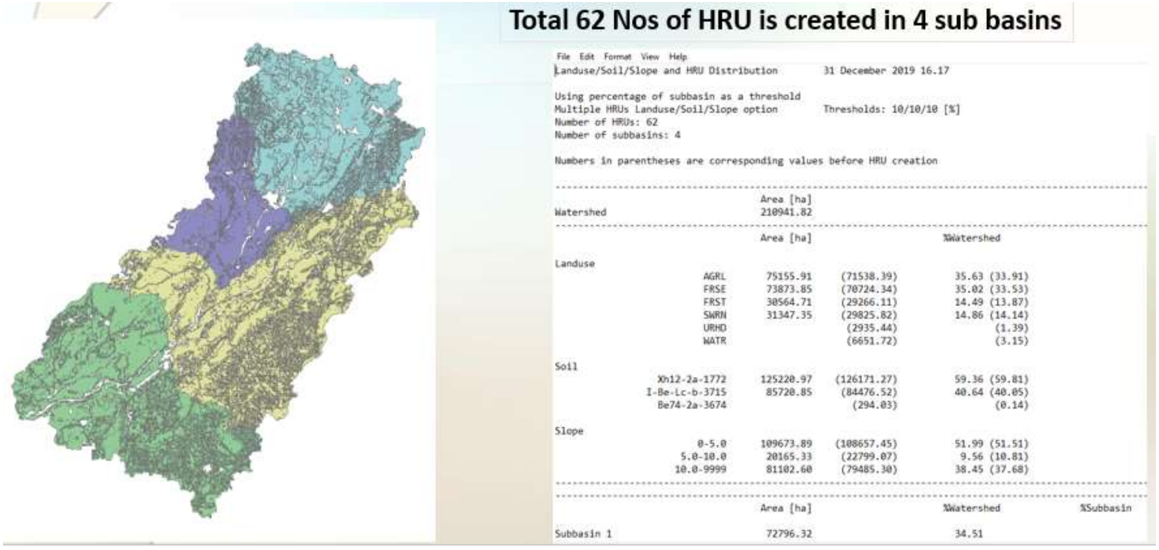


Figure 3. Hydrologic Response Unit

In the absence of discharge data, satellite based evapotranspiration data (GLEAM) was used to calibrate SWAT model. The model was calibrated and validated for Sabi basin and then the parameters were used to determine runoff from all other basins. The Global Land Evaporation Amsterdam Model (GLEAM) is a monthly global ET dataset spanning the 18-year period from 2003 (January 1st) to 2018 (July 31st). Inititally, the model was setup in SWAT and imported in SWAT-CUP for sensitivity, calibration and validation. The GLEAM data was extracted for the Sabi sub basins and used as an input in SWAT Cup calibration model. Initially, sensitivity analysis was carried out and found that curve number (CN2), base flow alpha factor (ALPHA_BF) and soil evaporation compensation coefficient (ESCO) were found the most sensitive parameters for modeling the evaporation in the basins. After selecting the sensitive parameters, data from 2003 to 2010 is used for calibration and from 2011 to 2018 for validation (Figure 4).

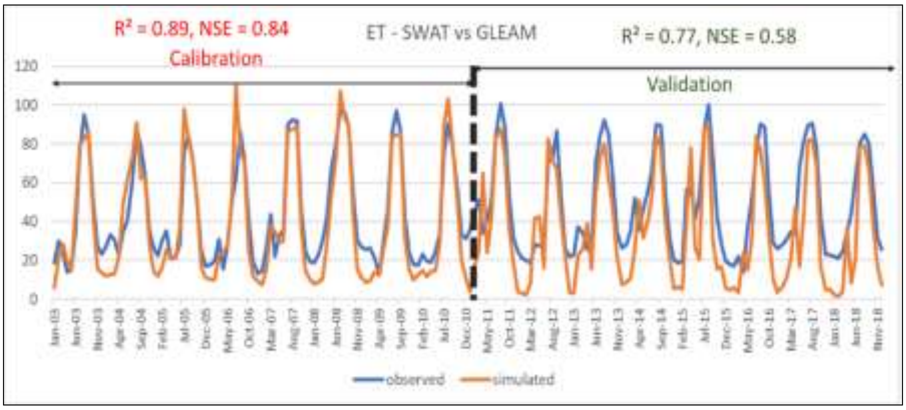


Figure 4 Chart represeting calibration and validation results

In the present study, an attempt was made to model hydrological processes in Banganga, Gambhiri, Parbati, Sabi and Sekhabati basins of Rajasthan state. The GIS database of the study area was prepared where, it has been found some misconception in TAHAL report about outlets that have been corrected based on recent digtial elevation model of the study area. The decadal landuse of 1985, 1995, 2005 and 2015 was prepared using supervised classification in google earth engine. It may be concluded that all the basins are agragrian basins where barren land has increased all basins from 1985 to 2015. There is considerable increases in agriculture land was found in Parbati basin.

Due to non availability of long-term discharge data, large intervention due to reservoirs and non availability of reservoir releases, it was not possible to model the hydroligcal processes using observed runoff. Therfore, in the study, cloud based evapotranspiration data from GLEEM was used to calibrated the model at Sabi basin. The SWAT model was prepared and exproted to SWAT CUP, where SUFI 2 technique was used to model evaporation. The sensitivity analysis suggested that curve number (CNII), soil evaporation compensation factor (ESCO) and base flow alpha factor (ALPHA_BF) are the most sensitive factors to model hydrolgical processes. The model was calibrated for the period of 2003 to 2010 with nash-sutcliffe efficiency (NSE) of 0.84 respectively and validated for 2011 to 1018 with NSE of 0.58. The calibrated parameters were used to determine runoff from all other sub-basins and basins considering no significant change of ET in the region.

Cloud data are being used increasingly in hydrolgical modeling and assessment and in the study, a GEE based SCS CN model was developd where cloud based landuse, soil and rainfall data were used to model runoff processes in any medium size catchment in the world. The model uses dynamic land use for computation of curve number. The model was applied in Sabi basin with coefficient of determination of 0.81 on monthly scale with SWAT results. The water availability are prerequisite for plaaning water resource projects and from different in sub-basins of Banganga, Gambhiri, Parabati, Sabi and Sekhabati basins from SWAT model were used to devlop a database and das board in Excel. The developed dashboard can be used by WR managers to determine the monthly runoff from any sub basins of these basins for any selected LULC.

ONGOING STUDIES (SPONSORED)

1. PROJECT REFERENCE CODE: NIH/SWHD/19-23

Project Title:

Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh

Study Group

Principal Investigator : P C Nayak, Y.R.Satyaji Rao, A.K. Lohani, B. Venkatesh, A. R. S. Senthil Kumar, T. Thomas

Budget and Funding : Rs. 55.6 lakhs

Period : 3 year (Sept 2019 to April 2023)

Funding Agency : NHP

Status : Ongoing

Objectives:

- Dam break analysis of Kandaleru and Pulichintala dam using HEC-RAS. The study includes the sensitivity analysis for dam breach parameters.
- Computation of flood hydrograph and water level at different cross-sections.
- Assessment of flood inundation extent and water depth at different places in the downstream of dam.

Overall progress of the Study:

In the preliminary investigation, dam break modeling is performed using 1D HEC-RAS software for Kandaleru dam. Kandaleru dam is an irrigation project built on Kandaleru river in Nellore district of Andhra Pradesh. The project is a part of the Telugu Ganga project which supplies drinking water to Chennai city from the Srisailam reservoir in Krishna river. Kandaleru reservoir is mainly fed by a link canal from the Somasila dam. Kandaleru dam is an earthen dam of 10.752 Km length with a height 49.00m. The Gross Storage Capacity of reservoir at Full Reservoir Level (FRL) is 68.03TMC with a FRL value 85.00m and Top Bund Level (TBL) of dam is 89.00m. In this work, modeling is performed up to 10km downstream of dam with 1km interval. The dam breach is assumed as overtopping failure and the result are analyzed for it. The study of Kandaleru dam break is performed upto 10km downstream distance from dam. It may be noted that maximum flow at dam site is 59209.70m^3/sec and 10km away from dam the value of discharge is 56175.51m^3/sec and Peak flow travel time from dam site to last cross-section is 1hour. A graph showing flood hydrograph at different location is presented in Figure.

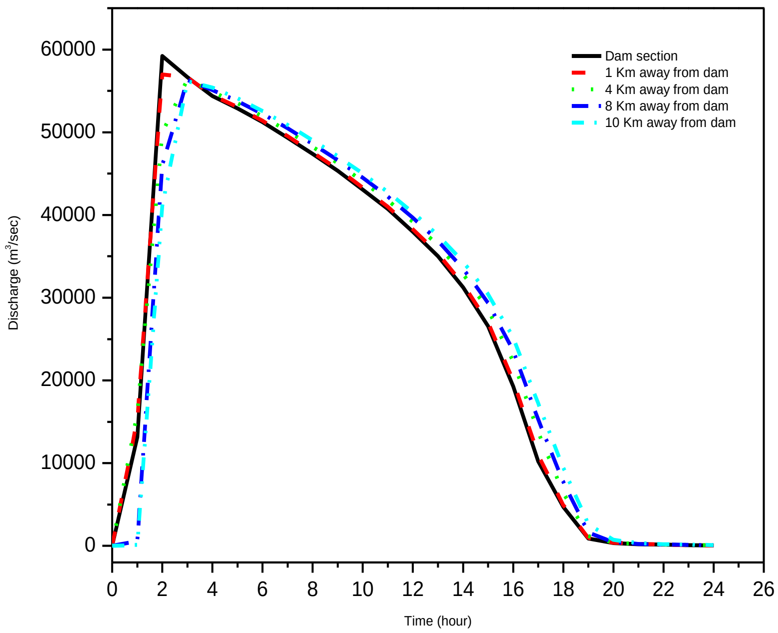


Figure: Flood Discharge at different locations from dam site

A sensitivity analysis has been carried out changing the breach width. In the analysis, the model is simulated with variation of breach width from 200m, 300m, 400m, 500m, 600m. In the analysis, it is noticed that as the breach width increases the discharge and water surface elevation at the dam section and all downstream sections also increases. The effect of roughness corresponding to river bed and flood plains are considered on the present study with four sets of manning's coefficient values. As the river roughness increases from 0.035, 0.040, 0.045 and 0.050 the discharge value decreases and water surface elevation increases

Objective vis-a-vis Achievement

As mentioned in the objectives, dam break analysis using HEC-RAS model has been carried for Kandaleru dam. Flow hydrograph has been generated at different location downstream of the dam up 10 km. Sensitivity analysis has been carried out for breach widths, changing breach formation time, changing roughness coefficient.

Progress since last meeting

The required hydrological and hydraulic data pertains to Kandaleru dam has been collected from A.P State irrigation department. Analysis is under progress

Future work for the next year

Flood inundation mapping for Kandaleru dam

COMPLETED STUDIES (INTERNAL)

1. PROJECT REFERENCE CODE: NIH/SWHD/21-22

Title of the Study

Application of generalized unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Upper Narmada -3e

Study group	Sushil K. Singh**,** Scientist F
Date of start of study	01 April 2021
Duration and scheduled	One year
Date of completion of study	31 March 2022
Type of study	Internal (without/no funding)

Study has been completed and report will be placed on table.

Results & Findings

An innovative unified-extreme-value (UEV) distribution by Singh (2016, 2017, 2019) for analyzing extreme events is further extended and applied to the annual peak-flows at the respective outlets of several catchments in (1) *Mahi and Sabermati subzone-3a*, and (2) *Upper Godavari subzone 3e*. The author has previously applied successfully this new UEV-distribution to the peak-flows observed for several catchments in Indian *subzone-3f* (Singh 2021), *subzone-3b* (Singh 2021), *subzone-3c* (Singh 2020), *subzone-3h* (Singh 2019), and *subzone-3d* (Singh 2018). The UEV-distribution closely reproduces the observed peak-flow similarly outperforming the prior other methods and procedures, and has been appropriately generalized in report as generalized extreme-value-distribution (GUEV). The GUEV-distribution encompasses seven extreme-value distributions additionally including four new extreme-value distributions besides the widely used existing three extreme-value distributions. The additional new extreme-value distributions that it represents can also been identified from the series of annual peak-flows at a gauging site using the proposed methods.

The GUEV-distribution and the proposed computationally simple methods for its parameter-determination enable data-driven implicit identification of the appropriate member-distribution of the GUEV-distribution that is followed by the data, which do away with the repetitive separate fitting of different extre-value distributions to arrive at the appropriate extreme-value distribution for the observed data. The new deterministic confidence interval/band (within which the predicted peak-flows are supposed to lie) initially proposed by Singh (2017), which replaces the existing and widely used probabilistic confidence limit initially introduced by Neyman and Pearson (1932), has also been found to work well on the peak-flow data analyzed herein. The fitting of the GUEV-distribution to observed series of peak-flow using the proposed methods is simple and easy and can even be performed on a hand-held calculator or a computer spreadsheet, and hence is of help to field engineers and practitioners.

COMPLETED STUDIES (INTERNAL)

2. PROJECT REFERENCE CODE: NIH/SWHD/18-20

Title of the Study

Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin

Study Team

Dr. Archana Sarkar, Sc D, SWHD (PI)
Dr. Surjeet Singh, Sc E, GWHD (Co-PI)
Ms. Suman Gurjar, Sc C, GWHD
Dr. Sunil Gurrapu, Sc C, SWHD

Type of Study

Internal

Date of Start

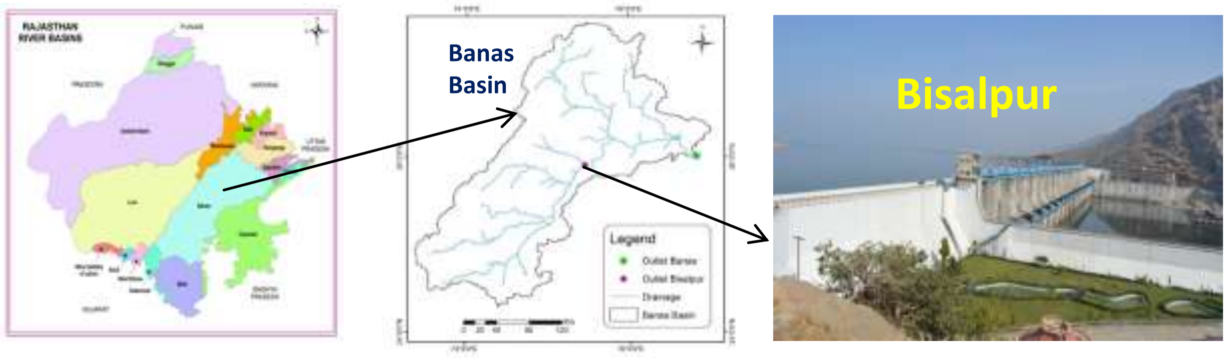
1 Nov. 2018
Scheduled date of completion: August 2021 (Total duration 2 years)

Two extension were taken and after extension the study was completed in 4.5 years

Report is not yet submitted

Study Area:

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.

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

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.

Approved Action plan and timeline

S. No	Work Element	First Year				Second Year				Third Year		
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
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	Development of Climate Impact Indicators				■	■						
6	Input data preparation for Rainfall runoff model					■	■					
7	Preparation of Interim Report					■						
8	Calibration and Validation of rainfall runoff model							■	■	■		
9	Preparation of Interim Report									■		
10	Inflow Outflow Analysis for the Bisalpur Dam								■	■		
11	Climate change scenario analysis for future water availability									■	■	■
12	Preparation of Final report										■	■

Progress (after last working group meeting)

Objectives/work elements	Achievements
July 2021- March 2022	
Trend analysis of bias corrected GCM data of ECVs for future period	Completed
Input data preparation for Rainfall runoff model	Completed
SWAT model runs and inflow outflow analysis	Completed
Development of Climate Impact Indicators for future Water Availability, Drought and Agriculture Productivity	Completed

Analysis and Results

Data Used

Essential climate variables of 16 GCMs (Table below) at 0.5 degree grid have been extracted from the Climate data store of COPERNICUS. These ECVs have been processed and bias corrected on daily time interval for a period up to year 2100 for two climate change scenarios, i.e., RCP4.5 and RCP 8.5.

S.No	Institute	GCM Name	Scenario	Resolution: Grid Lat	Resolution: Grid Long
1	CSIRO-BOM	ACCESS1-0	historical, rcp4.5, rcp8.5	1.25	1.875
2	CSIRO-BOM	ACCESS1-3	historical, rcp4.5, rcp8.5	1.25	1.875
3	BNU	BNU-ESM	historical, rcp4.5, rcp8.5	2.7906	2.8125
4	IPSL	IPSL-CM5A-MR	historical, rcp4.5, rcp8.5	1.2676	2.5
5	IPSL	IPSL-CM5A-LR	historical, rcp4.5, rcp8.5	1.8947	3.75
6	IPSL	IPSL-CM5B-LR	historical, rcp4.5, rcp8.5	1.8947	3.75
7	MPI-M	MPI-ESM-MR	historical, rcp4.5, rcp8.5	1.8653	1.875
8	MPI-M	MPI-ESM-LR	historical, rcp4.5, rcp8.5	1.8653	1.875
9	NCC	NorESM1-M	historical, rcp4.5, rcp8.5	1.8947	2.5
10	NOAA-GFDL	GFDL-ESM2G	historical, rcp4.5, rcp8.5	2.0225	2.5
11	GFDL-ESM2M	GFDL-ESM2M	historical, rcp4.5,	2.0225	2.5

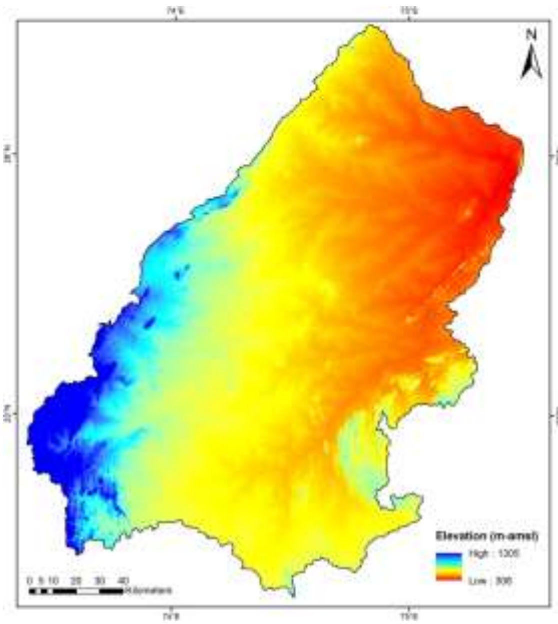
S.No	Institute	GCM Name	Scenario	Resolution: Grid Lat	Resolution: Grid Long
			rcp8.5		
12	NOAA-GFDL	GFDL-CM3	historical, rcp4.5, rcp8.5	2	2.5
13	CNRM-CERFACS	CNRM-CM5	historical, rcp4.5, rcp8.5	1.4008	1.40625
14	BCC	BCC-CSM1.1	historical, rcp4.5, rcp8.5	2.7906	2.8125
15	BCC	BCC-CSM1.1(m)	historical, rcp4.5, rcp8.5	2.7906	2.8125
16	ICHEC	EC-EARTH	historical, rcp4.5, rcp8.5	1.1215	1.1215

For calibration of SWAT model for the Banas basin upto the Bisalpur reservoir, observed data of rainfall at 30 stations and runoff at 1 intermediate station have been used. For temperature data, IMD one-degree gridded data was used. +Other data required for SWAT simulation has been used from SWAT Tamu.

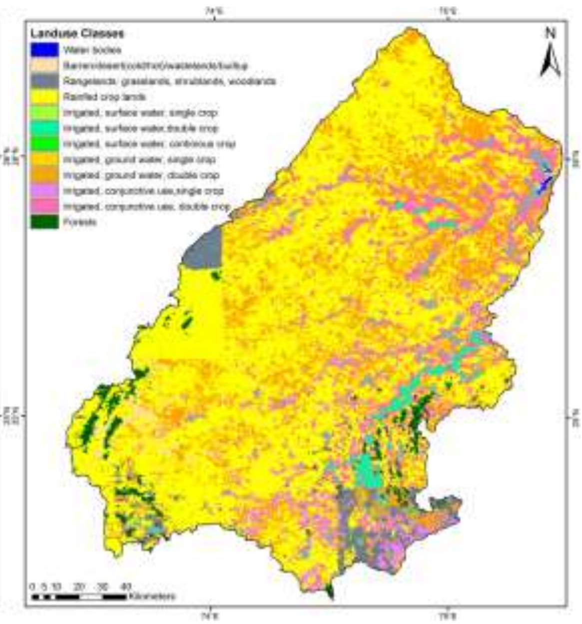
Results

Relevant climate impact indicators for the basin have been calculated and variability in future periods has been studied.

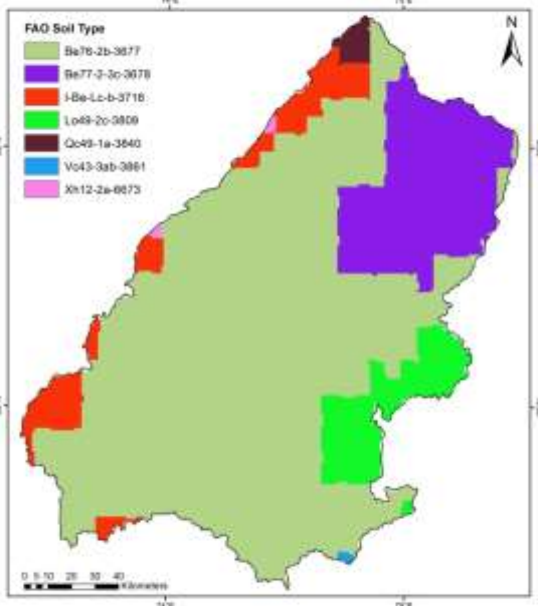
Simulation runs of SWAT model using default data as well as observed data of intermediate station have been carried out. Following maps depict properties of the basin:



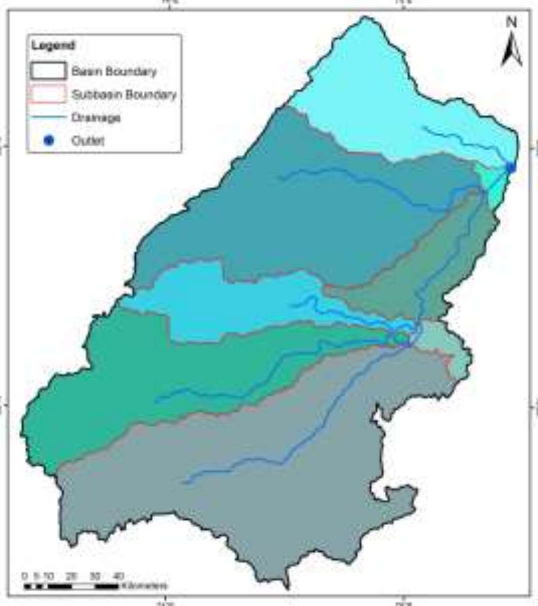
(a) DEM of Study area



(b) LULC of Study area

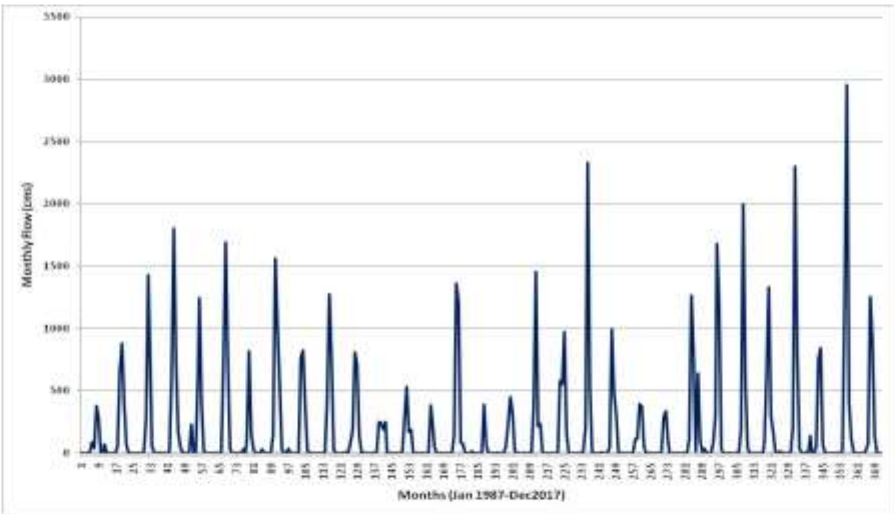


(c) Soil Classification of Study area

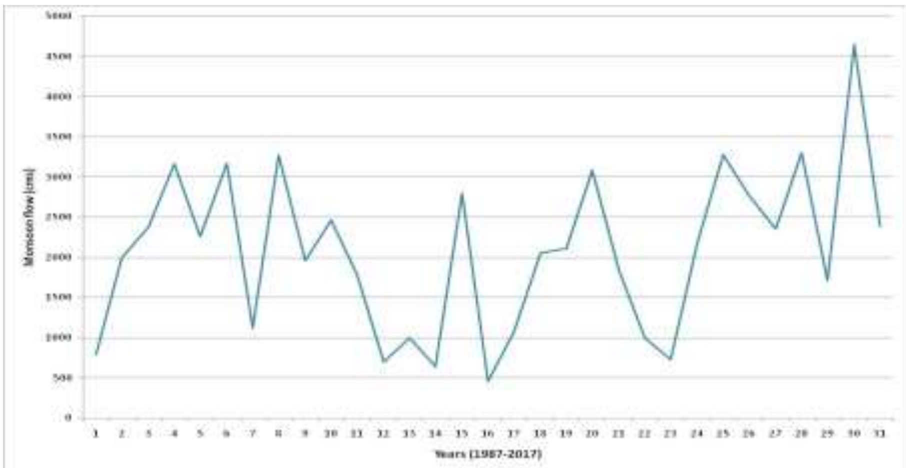


(d) Sub-basin division in Study area

Following graphs show the rainfall runoff simulation results of SWAT runs:



Simulation of Monthly Flows at Bisalpur Reservoir (upstream)



Simulation of Monsoon Flows at Bisalpur Reservoir (upstream)

Expected Adopters

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.

Deliverables
Research papers, report, stakeholder engagement

Data Procured and/Generated during the Study
Daily rainfall data of 30 raingauge stations in the Bisalpur River basin for a period of 30 years (1990-2019). Gridded temperature data at $1^{o}X1^{o}$ for the Banas basin from IMD (previously procured for other study), Essential climate variables (precipitation, temperature) at 0.5deg resolution from ECMWF. DEM, Soil and LULC maps of Banas River basin upto Bisalpur reservoir.

COMPLETED STUDIES (INTERNAL)
3. PROJECT REFERENCE CODE: NIH/SWHD/18-21

Title of the Project: **Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario**
Thrust area under XIIth Plan: Impact of climate change on water resources and hydrology of xtremes

Project team: Dr. Ashwini Ranade, Scientist 'D' (PI)
Dr. Archana Sarkar. Scientist 'E' (Co-PI)
Type of Study: Internal
Status: completed
Duration: **3 years**
Date of Start: 1 April 2018
Scheduled date of completion: 31st Dec 2021
After Extension the study was completed in 3.5 years

Report submitted

Objectives

Sr. No	Objectives	Status
1.	Updation of longest instrumental area-averaged monthly rainfall series (1813-2000) of 11 major and 9 independent minor river basins of India and to document climatological and Fluctuation features of annual, seasonal and monthly rainfall	Completed
2.	Identification of different types of seasonal extreme rain events concerning rainfall amount, rainfall intensity and duration over seven homogenous rainfall zones of India from 1951to 2020.	Completed
3.	Evaluation of 3D global atmospheric parameter changes conducive to the occurrence of large-scale extreme rain events over seven homogeneous rainfall zones during different seasons.	Completed
4.	Time series modelling of the longest instrumental monthly rainfall series (1813-2020) of major and independent minor river basins for their extrapolation for 2 to 10 years	Completed

1. Statement of the problem

Uneven warming of the global troposphere in last few decades are observed to make changes in spatio-temporal characteristics of rainfall across the country. The IPCC 6th assessment report projected that South Asian summer monsoon precipitation decreased over several areas since the mid-20th century (high confidence) but is likely to increase during the 21st century, with enhanced inter-annual variability and Extreme rainfall are projected to be intensified by 7% for each additional 1ºC due to acceleration of hydrological cycle in warmer climate across the globe. After general acceptance of global warming as a reality, numerous studies have been undertaken to generate information useful for the assessment of water resources and hydro-meteorological disasters to comprehend the impact of climate change. It has been seen that 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. Earlier we have studied climatological and fluctuation features of parameters of the hydrological wet season in 11 major and 36 minor river basins in India. We did not find any significant long term trends in wet season parameters for any basin but noticed a declining tendency in wet season rainfall in some major basins of Central India. Numerous studies have reported the rising frequency in short period extremes, especially in Central India and attributed to the significant increase in synoptic activities, convective instabilities' etc. We found that 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. Few intense rain spells, consequently heavy flooding and disasters occur across the country even in dry monsoons. Locations of warming and cooling across the globe are the determinant of the plausible locations for the origin of various types of weather systems. There is a pressing need to understand the climatic changes in the 3-D structure of global temperature. Keeping in mind, recent changes in global atmospheric thermal structure, monsoon circulation pattern, and occurrence of EREs, we have studied the rainfall variability in annual and seasonal rainfall of 11 major basins, 9 independent minor basins and 7 homogeneous zones across India and associated 3-D structure of global temperature.

2. Dataset used and Study area:

- The global daily reanalysis product of the atmospheric temperature, geopotential height, wind speed at(1000-100hPa), mean sea level pressure and precipitable water available at 2.5º grid resolution from 1979 to 2020 from 'The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR & CFSv2) are used.
- The longest instrumental area-averaged monthly rainfall series for 11 major basins, 9 independent minor basins and 7 homogeneous subzones) earliest available from 1813 to 2000.
- IMD gridded 1º X 1º and 0.5º X 0.5º degree rainfall data from 1951-2020 to update the rainfall series from 2001 to 2020.

3. Analysis and results:

3.1 Updation of monthly rainfall series:

Longest instrumental area-averaged monthly rainfall sequence of major river basins (Indus, Ganga, Brahmaputra, Sabarmati, Mahi, Narmada, Tapi, Godavari, Krishna, Mahanadi, Cauvery); independent minor basins (Luni, Surma, Kasai, Damodar, Subarnarekha, Brahmani, Penner, Palar & Ponnaiyar, Vagai); The West Coast Drainage System (WCDS), All India and 7 homogeneous zones : (i) South Peninsular India (SPI); ii) West peninsular India (WPI); iii) East Peninsular India (EPI); iv) Northwest India; v) North Central India (NCI); vi) North East India (NEI); and North Mountainous India (NMI); have been developed and updated in three phases. In the first phase, for the period 1901 to 2000, simple arithmetic mean of all available gauges in the basin/zone from a fixed well spread instrumental network of 316 rain gauge stations were used. In the second phase, the dataset has been extended backwards from 1900 to 1813 (starting year is different for each basin) when a lesser number of observations were available, by applying a theoretically vindicated numerical method on limited available observations; and in the third phase, river dataset has been updated with the ratio method, by extracting each station value from the corresponding value of the grid from the 1º X 1º gridded rainfall dataset of IMD. While homogenous zone dataset has been updated by developing area-averaged daily rainfall series from 0.5-deg gridded rainfall data from IMD

3.2 Chief Statistical Features and Interannual variations

Area-averaged monthly, seasonal and annual rainfall series for all basins and zones have been developed and analyzed. Climatological and fluctuation features of all the time series have been calculated and documented. Normal (1901-2000) annual rainfall of the river basins across the country varies from 487.7mm (Luni) to 2519.5mm (Surma). The normal annual rainfall of the country is 1165.9mm, the highest rainfall of 1435.3mm occurred during the year 1917 and lowest of 895.7mm during year 1918. Normal (1901-2000) monsoon rainfall of the river basins across the country varies from 445.4mm (Luni) to 1706.6mm (Surma). For the country as a whole, the normal monsoon rainfall is 906.5mm, highest rainfall of 1088.8mm occurred during year 1961 and 661.3mm during year 1918.

For independent minor basins, the mean annual rainfall varies from 487.7mm over Luni to 2519.5mm over Surma. The coefficient of variation varies from 12.1% (Surma) to 37.4% (Luni).

Normal annual rainfall of seven homogeneous zones varies from 775.2mm over NWI to 2159.6mm over NEI. The year-wise highest rainfall varies between 1181.9 mm (NWI) and 2490.8mm (NEI), while that of lowest from 367.8mm (NWI) to 1725.1mm (NEI). Normal monsoon rainfall of seven homogeneous zones varies from 685.2mm over NWI to 1509.9mm over NEI. The year-wise highest rainfall varies between 950.9mm (NWI) and 1930.8mm (NEI), while that of lowest from 327.3mm (NWI) to 1242.5mm (NEI). Seasonal and annual rainfall time series 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 regions have been prepared and analyzed. The inter-annual variation in the categorized monsoonal rainfall from 1813 to 2020 for the country as a whole is shown in fig.1.

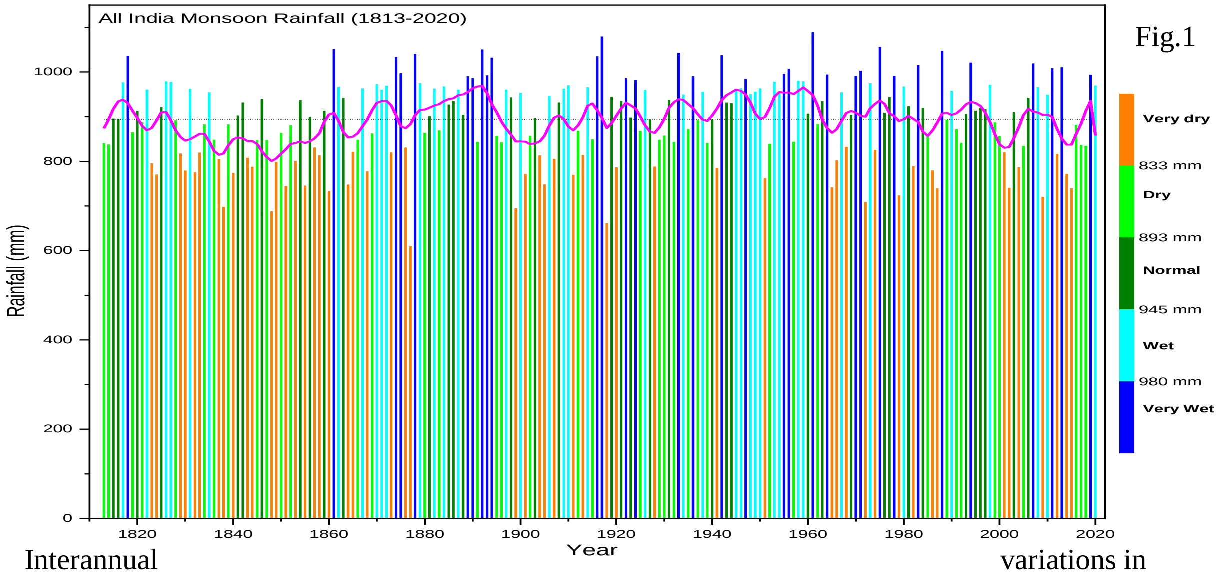


Fig.1 Interannual variations in categorized rainfall distribution of All India from 1813-2020

3.3 Short-term and Long-term rainfall fluctuations in basin rainfall series

The Cramer's t_k statistics have been applied to moving averages of each of the time series of river basins 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 t_k is calculated and significance is tested for times series. Visual examination reveals that the monthly, seasonal and annual rainfall is found to exhibit a wide range of fluctuation characteristics across the country.

Significant increasing trend is noticed in recent 101 years in monsoon rainfall over Krishna major (2.9%), Tapi (4.2%), WCDS (2.9%), Surma (2.1%), Pennar (2.8%) and the whole country (1.3%) compare to preceding instrumental period. While significant decreasing trend is noticed in Brahmaputra (-1.8%) and Brahmani (-1.4%). During recent 20 years (2001-2020) compare to last century (1901-2000), the significant decrease is noticed over Ganga major (-6.6%), Brahmaputra major (-7.6%), Cauvery (18.7%), Brahmani (-12.9%) and Pallar and Ponniyar (-19.7%). While significant increase is seen over Surma basin (7.9%). Compare to 20th century (1901-2000) monsoon rainfall over basins in northeast India, central northeast India, northwest India, and south peninsular India has been lesser while that over central northwest India, north peninsular India and north India has higher in recent 20 years.

3.4 Fluctuation characteristics of rainfall of homogenous zones

Inter-annual variations in annual and seasonal rainfall are filtered with 9-point filtering technique. Visual examination reveals that the monthly, seasonal and annual rainfall is found to exhibit wide range of fluctuation characteristics across the country. But over a longer period, the time series of all zones is appear to be approximately homogenous and random.

Changes in annual and seasonal rainfall of seven zones during 2001-2020 have been tested in relation to more reliable instrumental monthly rainfall records of last 100 years (1901-2000). The significance of the changes have been tested by using students' t-test for the difference between the two sub-period means. In recent 20 years, the monsoon rainfall of NCI and NEI have been significantly decreased by -9.7% and -7.3% respectively, while that of WPI and NWI increased significantly by 7.5% and 4.5 % respectively. The annual rainfall of NCI, NMI and NEI are decreased significantly by -9.6%, -12.9% and -9.4% respectively and SPI and WPI are increased significantly by 1.1% and 5.5% respectively.

3.5 Interannual variations in Precipitation Concentration Index(PCI) of homogenous zones

Changes in seasonal precipitation can be quantitatively assessed using this index. PCI characterizes monthly precipitation on a scale that ranges from 8.3 to 100. Year-wise annual and seasonal PCI for each zone have been calculated using monthly rainfall data. The average annual PCI for an individual homogeneous zones varies form 14.1 over SPI to 25.1 over NWI. It Indicates that, the rainfall is more uniformly distributed over SPI while more concentrated over NWI. The monsoonal PCI varies from 8.6 over NEI to 10.4 over NWI, indicating uniformly distributed rainfall during monsoon season. No considerable significant long-term trend is observed in annual and seasonal rainfall time distribution across India. However, in recent 20 years, annual rainfall of NMI, NEI and EPI and monsoonal rainfall of NEI are more concentrated in few spells.

3.6 Spectral Analysis:

We observe that the longest instrumental rainfall series across the country does not show any significant long-term trend however inter-annual variations at different time scales (annual, seasonal and monthly) does show a mixture of various periodic and random oscillations. Classical harmonic analysis has been used to understand the relative strength of periodic cycles in longest rainfall series. The Interannual variability of rainfall series of all time-series are is highly dominated by short-term fluctuations (~75%), followed by decadal changes (15%) and long-term variability (~10%). Simple classical harmonic analysis doesn't serve the purpose of extrapolation of rainfall time series

3.7 Fluctuation characteristics of 1- to 10-day Large-scale Extreme rain events over seven homogenous zones of India

The large-scale extreme rain events (EREs) of 1-to 10-days duration are intended to quantify severity of persisting intense rains over particular area. 1- to 10- EREs concerning rainfall amount and rainfall intensity are identified for each year. 1 The mean RI of 1-day ERE-RI varies from 20.3mm over Northwest India (NWI) to 45.2mm over Northeast India (NEI) while that of 10-day ERE-RI varies from 9.8 mm over North mountainous India (NMI) to 24.5mm over NEI. The mean cumulative rainfall of 10-day ERE-RA varies from 97.8 mm over NMI to 245.1mm over NEI. The rainfall amount of ERE-RA increases with duration overall subzones. Significant increasing trend is noticed in rainfall of 1-day EREs over WPI (16.2mm/year), EPI (22.8mm/year) and NMI (32.4mm/year) while significant decreasing trend is noticed in RI (9.1-12mm/year) and RA (10.8-12mm/year) of 7- to 10-day EREs over NCI. In recent 20 years (2001-2020) the WPI experiences, significant increase in rainfall during 1- 2-day EREs (16.9% and 18.3% respectively). The EPI experiences significant increase during 1-. 2- and 5-day EREs (15.7% , 13.1% and 12.2% respectively).

3.8 Global Climatic Changes in 3-D structure of Atmospheric temperature

The column-area mean monthly temperature of the lower troposphere (LTT: 1000-600hPa), upper troposphere (UTT: 550-250hPa), tropopause (TPS: 200-100hPa), whole troposphere (TT: 1000-250hPa) and stratosphere (STT: 70-1 hPa) have been area averaged at global, hemispheric, zonal and regional scale. Based upon geographical, astronomical and meteorological characteristics and climatic conditions, the whole globe (GLB) is divided into nine climatic zones: north polar (NP), north mid-latitudes (NMLAT), north subtropic (NSBT), north tropic (NTP), equator (EQ), south tropic (STP), south subtropic (SSBT), south mid-latitudes (SMLAT), south polar (SP). Each climatic zone is further subdivided into 6 macro geodomains, so the whole globe is divided into 54 geodomains.

The calendar month-year temperature data of the period 1979-2018 has been homogenized (standardized with respective monthly mean and standard deviation and multiply with annual standard deviation) in order to make the monthly temperature variations comparable before plotting. Fig. 2 shows the homogenized month-year TT variation during 1979-2018 over nine climatic zones, the two hemispheres and the globe. It also shows the 37-month (~3 years) running mean as well as the linear trend. Significant increasing trend is noticed in TT across the globe. Since 1979, TT has been increased at the rate of 0.25°C/decade over the globe. NH is warming at a faster rate (0.30°C/decade) than SH (0.20°C/decade). Stratosphere of the GLB, NH and SH shows cooling trend (approx. -0.55°C/decade). During 2009-2018, compare to base period of 30 years (1979-2008), the annual mean TT of the globe has been increased by 0.50°C, NH (0.57°C) and SH (0.42°C). The highest change is observed over NP (0.80°C) while lowest over SP (0.07°C). Across 54 geodomains, the highest positive anomaly in LTT is seen over eastern NP (+1.22°C), followed by eastern NSBT (+0.69°C) in NH and southern and equatorial Indian Ocean (+0.59°C & 0.55°C respectively). The upper troposphere of oceanic regions are warming at higher rate than that over land areas across the globe. The tropopause of tropical and subtropical regions are warming while mid-latitude regions are cooling.

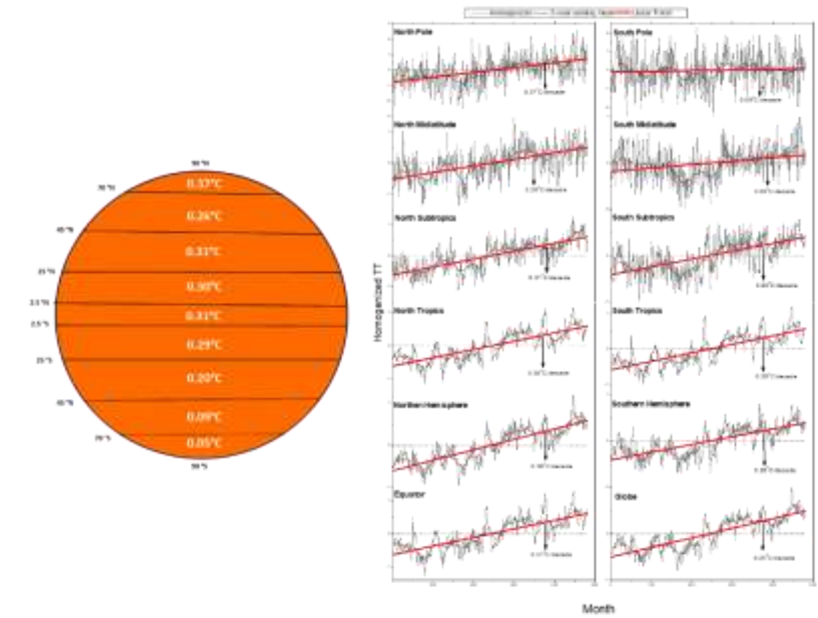


Fig.2 Linear trend (°C/10-yr) in Tropospheric Temperature (TT) during 1979-2018

3.9 Global Temperature conditions associated with Wet/Dry monsoon months

An attempt has been made to understand the meteorological changes associated with the most extreme wet and dry monsoon months (June to September) in the recent 37 years (1979-2015) over India. Composite anomalies in the temperature, geopotential height at 12 isobaric levels and mean sea level pressure across the globe during most extreme four wet and dry years for India have been constructed. Further the anomalies are averaged for 11 subzones and 54 geo-domains across the globe to comprehend the result.

During extreme wet years, although significant changes in departure field have not been noticed across the globe, NSBT and TBT show comparatively more intense departure field than other subzones. Tibet is warmer by 1.1º and thicker by 43.9m than normal in June, 0.54°C/23.6m in July, 0.2°C/7.9m in Aug and 0.04°C/7.8m in Sept. During extreme dry years, majority of the subzones show negative departure field compare to normal. Tibet is cooler by -0.22°C and thinner by 10m in June, -0.32°/-19.7m in July, -0.25°C/-7.3m in Aug and -0.54°C/-24.8m in Sept as compare to its normal values. It has been seen that even small changes on terrestrial scale may produce vigorous changes on local scale. In short, during wet months of the season, subtropical Asia especially Tibet-Himalaya is warmer and thicker and entire equatorial-tropical Pacific and Asian landmass is under negative pressure anomaly extends up to north pole. During driest months, the subtropical Asia is cooler and thinner while entire Asia-Pacific region is under positive pressure anomaly.

4. Important Results:

1. Significant decrease in monsoon rainfall is noticed over Ganga major (-6.6%), Brahmaputra major (-7.6%), Cauvery (-18.7%), Brahmani (-12.9%) and Pallar and Ponniyar (-19.7%) in recent 20 years (2001-2020) compare to last century (1901-2000), while significant increase is seen over Surma basin (7.9%).
2. On zonal scale, the monsoon rainfall of NCI and NEI have been significantly decreased by -9.7% and -7.3% respectively in recent 20 years, while that of WPI and NWI increased significantly by 7.5% and 4.5 % respectively.
3. No considerable significant long-term trend is observed in annual and seasonal rainfall time distribution across India. However in recent 20 years, annual rainfall of NMI, NEI and EPI and monsoonal rainfall of NEI are more concentrated in few spells.
4. The Interannual variability of rainfall series of all basins and homogeneous zones are highly dominated by short-term fluctuations (~75%), followed by decadal changes (15%) and long-term variability (~10%). Simple classical harmonic analysis doesn't serve the purpose of extrapolation of rainfall time series
5. Significant increasing trend is noticed in rainfall of 1-day EREs over WPI (16.2mm/year), EPI (22.8mm/year) and NMI (32.4mm/year) while significant decreasing trend is noticed in RI (9.1-12mm/year) and RA (10.8-12mm/year) of 7- to 10-day EREs over NCI during 1951-2020.
6. In recent 20 years, the WPI experiences, significant increase in rainfall of 1- 2-day EREs (16.9% and 18.3% respectively). The EPI experiences significant increase for 1-. 2- and 5-day EREs (15.7%, 13.1% and 12.2% respectively).
7. The tropospheric temperature across the globe has been increased significantly, from 1979-to 2018 at the rate of 0.25°C/decade. NH is warming at a faster rate (0.30°C/decade) than SH (0.20°C/decade).

8. Major Conclusion:

Due to faster warming of the troposphere of northern hemisphere compares to southern hemisphere, the monsoon circulation is intense but its 3D structure is highly distorted. Consequently, rainfall space-time distribution is heterogeneous, and extreme rain events (EREs) are highly varying type. Few selected case studies of most extreme rain events reveal that persistence in tropospheric warming and circulation anomalies over different parts of the globe drastically modulates the monsoon circulation and intensify the associated weather systems causing occurrences of severe rain events over a wide-ranging scale from small-scale short-period heavy rain events to large-scale long-period extreme wet spells. Anomalous and abrupt warming of the upper troposphere of Tibet and Turkey sector favors the formation of deep troughs and strengthened ridges in subtropical westerlies and seen to be associated with sudden intensification of the monsoon circulation. However, detailed features of the EREs in relation to Monsoon circulation yet to be investigated.

Deliverables: It is expected that the results from this study will be useful to understand the effect of global warming on rainfall pattern across India. The results are beneficial for water resources planning and management of different river basins for next few years.

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: Shortage of manpower

Future Plan: To understand the role of global temperature change in modulation of monsoon circulation and to extreme rain events across the country.

COMPLETED STUDIES (INTERNAL)

4. 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 Godavari and Narmada River watersheds
Project team:	Dr. Sunil Gurrapu, Scientist C (PI) Dr. Ashwini Ranade, Scientist D Er. Jagadish P. Patra, Scientist D
Type of Study:	Internal
Status:	Completed
Duration:	3 years
Date of Start:	1st November 2018
Scheduled date of completion:	31st October 2021

The study is completed in time

Statement of the problem:

Globally, floods are ranked among the largest and costliest natural disasters having major impact on various economic sectors. In India, flooding is one of the three prominent climate extremes, other two being droughts and cyclones. 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 15th to 17th August 2018. Summer monsoon rainfall being the major source of water input to the Indian subcontinent, optimal design and operation of water resources infrastructure (e.g. major dams) is very much essential. Planning and design of such structures require a great depth of knowledge on the magnitude and frequency of extreme floods. Traditionally, the frequency of extreme floods is derived based on the analysis of historically observed annual maximum flows assuming they are independent and identically distributed (*i.i.d*) and the system fluctuates within a fixed envelope of variability, i.e. stationarity assumption. 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. Moreover, Indian summer monsoon is influenced by several low-frequency atmosphere-ocean oscillations including Atlantic Multi-Decadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), El Niño-Southern Oscillation (ENSO) etc.

The failure probability of large hydraulic structures such as large dams and spillways, should be as low as possible. BIS specifies that the design flood for a large structure (i.e. gross storage > 60 MCM) is the probable maximum flood (PMF). The design flood for such structure is estimated based on the probable maximum precipitation (PMP). PMP is the maximum precipitation that is physically possible over a region for a given duration. PMP can be estimated either from meteorological or statistical methods. However, the changing climate across the globe is said to modify the precipitation characteristics, i.e. intensity, frequency and magnitude, which will influence the PMP estimates, and its further use in the design and analysis of flood related studies becomes questionable. In this study, we propose to first analyze the annual floods (i.e. maximum flows) with the hypothesis that they are influenced by the low-frequency atmosphere oscillations originating in the equatorial Pacific and Indian Oceans. Secondly, we propose to evaluate the impact of climate change on PMP and prepare a status report.

The study was carried out on several sub-basins of Rivers Godavari and Narmada. We chose several streamflow gauging stations with a minimum 30 years of observed daily streamflow data. The maximum length of the available data among the chosen gauging stations is 50 years. The observed daily streamflow data for the selected gauging stations is obtained from India-WRIS website. Pacific Decadal Oscillation (PDO) indices is obtained from Joint Institute for the study of Atmosphere and Ocean (JISAO), University of Washington. And the El Niño-Southern Oscillation (ENSO) indices, quantified as Southern Oscillation Index (SOI) is obtained from Climate Research Unit, University of Eastern Anglia.

Current Status:

This study was 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, despite several studies showing strong correlations between monsoon rainfall and low frequency oscillations such as ENSO, PDO etc. The preliminary analysis was done on several gauging stations located on the stream networks of Godavari and Narmada River basins. Results from preliminary analysis are as follows;

From the daily streamflow data collected from India-WRIS, annual peaks were extracted for the water year (1st June to 31st May of the following year), with a condition that at least 200 days of flow data is available during both southwest (June – September) and northeast (October – December) monsoon seasons, i.e. a maximum of 14 days of missing data is allowed during the water year. Despite the risk of missing out on few peaks, we adopted this condition to include as many stations as possible in the study. Annual Mean flow in majority of the gauging stations of the Godavari River basin are influenced by ENSO. The correlations between ENSO index and annual mean streamflow show statistically significant correlations (Spearman's $\rho \leq 0.54$). In addition, we observed that the annual peaks are also significantly influenced by the ENSO. Similarly, annual mean streamflow showed statistically significant correlations with the PDO index. Which indicate that up to 50% of the variability in annual streamflow at these stations can be explained by the PDO variability.

In contrast to the Godavari watershed, only a few stations in the Narmada watershed showed statistically significant correlations with both ENSO and PDO indices. Although the correlations are significant for majority of the selected gauging stations, they are not evident at all the stations. One major shortcoming is the length of the available data, because the periodicity of PDO is approximately 20–30 years, although it is nearly 10 years for ENSO. So, we have identified a few stations, with no significant regulations upstream (as per the watershed Atlas of India). Among these, we have Chosen those stations with at least 15 years of water year peak flow data (with not more than 14 days of missing data during monsoon season). We also evaluated various probability distributions used in flood frequency analysis to propose a suitable distribution that can address the issue of non-stationarity. Details of all the methods of analysis along with the results are described in the final report, a first draft of which is prepared and will be circulated for review to selected reviewers after addressing the feedback (comments from the committee members) received from the WG meeting.

Status of the Deliverables:

#	OBJECTIVE	STATUS
1.	Propose an appropriate probability distribution to address all the concerns over non-stationarity in the streamflow datasets.	Analysis completed and the first draft of the report is prepared
2.	Research papers based on the established relations between low-frequency climate oscillations and flood magnitude and frequency.	One manuscript is drafted and is to be submitted for a publication
3.	Status report on the impact of climate change on probable maximum precipitation (PMP) in India.	First draft is ready.

ONGOING STUDIES (INTERNAL)

1. **PROJECT REFERENCE CODE: NIH/SWHD/20-22**

2. **Title of the study:**
Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.

3. **Study group:**
   a. Project Investigator: J.P.Patra, Sc. – D, SWHD
   b. Project Co-Investigator: Pankaj Mani, Sc. – F, CFMS Patna
   Sunil Gurrapu, Sc. – C, SWHD
   Rakesh Kumar, Ex-Sc. – G & Head SWHD

4. **Duration of study:** 2 Years (Aug 2020 to Jul 2022) : Ongoing

5. **Type of study: Internal.**

6. **Location map**

Figure 1: Location map of the study area

7. **Study Objectives**
   a. Estimation of probabilistic dam breach outflow hydrograph.
   b. Preparation of Exceedance Probability Inundation (EPI) Maps.
   c. Comparison outflow hydrographs due to level pool and dynamic routing of flows through the reservoir.
   d. Flood hazard and flood risk assessment due to Mahi Bajaj Sagar dam breach.

8. Statement of the problem

Dams have played a key role in fostering rapid and sustained agricultural and rural growth and development in India. Over the last fifty years, India has invested substantially in dams and related infrastructure. In India about 5254 large dams have been completed and another 447 under construction (NRLD 2017). However, failure of these structures may lead to catastrophic losses. In India there are 36 reported failures cases so far. The first such failure was recorded in Madhya Pradesh during 1917 when the Tigra Dam failed due to overtopping. The worst dam disaster was the failure of Machu dam (Gujarat) in 1979 in which about 2000 people have died. With increasing number of dams becoming older and older, the likelihood of dam failures in India is expected to be an ascending path. Considering these aspects India has undertaken the Dam Rehabilitation and Improvement Project (DRIP) to improve the safety and operational performance of selected existing dams in the territory of the participating states. Emergency Action Plan and flood inundation mas for the Dam are under preparation.

Dam breach modelling is a key component to a well-rounded and robust dam safety program. Various researcher and guidelines recommended combination of breach parameters. However, instead of mapping a large zone with equal probability of occurrence (either "in" or "out" of the flooding zone), modelling a full range of breach scenarios – from partial to complete, correlating the downstream impacts with a likelihood or probability of an area actually flooding would be of practical importance for dam owners. This risk-based approach arms decision makers with a probability based analysis map, would help them to visualize and prioritize actions in areas that are more likely to flood first. Such analysis would lead to smarter emergency action planning, allowing first responders and other agencies to stage critical resources such as disaster response team in key places to allow for systematic evacuation.

A flood hazard is an indication of the possible source of danger due to flooding. It, however, does not imply any risk unless persons or objects that are vulnerable to damage are exposed to it. The various hazards to be mapped include themes like the flood inundation areas, water depths and velocities, and arrival times of flood waves. Various guidelines and recommendations have been prepared under the DRIP for classifying hazard to people, vehicle, buildings etc. Moreover, combined flood hazard maps can be developed from the relationships of flood depth and velocity. Traditionally, floodplain management in India is dominated by the hazard-based method. The severity of the risks is directly proportional to the significance of the impacts of flooding i.e., the consequences of flooding. Limiting the flood hazards and reducing the degree of vulnerability to the flood impacts (such as proneness to water and velocity damage) may significantly reduce the consequences of flooding. Better management of future flood risk aims at reducing potential losses.

9. **Approved action plan and timeline**

S.N.	Work Element	1st Year				2nd Year			
1	Collection of basic data, topography, cross-section, satellite images, thematic maps etc.	■	■				■		
2	1-D level pool dam breach model setup.		■	■	■				
3	Quantification difference between level pool routing and full unsteady flow routing.				■	■			
4	Generation of probabilistic breach parameters		■	■		■			
5	Estimation of probabilistic dam breach outflow hydrograph.				■	■	■		
6	Preparation of Exceedance Probability Inundation (EPI) Maps.						■	■	
7	Combined general flood hazard classification and preparation of Flood Hazard Maps.							■	■
8	Risk identification.								■
9	Estimation of Population at risk and potential loss of life.								■
10	Workshop/ Training.							■	
11	Report.				■				■

10. Brief Methodology

Dam breach models are commonly used to predict outflow hydrographs of potentially failing dams and are key ingredients for evaluating flood risk. The standard practise deterministic approach with assumption of various breach parameters viz. breach size, shape, formation time etc. Such approaches are generally conservative and there is no communication of risk and uncertainty. In this study it is proposed to apply a dam breach modelling framework to improve the reliability of hydrograph predictions. The EP will be determined by using Monte Carlo simulation technique: (i) Realization: "A Single Modelled Event in a Probabilistic Simulation", (ii) For each Realization, randomly sample uncertain input parameters (breach parameters) about pre-defined probability distributions, (iii) Run a large number of Realizations (10,000?) – large enough to demonstrate convergence of statistical moments (mean, variance, skewness, kurtosis, (iv) sort the results and select percentiles = EP discharges. Finally, routing of the chosen EP hydrograph downstream to determine its associated inundation and damages using a hydrodynamic model (HRC-RAS). This would help to answer-given a dam failure, what is the probability of any discrete location being in the flood zone?

The storage reservoir area upstream of the dam is modelled as storage area i.e. level pool routing through the lake. However, full unsteady flow routing through the reservoir pool can be carried out in 1-D with cross-sections or with bathymetry in 2-D. In general, full unsteady flow routing (1D or 2D) would be more accurate for both with and without breach scenario. However, availability of cross-section / bathymetry data in the reservoir area is often problematic. In this study the difference between level pool routing and full unsteady flow routing through the Mahi Bajaj Sagar dam reservoir will be estimated for peak flow and routed outflow hydrograph. Classified flood hazard vulnerability maps will be developed from the relationships of flood depth and velocity for various categories viz. Generally safe for vehicles, people and buildings; Unsafe for small vehicles; Unsafe for vehicles, children and the elderly; Unsafe for vehicles and people; Unsafe for vehicles and people, all buildings vulnerable to structural damage, some less robust buildings subject to failure; Unsafe for vehicles and people, all building types considered vulnerable to failure. Risk analysis has brought a paradigm shift that has allowed advancement in the evaluation and management of flood risks, which may affect people, the environment, and human development. For estimating the efficiency of the measures targeting risk reduction, the estimation of the potential life loss and the economic loss are of great importance. Various method for estimation of potential life loss are given by Graham (1988) Sustainable Strategies of Urban Flood Risk Management (SUFRI) tool, Life Safety Model (LSM, Lumbroso et. al. 2011), LIFESim model. Synthetic damage assessment will be carried out by compiling detailed average inventories of property contents for different structure types using depth-damage curves.

11. **Results achieved with progress/present status**

The salient features of Mahi Banswara project is obtained from the project authority and literatures. The contour map for the reservoir spread area is obtained from Gujarat Engineering Research Institute (GERI). The river cross-section at some of the locations are collected and openly available DEM for the area is also collected. The dam break analysis of Mahi Bajaj Sagar dam projects has been carried out to estimate the breach outflow from the reservoir storage. The reservoir is assumed to be at MWL and breach parameters are estimated based on the physical characteristics of dam and its construction material. The breach parameters have been estimated using regression equations and has been verified for their upper and lower bound from table suggested by Federal Agency guidelines. The breach in dam is considered when the inflow in Mahi Bajaj Sagar raises the reservoir level above the MWL of RL 281.5 m. The computed breach parameters from various methods are summarized in Table 1. The Mahi dam being earth rock fill dam, a trapezoidal breach section with is considered. The maximum water level for MBS dam is RL 281.5 m. The length of the earthen portion of the dam is 2627.07 m. The time of failure computed by Xu and Zhang is excessively high. At the start of breach, the reservoir is considered at FRL (RL 281.5 m) and the breach continues till water in reservoir lowers down to minimum reservoir level. The resulting dam breach flood hydrograph is shown in Figure 2.

Table 1: Description of breach parameters.

SN	Method	Average Breach width (m)	Time of failure (hour)	Side slope of breach section
1	MacDonald	461	4.96	0.5
2	Froehlich (1995)	307	10.75	0.9
3	Froehlich (2008)	280	8.87	0.7
4	Von Thun & Gillete	106	0.78	0.5
5	Xu & Zhang	174	12.97	0.5

The recently developed guideline in DRIP, advocate for use of the equations given by Froehlich (2016) for estimation of breach parameters. However, it has also associated uncertainty in estimation of various parameters viz. breach width (B), side slope, formation time etc. More over these parameters are also limited by the design section of dam. The outflow hydrograph with breach parameters at different statistical level in a deterministic approach are shown in Figure 2. It is evident that there is large variation in the estimated values of peak flood using various methods.

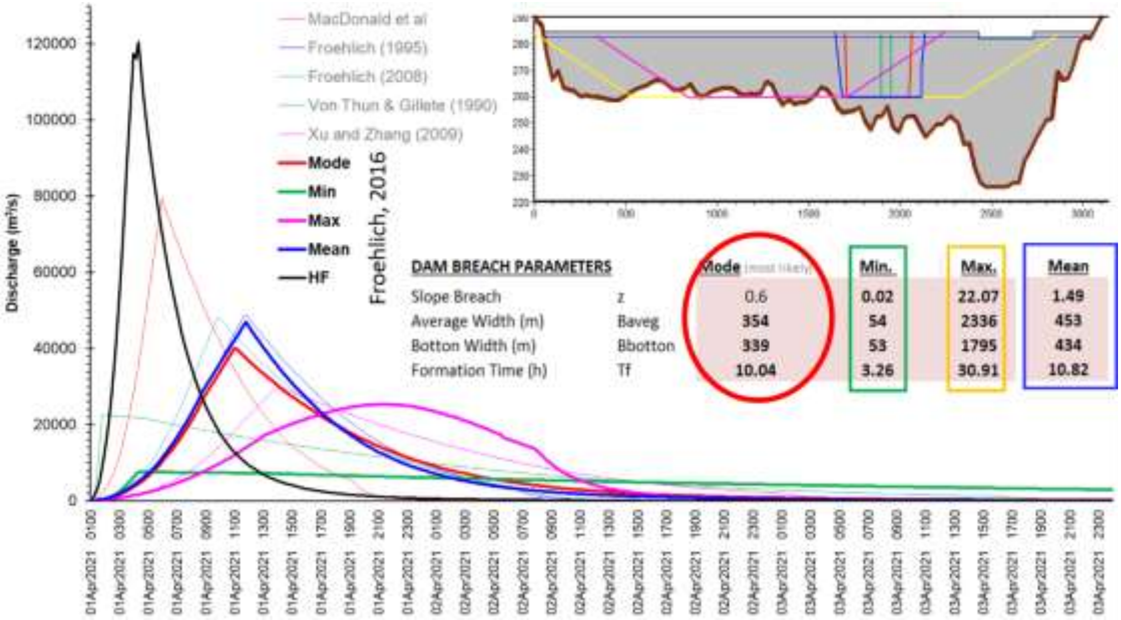


Figure 2: Dam breach flood hydrographs

However, such approaches are generally conservative and there is no communication of risk and uncertainty. In this study it is proposed to apply a dam breach modelling framework to improve the reliability of hydrograph predictions. The Exceedance Probability (EP) of hydrograph is determined by using Monte Carlo simulation technique, where each breach parameter is randomly sampled about pre-defined probability distributions. This require a large number of realizations to demonstrate convergence of statistical moments (mean, variance, skewness, kurtosis) as shown in Figure 3. It may be notes that with 100,000 realizations is quite adequate for this case (Figure 4). The estimated peak discharge at 1%, 5%, 10% and 50% EP are 74100 m^3/s, 61183 m^3/s, 55221 m^3/s and 37612 m^3/s respectively. The Map showing different hazard vulnerability classes due to PMF is shown in Figure 5.

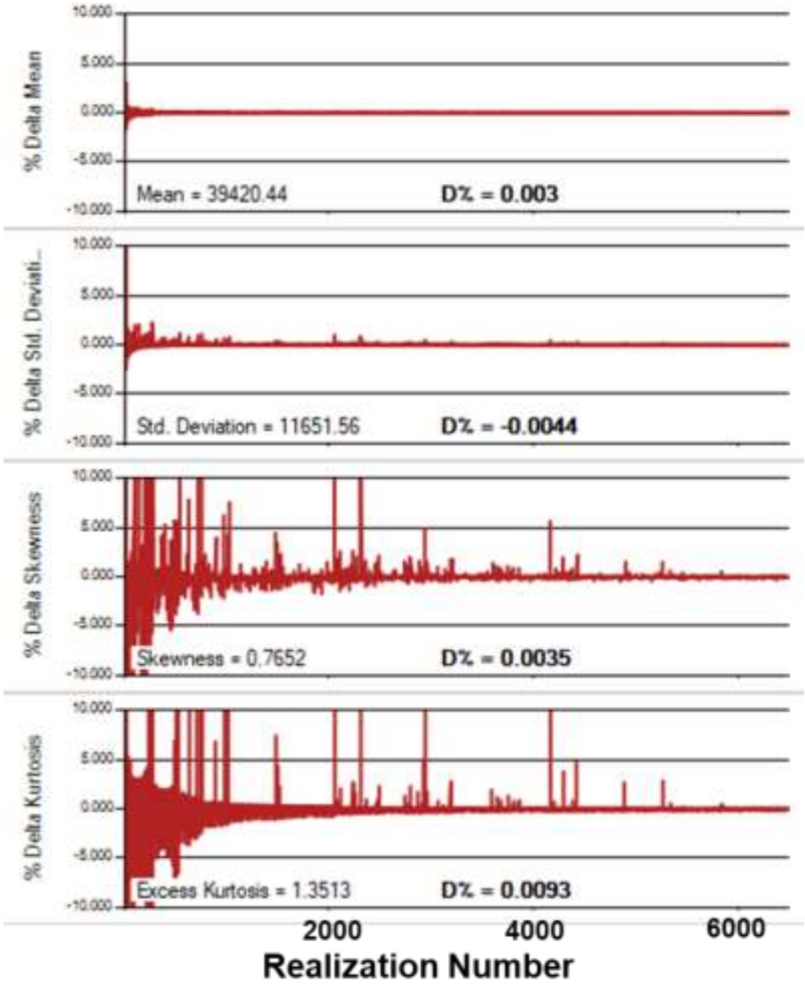


Figure 3: convergence of statistical moments

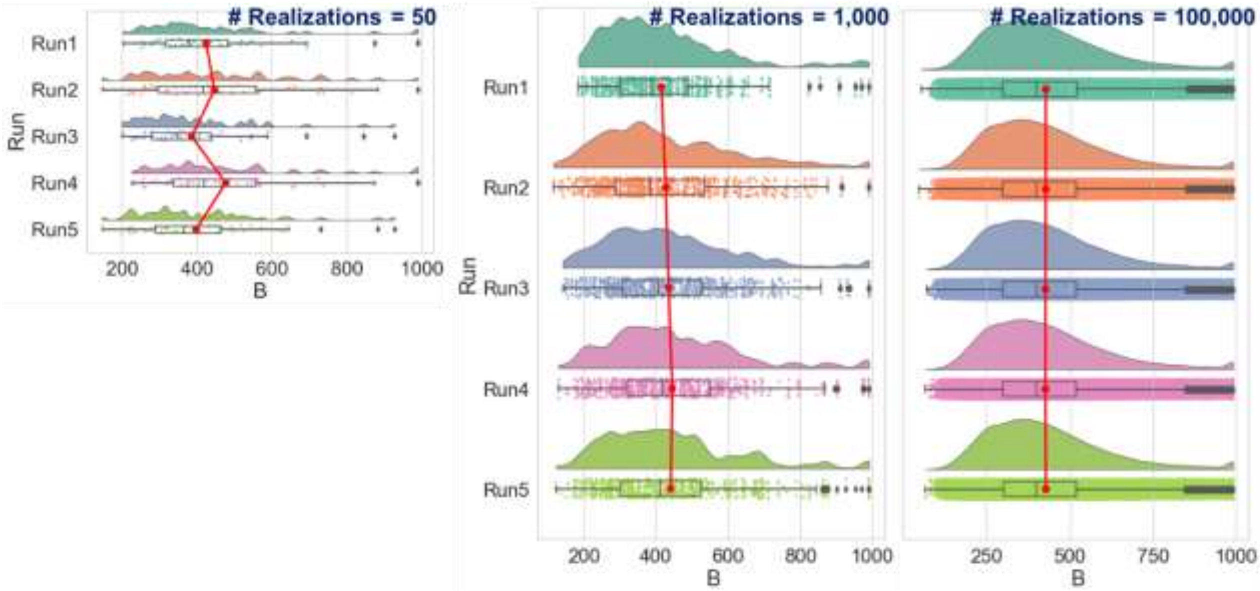


Figure 4: Distribution breach bottom width for different size of realizations.

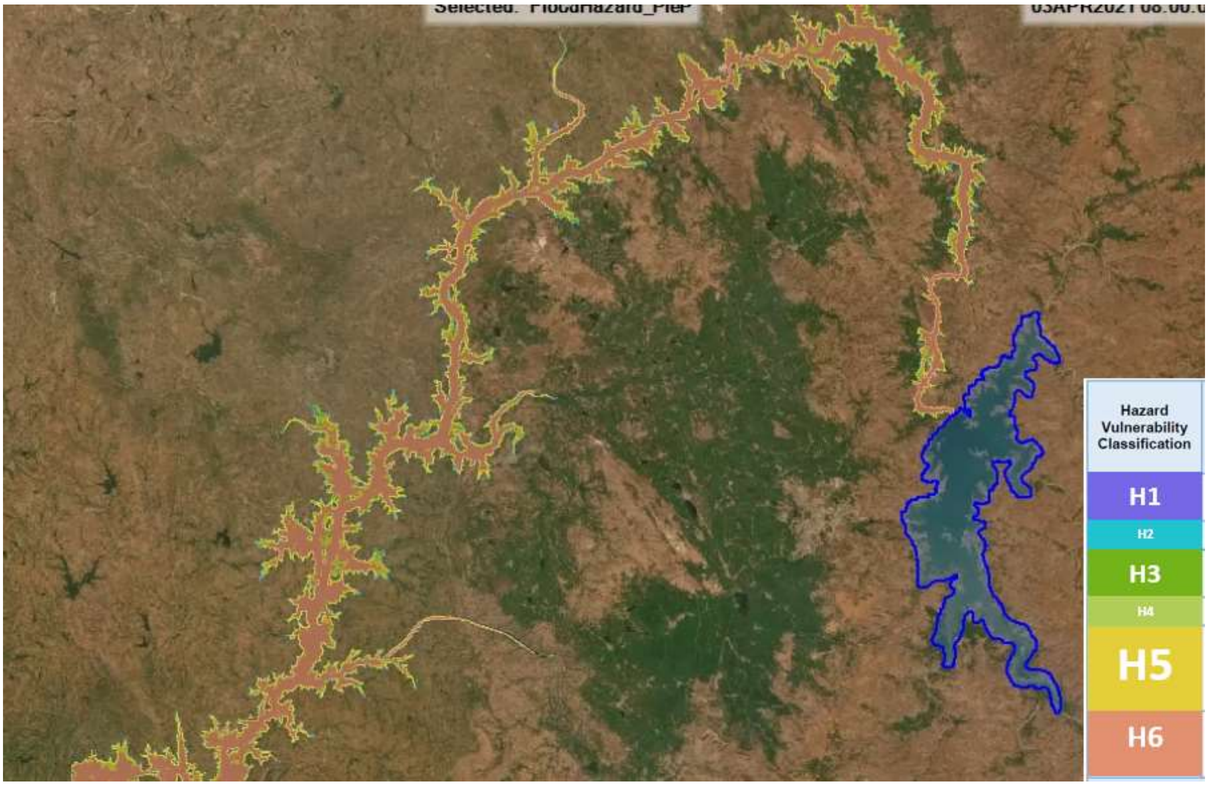


Figure 5: Map showing different Hazard Vulnerability classes

9. **Action taken on comments of previous working group meeting**

There were no specific comments.

10. **List of deliverables**

- Exceedance Probability Inundation (EPI) maps for Mahi Bajaj Sagar dam breach condition.
- Quantification of difference between level pool routing and full unsteady flow routing through the Mahi Bajaj Sagar dam reservoir.
- Maps showing depth, velocity, time of flood arrival, vulnerability due to large controlled release and dam break of Mahi Bajaj Sagar dam.
- Capacity building for assessing and mapping risks associated with dams.

ONGOING STUDIES (INTERNAL)

2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/21-22

1. Title of Study: **Uncertainty in rating curves and discharge estimation**

2. Study Group:

Sanjay Kumar, Sc-E, PI
L. N. Thakural Sc-D, Co-PI
Sunil Gurrapu Sc C, Co-PI
J. P Patra Sc 'D' Co-PI
N. K. Bhatnagar Sc 'B' Co-PI

3. Study Period: **Two Years (**April 2021 to March 2023)

4. Objectives of the Study: The objectives of the study are:

1. To estimate uncertainty in stage discharge relationship.
2. To estimate uncertainty in river discharge estimation.

5. Statement of the Problem:

The uncertainty in the river discharge measurement and estimation is caused by different sources of errors. These mainly includes uncertainty in (a) observations of river stage and discharge used to parameterize the rating curve, (b) presence of unsteady flow conditions, and (c) interpolation and extrapolation errors of the rating curves. The study will provide a framework for analyzing and quantifying the uncertainty in the (i) river flow data (ii) stage-discharge relationship The study will also examine various hydraulic factors controlling the flow at a cross section in the river and provides an understanding of independent variables that describes relations among stage, discharge and other parameters. specifically discharge measurement under steady flow conditions.

6. Methodology:

Statistical methods/tools and the procedures described in various ISO documents (GUM, HUG) will be used for the estimation of river discharge uncertainties. The uncertainty in discharge measurement (assuming velocity area method) will be quantified as per the ISO 748 which provides the magnitude of these errors at 95% confidence level. The GUM defines the law of propagation of errors for combining uncertainties from several sources and HUG described it for different types of mathematical expressions generally used in hydrometry. This is illustrated by considering the quantity Q as a function of several measured quantities x, y, z . The error δQ in Q due to errors δx, δy, δz…. in x, y, z…., respectively, is given by

$$\delta Q = \frac{\partial Q}{\partial x}\delta x + \frac{\partial Q}{\partial y}\delta y + \frac{\partial Q}{\partial z}\delta z + \cdots$$

The uncertainty of a discharge measurement determined from a stage-discharge rating function (as opposed to a gauged discharge which is determined from a current meter) shall be evaluated using statistical equations based on law of propagation of errors described above. Let X_{rd} be the uncertainty in the recorded discharge, the above error equation is then modified for uncertainty in discharge computation using stage-discharge relationship as

$X_{rd}=\pm(X_{\alpha}^{2} + \beta^{2}X^{2} H)^{1/2}$

In practice, X_{α} is the standard error of the mean relation ($S_{mr)}$ and XH_{h0} is the standard error of measured gauge.

7. Progress:

Observed and estimated discharge data of gauging sites in the subzone 1f has been collected. The observed stage and discharge data of these sites has been used to determine the Stage-Discharge relationships and their variation. The relevant literature has also been referred for uncertainty in the discharge estimation. A framework is being developed for the estimation of uncertainty in the stage-discharge relationships. The stage-discharge relationships for various sites has been shown graphically and preliminary analysis has been conducted for the observed stage and discharge data for evaluation of uncertainty.

8. Action Plan and Timeline:

S.N.	Major Activities	1st Year		2nd Year	
1	Literature review				
2	Development of a framework for quantifying the uncertainty				
3	Uncertainty in discharge measurements (Interim Report -1 in progress)				
4	Estimation of uncertainty in stage-discharge (rating curve) relationship.				
5	Uncertainty in discharge estimation and Final Report				

9. End users/beneficiaries of the Study: Central and State government departments, academicians, BIS etc.

10. Deliverables: Report/Manual, Publications

NEW STUDIES (INTERNAL)

1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-22

1. **Thrust Area under XII five year Plan:**

Surface Water/Flood Forecasting

2. **Project team:**

a. **Project Coordinator:** Dr. A. K. Lohani, Sc-G **(PI)**
Dr. R. K. Jaiswal, Sc-E **(PI)**

Project Investigator(s)

Dr. J. C. Patra, Sc-E **(Co-PI)**
Dr. P. C. Nayak, Sc-F **(Co-PI)**
Dr. Vishal Singh, Sc-D **(Co-PI)**

3. **Title of the Project**

Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Flood Management

4. Objectives

- To collect and analyse rainfall and runoff for selected reservoirs
- Water balance of reservoirs for computation of runoff
- Development of real time rainfall-runoff model for the catchment of reservoirs
- Development of integrated framework for real time flood forecasting using cloud based climatic data for early warning and efficient flood management
- Development of hydrodynamic model for assessment of flood impact downstream of dam

5. Present state-of-art

Flooding is an overflowing of water onto land that is normally dry. floods can happen during heavy rains, when ocean waves come on shore, when snow melts too fast, or when dams or levees break. flooding may happen with only a few inches of water, or it may cover a house to the rooftop. Floods are the catastrophic events cause damage to lives and properties. Due to impact of climate change, high intensity rainfalls are being observed in the most part of world and India. These extreme precipitations may cause unprecedented runoffs and resulting higher floods in the catchment. The recent change in climate pattern and land use in the catchment further aggravate the situation especially downstream of dams and reservoirs. The old formulae used to compute routed flood and flood protection works need to be evaluated and reformulated under changing climate situation.

Generally, regression based equations are commonly used for flood forecasting at reservoirs. In this method, water levels in the upstream and future forecast conditions from IMD are used to determine inflow in the reservoirs and according operation of gates are made during flood season. Nowdays, several sirce of forecast data for cliamate variables on grid levels are available which can be used in well calibrated rainfall-runoff model to determine pssible inflows to the reservoir through an integrated system. The gatherd knowledge of future inflows can be used for efficient reservoir operation and assessment of downstream flood and issue apporoprite preparedeness for evacuation in the event of high flood. In the present study, Tawa dam of Madhya Pradesh, RaviShankar Sagar dam from Chhattisgarh, Dharoi dam from Gujarat and Beesalpur dam from Rajasthan in India.

Tawa Dam

Tawa dam is situated on Tawa River in Itarsi of Narmadapuram District of Madhya Pradesh state. The construction of Tawa dam was began in 1958 and was completed in 1978. The dam provides for irrigation to several thousand hectares of farming land in Hoshangabad and Harda districts. The gross storage of Tawa reservoir is about 2311 MCM.

Tawa Dam

Ravishankar Sagar Dam

Ravishankar Sagar Project (RSP) dam was constructed in 1978 on river Mahandi in Chhattisgarh state. It is a multipurpose reservoir that serves municipal and industrial demands, irrigation demand, and hydel-power generation. The gross capacity of Ravishankar Sagar reservoir is 910.50 MCM designed to supply water for irrigation, power generation, domestic and industrial uses.

Ravishankar Sagar Reservoir

Dharoi Dam

Dharoi Dam is a gravity dam on the Sabarmati river near Dharoi, Satlasana Taluka, Mehsana district of Gujarat. The dam is constructed in 1978 and designed for irrigation, power generation and flood control. THe gross storage capacity of Dharoi reservoir is approximately 813 MCM.

Dharoi dam

Bisalpur Dam

Bisalpur Dam is a gravity dam situated on the river Banas in Tonk district, Rajasthan, India. The dam was completed in 1999 for the purpose of irrigation and water supply. The gross storage capacity of the dam is 1100 MCM.

Bisalpur dam

Thokarwadi dam

Thokarwadi dam is situated near Maval, Pune district in the state of Maharashtra. The dam is situated on river Indiravati. The gross storage capacity of Thokarwadi reservoir is 363 MCM.

Thokarwadi dam

These are the tentative selection of the dams and can be changed on the basis of data availabilityu and discussion with WRD officials of respectrive states.

6. Methodology

Development of GIS Based data base of catchments

The GIS database of all the dam catchment consisting of topography, land use, soil, draininage, downstream structures etc. will be craeated foe all the dams selected for the study. The GIS database will work as base information for modeling the rainfall-runoff processes.

Collection and analysis of climatological data and past catastrophic events

The climate data, rainfall, runoff, reservoir levels, releases, and supplies etc. if any will be collected and analyse with special referenc of catestrophic events in the reservoirs

Water balance of reservoirs for computation of inflows

Non-availability of runoff data is one of the major problems in India. The runoff records upstrem of dams are generally not avaialble and under this situation a water balance of reservoir considering all inflows and outfloe components, reservoir levels, losses will be used to compute reservoir inflows in the reservoir

Development of hydrological model for the catchments of dam

Rainfall-runoff models can be used to assess the production of water from cathment under given hydrological condition. In the study, suitable rainfall-runoff model on daily or event basis will be developed for catchments of reservoir. The developed model will be able to accommodate future forecast climate data for forecast of runoff with acceptable accuracy.

Hydrodynamic model for risk assessment downstrem of dam

Hydrodynamic models in MIKE 1D or HEC RAS will be developed for downstream of dams to determine vulnearabvle spots under regulated flows from dams.

Development of integrted system for early warning and downstream alert

An integrated system for all the dams will be developed under the study in which hydrological and hydrodynamic models will be integrated for efficient reservoir operation and planning for systematic reduction of flood using forecast data.

Development of awareness and technology transfer

Series of mass awareness in the officers of WRD departments and general public will be organized for utilization of results and operate reservoir to avoid flood with efficient management

7. Research outcome from the project

The catastrophic events are more and more common in all over the world and India. The proposed integrated system for forecasting reservoir inflows will be useful to water resource Departments of respective states for efficient reservoir opearion and issue emergency warning well in advance to evacuate the people. The general public will be benefitted by getting timely information in the event of catestropic flood situation.

8. Cost estimate

a. Total cost of the project : Rs. 34,80,000
b. Source of funding : NIH internal funds
c. Sub Headwise abstract of the cost

S.No.	Sub-head	Amount (in Rupees)
1.	Salary	16,80,000
2.	Travelling expenditure	10,00,000
3.	Infrastructure/Equipment including a desktop, remote sensing data, etc.	2,00,000
4.	Experimental charges/consumables	2,00,000
5.	Misc. expenditure and Trainings	4,00,000
	Grand Total:	**34,80,000**

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

(1) **Salary** for one Junior Recourse Person @ 35,000 per month to support in various activities like collection of data, GIS database development, analysis, etc.

(2) **Travelling expenditure:** Field visits will be made in the catchment and downstream of dam sites in MP, Chhattisgarh, Rajasthan and Gujarat for collection of data, from different agencies, ground truth and discussions regarding the study.

(3) **Infrastructure/Equipment including a desktop, remote sensing data, etc.:** Remote sensing data for assessment of land use / land cover of the strudy area will be purchaed, a desktop will be purchased for analysis and data processing

(4) **Experimental charges/consumables:** Field soil tests will be conducted to determine the infiltration rate and textural properties. Consumeable item like hard disk, pen drive, etc. may be purchased for data storage and transfer.

(5) **Misc. expenditure:** Procurement of hydro-meteorological data, Stationary charges and Other miscellaneous field expenditure

10. Work Schedule:

a. Probable date of commencement of the project: April 2022
b. Duration of the project: 2 Years (April 2022 to March 2024)
c. Stages of work and milestone:

S. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Literature survey and Data collection								

S. No.	Work Element	First Year				Second Year			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
2.	Discussion with field officers and dmas								
3.	Processing and analysis of hydrometereological data, GIS database development, Water sample collection, Spatial Database creation,								
4.	Water balance of reservoirs								
5.	Development of hydrological model for the catchments of dam								
6.	Hydrodynamic model for risk assessment downstrem of dam								
7.	Development of integrted system for early warning and downstream alert								
8.	Development of awareness and technology transfer								
9.	Publication of reports								

NEW STUDIES (INTERNAL)

2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-22

Title of Study: Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A.

Study group	Sushil K. Singh**,** Scientist F
Date of start of study	01 April 2022
Duration and scheduled	Six months
Date of completion of study	30 September 2022
Type of study	Internal (without/no funding)

Objectives of study

This study is undertaken as an extension of the prior approved projects "*Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data-*2016" and "*Application of unified extreme value distribution for flood frequency to different subzone-basins of India-*2018," to practically demonstrate the wider applicability of the proposed GUEV distributrion.

To illustrate and demonstrate the practical application of previously developed generalized GUEV (unified extreme-value) distribution for analyzing the flood frequency of peak flows in basins falling under different subzones of India. The internal studies (without/no funding) completed for different subzones are:

1. Mahanadi subzone-3d – "Singh, S. K. (2017-18). *Generalization and parameter estimation of UEV distribution for flood analysis: Specific application on Indian data*." [This report considers Mahanadi sunzone-3d]
2. Krishna & Pennar subzone-3h – "Singh, S. K. (2018-19). *Application of unified-extreme-value distribution for flood frequency: Krishna & Pennar subzone-3h*."
3. Narmada & Tapi subzone-3c – "Singh, S. K. (2019-20). *Application of unified-extreme-value (UEV) distribution for flood frequency: Narmada & Tapi subzone-3c*."
4. LowerGodavari-3f – "Singh, S. K. (2020-21). *Application of unified-extreme-value (UEV) distribution for flood frequency: Upper Godavari-3e*."
5. Lower Narmada & Tapi subzone-3b – "Singh, S. K. (2020-21). *Application of unified-extreme-value (UEV) distribution for flood frequency: Lower Narmada & Tapi subzone-3b*."
6. Mahi & Sabermati subzone 3a – "Singh, S. K. (2021-22). *Application of unified-extreme-value (UEV) distribution for flood frequency:* (1) Mahi & Sabermati subzone 3a."
7. Mahi & Sabermati subzone 3a – "Singh, S. K. (2021-22). *Application of unified-extreme-value (UEV) distribution for flood frequency:* (2) Upper Godavari subzone 3e."

The current year study is intended for the rivers of U.S.A. to practically assess the wider applicability of the proposed GUEV distribution

Statement of problem and brief methodology

In an earlier report, the innovative model of UEV distribution for analyzing extreme events has been developed by the author, which is a true mathematical unification of the three extreme value

(EV-1, EV-2, and EV-3) distributions and better substitutes the GEV (generalized extreme-value distribution), is intended to be applied to the peak flows observed in the basins falling under two above mentioned subzones of zone-3 of India. Also, proposed therein to quantify the deterministic confidence limit and interval applicable for predicting the flood peaks.

Adopters of the results of study and their feedback

Practitioners, field engineers, and academic personals.

Deliverables

Research report detailing the application for flood frequency analysis of peakflows and research papers in International Journals with illustrative application on the published international data and the Indian data available/collected at NIH.

NEW STUDIES (INTERNAL)

3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-23

Title of Study: Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution.

Study group	Sushil K. Singh**,** Scientist F
Date of start of study	01 October 2022
Duration and scheduled	Six months
Date of completion of study	31 March 2023
Type of study	Internal (without/no funding)

Statement of problem and brief methodology

In this report, the comparison of results using GEV distribution and that using the proposed GUEV distribution is intended, for a couple of Indian subzones.

Adopters of the results of study and their feedback

Practitioners, field engineers, and academic personals.

Deliverables

Research report detailing the application for flood frequency analysis of peakflows and research papers in International Journals with illustrative application on the published international data and the Indian data available/collected at NIH.

NEW STUDIES (INTERNAL)

4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-23

1. **Title of the Study:** Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model

2. **Study Group:**

   Study Team
   Dr. P. C. Nayak, Sc. F– Principal Investigator
   Dr. A. K. Lohani, Sc. 'G'- Project Coordinator
   Er. J. P. Patra, Sc. 'D'
   Dr. Sunil Gurrapu, Sc. 'C'
   Dr. T. Thomas, Sc. 'E', NIH, Bhopal

   Supporting Staff
   Mr. Om Prakash, PRA
   Mr. Jatin Malhotra, SRA

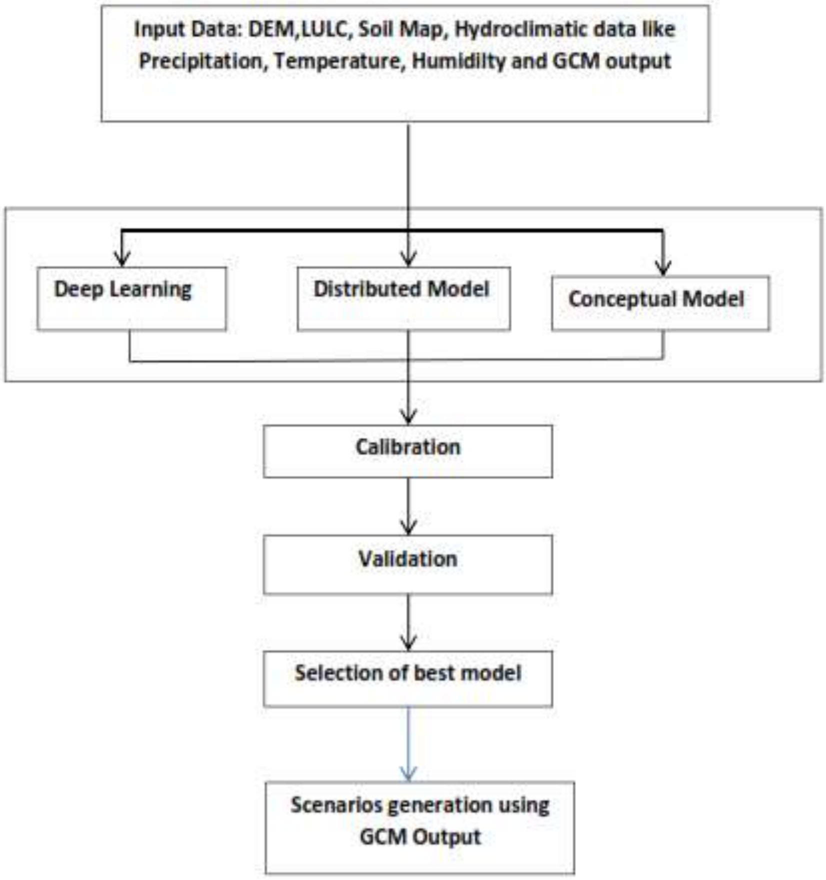
3. **Type of Study:** Internal Study
4. **Nature of Study:** Basic and Applied Research
5. **Date of Start:** July 2022
6. **Scheduled date of Completion:** June 2025
7. **Duration of the Study:** 3 years
8. **Study Objectives**
   - Develop a deep neural network-based hydrologic model to predict the long-lead-time flood forecasting
   - Comparison between conceptual/distributed model with deep neural network to improve the flood forecasting
   - The performance of the proposed model will be tested for Baitarani and Brahmani basin in Odisha state
   - To predict the long lead time flood forecasting under changing climatic conditions, *i.e.,* include the GCM models output for future predictions

9. **Statement of the Problem**

Nowadays, floods have become the widest global environmental and economic hazard in many countries, causing huge loss of lives and materials damage. It is, therefore, necessary to build an efficient flood forecasting system. The physical-based flood forecasting methods have indeed proven to be limited and ineffective. In most cases, they are only applicable under certain conditions. Indeed, some methods do not take into account all the parameters involved in the flood modelling, and these parameters can vary along a channel, which results in obtaining forecasted discharges very different from observed discharges. While using machine learning tools, especially artificial neural networks schemes appears to be an alternative. However, the performance of forecasting models, as well as a minimum error of prediction, is a very interesting and challenging issue. In this work, a comparison of deep neural networks and conceptual models are developed and compared in order to design a flood forecasting model and use discharge as input-output variables. The designed model will be tested upon intensive experiments and real case examples.

10. **Methodology**

It is proposed investigate prediction of flow statistics using conceptual/physical based model and DLNN. The river flows can be predicted using DLNN approach from mean precipitation, antecedent flows at previous time steps, and other catchment characteristics. Future stream flow can be generated using GCM output. Flow chart of the proposed methodology is given below:



11. Work Plan

S. No.	Major Activities	2022-23				2023-24				2024-25			
		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	Literature survey		■										
2	Data collection and preprocessing of data		■	■	■								
3	Calibration & Validation of DLNN			■	■	■	■	■	■	■	■	■	■
4	Calibration, Validation of conceptual/physi cal based model							■	■	■	■	■	■
5	Future projection using GCM output									■	■	■	■
6	Interim Report				■				■				■
7	Final Report												■

12. **Cost estimate:** Rs. 20,24,000 (NIH Internal Fund)

S. No.	Sub-Head	I Year	II Year	III Year	Total
1.	Manpower	405480	405480	405480	1216440
2.	Travelling expenditure	150000	100000	100000	350000
3.	Infrastructure /Equipment /Consumable	30000	30000	30000	90000
4.	Experimental charges/Analytical charges	0	0	0	0
5.	Misc. Expenditure	20000	20000	20000	60000
6.	Grand Total	605480	555480	555480	1716440

a. Justification for sub-head-wise abstract of the cost

- Manpower: For timely collection of hydro-meteorological data required for thesimulation

S. No.	Manpower Category	Nos.	Gross Salary per month including HRA	1st year	2nd year	3rd year	Total
1.	Junior Reserch Fellow	1	33790	405480	405480	405480	1216440

- Travelling expenditure: For visit to study area, attending conferences, data collection,
-

13. Research outcome from the project:

a) Identification of hydrological characteristics in flood estimation
b) Identification of rainfall variation over the basin
c) Future projection of flood using GCM output
d) Technical report and papers

14. End Users/Beneficiaries of the study: Department. of Water Resources, Govt of Odisha

15. List the actions that will be necessary to put the results to use.

a) Apprise the officials of the various departments of the findings of the study through reports, seminars, workshops etc.
b) Prepare and demonstrate some case studies to the user organisations showing the effect of particular developmental activities proposed/ being carried out by them in the study area.

NEW STUDIES (INTERNAL)

5. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

4. **Title of the Project**: Hydrological Study to conserve the water resources of Bikaner, Rajasthan
5. **Project team:**

a. Project Coordinator	Dr. A. K. Lohni, SC-G
b. PI Project Investigator(s)	Dr. L. N. Thakural, Sc-D, Lead PI Sh. J. P. Patra, Sc-D Dr. M. K. Shama,Sc-E Dr. Rahul Kumar Jaiswal, Sc-E Dr. P. K. Mishra, Dc-D Dr. Nitesh Patidaar, Sc-B Sh. N. K. Bhatnagar, Sc-B, Co-PI Sh. Jatin Malhotra, SRA, Co-PI
c. PI from Partner Organisation:	Dr. Anil Kumar Chhangani, Professor Department of Environmental Science, Maharaja Ganga Singh University, Bikaner

6. **Objectives:**

a) To prepare inventory of water bodies in Bikaner and to understand the role of the water bodies in the human survival, livestock and livelihood sustainable and in biodiversity conservation.
b) Long-term spatio-temporal analysis of rainfall, temperature and meteorological variables.
c) Landuse land cover (LULC) change detection in the study area and selection of pilot water bodies (ponds).
d) Trend analysis of groundwater levels and assessment of recharge to groundwater in Bikaner district
e) Surface water availability analysis of pilot water bodies.
f) Identification of various issues both quantitative and water quality assessment of pilot water bodies.
g) To understand the socio-economical role of the water bodies to meet the daily requirement of community for water and other natural resources in and around water body.
h) To understand the existing governance and management practices of water bodies by the local community or any other authorities.
i) Suggesting ameliorative measures to restore water quality of water bodies and daptive and mitigation measures for rejuvenation and sustenance of water bodies.

7. **Present state-of-art**

Small traditional waterbodies including ponds and tanks are the most important water sources especially in rural areas. These waterbodies are increasingly recognized for their role in meeting rural water needs, aquifer recharge, providing livelihood opportunity, maintaining ecological balance and ecosystem services (Biggs et al., 2016). Small waterbodies are playing vital role in socio-cultural, economic and environmental development. Often, tanks and ponds support rural livelihoods of the marginalized community in rural, urban, coastal and tribal areas. There are about 5,00,000 tanks in India and mostly situated in semi-arid parts of India. As per 5th Census of Minor Irrigation Schemes Report, in surface flow schemes, tanks/ ponds have largest share of 41% followed by reservoir (14%) and temporary diversions (10%). These tanks help in capturing the runoff during monsoon and providing water for irrigation and other multiple uses for the community. However, continued unsustainable exploitation, increasing negligence and lack of conservation and urban growth resulting in huge adverse impact on these small waterbodies. In the last few decades, waterbodies have been under continuous and unrelenting stress, caused primarily by rapid urbanisation and unplanned growth. Encroachment of these waterbodies, often, identified as one of the causes of urban floods. Further, these waterbodies are being polluted by untreated effluents and sewage (Bindu and Mohamed (2016); Matto, 2019). Waterbodies are the lifeline for human existence and always the backbone of water resource sustainability in any urban area. They are going to disappear around the world. Solid waste dumping, industrial pollution, sewage pollution, encroachments, commercial fish farming and other practices are the main causes of this situation. Urbanization and industrialization have increased the intensity of pollution to such an extent that waterbodies' self-healing capacities are no longer enough to counter these multiple onslaughts. Flood mitigation, groundwater recharge, biodiversity enhancement, industrial development and water security are just a few of the benefits that waterbodies provide to a city. It is time their role is properly evaluated in the urban economy and effective actions are initiated for their rejuvenation. Bikaner city has a number of water bodies since ancient time, which has been disappeared due to ignorance and non-maintenance of these water bodies.Bikaner city will be studied followed by broad recommendations on site-specific approaches for revival and restoration.

8. Methodology:

Present GW Scenario and trend analysis (Dr. Nitesh Patidaar)

Land use change detection in study area for selection of pilot water bodies using remote sensing and GIS environment. The analysis of present GW status will be performed using the observed GW levels of Central Ground Water Board (CGWB). The analysis will be performed by generating spatial maps using interpolation atannual scale.GW data will be processed to check the consistency of observations. In order to derive groundwater level maps, data of observation wells will be interpolated using Kriging, a geo-statistical interpolation technique. The interpolated groundwater levels will be used in analyzing the spatial variability of groundwater in the study area.Trend analysis will be performed at annual scale using modified Mann-Kendall (M-K) test. The Mann-Kendall test is a non-parametric test for identifying trends in time series data. Being non-parametric, it allows to perform trend analysis on any distribution of data.

Estimation of GW recharge

Recharge to groundwater will be estimated using the integrated model developed at NIH. Remote sensing based data, such as land cover, impervious surface map, Leaf Area Index (LAI), Elevation, etc., will be utilized in the model. In addition, the well lithologs will be utilized to define aquifer geometry and parameters. The observed groundwater head will be utilized for validating the recharge.

Trend analysis (Dr L N Thakural)

Trend analysis will be performed at annual scale using Mann-Kendall (M-K) and Sen's Slope of Estimator in rainfall and temperature parameter test in time series data.

Assessment of Land use/Land Cover and its impact on runoff characteristics in the catchments of Waterbodies (Dr R. K. Jaiswal)

The land use/land cover influences the characteristics of runoff and in turn considered as one of the important physical aspects in defining the water availability and sediment from catchment of water body. The traditional water bodies have their definite catchments which are being encroached and converted from forest to urban/agricultural land. Due to rapid growth of urbanization and population growth, land use pattern is being changed significantly during recent periods and availability of remote sensing data from earth observation satellites has made it convenient to map and monitor land use/land cover at regional to local scales. The high as well as low resolution remote sensing data in GIS environment and Google Earth Engine using supervised classification technique for assessment of change in land use in different decades (1985 to 2015) and its impact on inflows in these lakes using SCS-CN or other suitable models in GEE using dynamic land use.

Assessment of Soil Loss from the catchments (Dr R. K. Jaiswal)

The soil erosion modelling with Remote Sensing (RS) and Geographic Information System (GIS) is a valuable tool for studying the land degradation over a variety of spatial and temporal scales. The revised universal soil loss equation (RUSLE) model will be used using spatially distributed topographic, land use, soil, management options and conservation practices maps. The environmentally degraded hot spots in the catchments of water bodies will be identified for selection of appropriate conservation measures.

Surface water availability analysis (Sh. J. P. Patra)

The rainfall analysis will be carried out for estimating dependable rainfall at monthly and seasonal scale. The meteorological data will also be analysed along with rainfall for annual variation with respect to water availability in selected water bodies. The long term series of runoff generated from the catchment area of water bodies will be estimated using SCS-Curve number approach and other suitable methods. The runoff generated will also be analysed with respect to change in LULC and other interventions in the catchment area.

Water Quality Assessment from water bodies (Dr. Mukesh Sharma)

Water quality assessment by collecting water samples from water bodies during pre- and post-monsoon season and analyzing these for physico-chemical parameters, demand parameters, heavy metals and pesticides. Metal pollution assessment of aquatic bed sediments of water bodies. Suggesting ameliorative measures to restore water quality of water bodies.

Site-specific approaches for revival and restoration (Dr. P. K. Mishra)

Water harvesting and its utilization is one of the major components of the watershed development programs which is realized through: (a) in-situ rain water harvesting measures, (b) surface water development measures, such as ponds, earthen reservoirs, small harvesting tanks, gully control structures and, drainage line treatments (c) sub-surface or ground water development measures such as percolation tanks, ponds, sub-surface dams, barriers, and, diaphragm dams (d) roof top collection and runoff water cistern and, (e) improved water management practices including micro-irrigation and on-farm water management (Pandey et al, 2003; Samra, 1997). In the present study, the traditional waterbodies in and around the Bikaner city will be studied followed by broad recommendations on site-specific approaches for revival and restoration and suggest adaptive and mitigation measures for rejuvenation and sustenance of water sources mainly ponds spread over in the Bikaner district, Rajasthan

True repositories of biodiversity (Professor A K Chhangani)

Inventory of different types of water bodies and GIS mapping of various water bodies in Bikaner district will be prepared using digital toposheets of survey of India and Global Positioning System (GPS). Further, selection of various types water bodies in the study area for the detailed ecological and socioeconomic studies. The record of the vegetations including trees, shrubs and grasses of the study area will be compiled. For this a center point will be identified randomly, using the transect method, 500 m area to cover for the availability of plant species in and around each types of after bodies after identification. Moreover, attempts will be made to prepare inventory of all the faunal (including mammals, birds and reptiles) diversity encountered in and around different water bodies of the study area. Direct observation as well as interviews to collect information on the present management practice of the water bodies at community level will be carried out. Also, detailed inventory of the extracted resources by neighboring communities like collection of fallen wood for fuel, coppicing of trees for food and fodder, collection of fodder grasses, and type of grazing. The existing governance and management practices of water bodies by the local community or any other authorities will be documented. Recommendations will be provided on site-specific approaches for revival and restoration of identified ponds.

9. Research outcome from the project

The outcome of the study will help in revival and restoration of ponds in water bodies.

10. Cost estimate:

a. Total cost of the project : Rs. 33,80,000
b. Source of funding : NIH internal funds
c. Sub Headwise abstract of the cost

S.No.	Sub-head	Amount (in Rupees)
1.	Salary	16,80,000
2.	Travelling expenditure	7,00,000
3.	Infrastructure/Equipment	Nil
4.	Experimental charges/consumables	5,00,000
5.	Misc. expenditure	5,00,000
6.	Training/ Workshop	5,00,000
	Grand Total:	**38,80,000**

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

(1) **Salary** for one Junior Resource Person @ 35,000 per month to support in various activities (GIS, Creation of data base, water sampling and analysis).

(2) **Travelling expenditure:** Field visits for data collection of water samples,GW & metrological data from different agencies, ground truth and discussions regarding the study.

(3) **Experimental charges:** Cosumables, chemicals / standards / Reagent glassware / plasticwares / filter papers/gases

(5) **Misc. expenditure**

- Procurement of hydro-meteorological data
- Stationary charges etc.
- Other miscellaneous field expenditure

11. Quarterly Break up of cost estimate for each year

Year: 2022-23

S.No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	**Salary**	2,10,000	2,10,000	2,10,000	2,10,000

2.	**Travelling expenditure**	87,500	87,500	87,500	87,500
3.	**Experimental charges**	75000	75000	75000	75000
4.	**Misc. expenditure** Hydro-meteorological Data and Satellite Data Miscellaneous	2,00,000		1,00,000	-
5.	Training/ Workshop			2,50,000	
	Sub- Total:	5,72,500	3,72,500	7,22,500	3,72,500
	Grand Total	**20,40,000**			

Year: 2023-24

S.No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	**Salary**	2,10,000	2,10,000	2,10,000	2,10,000
2.	**Travelling expenditure**	87,500	87,500	87,500	87,500
3.	**Infrastructure/Equipment**	-	-	-	-
4.	**Experimental charges**	75000	75000	50000	-
5.	**Misc. expenditure** Hydro-meteorological Data and Satellite Data Miscellaneous, Report Printing etc.	- - 50,000	- - 50,000	- - 50,000	- - 50,000
6.	Training/ Workshop			2,50,000	
	Sub- Total:	4,22,500	4,22,500	6,47,500	3,47,500
	Grand Total	**18,40,000**			

Note:

(i) The above table has to be prepared for each year of the project period

(ii) PI has to submit the revised table to the Finance Officer for the subsequent year (on or before 15th March of current year) considering the actual expenditure incurred during the current year

12. Work Schedule:

d. Probable date of commencement of the project: April 2022

e. Duration of the project: 2 Years (April 2022 to March 2024)

f. Stages of work and milestone:

S. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Literature survey and Data collection, selection of waterbodies , Field visits								

S. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2.	Processing and analysis of hydro-meteorological data, GIS database development, Water sample collection, Spatial Database creation,								
3.	Surface water availability, groundwater levels and assessment of recharge to groundwater								
4.	Identification of various issues both qualitative and quantitative bodies								
5.	Understand the existing governance and management practices of water bodies by the local community or any other authorities.								
6.	Suggesting ameliorative measures to restore water quality of water bodies. Suggest adaptive and mitigation measures for rejuvenation and sustenance of water								
7.	Training/ Workshop								
8.	Preparation of Interim/ Final report								

NEW STUDIES (INTERNAL)

6. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-25

1. **Title of the Study:**

   Review of design flood and dam break analysis of Khadakhai Dam in Odisha

2. **Project team**
   a. Project Investigator: J.P.Patra, Sc. – D, SWHD
   b. Project Co-Investigator: A. K. Lohani,, Sc. – G & Head SWHD
   Pankaj Mani, Sc. – F, CFMS Patna
   P. C. Nayak, Sc. – F, SWHD
   Sanjay Kumar, Sc. – E, SWHD
   c. WRD Odisha: Tapas Pattanaik, Damsaftey
   Tareni Sen Dhala, CE & BM Subarnarekha

3. Type of Study: Internal Study
4. Nature of Study: Basic and Applied Research
5. Date of Start: April 2022
6. Scheduled date of Completion: March 2025
7. Duration of the Study: 3 years
8. Objectives
   a. To estimate design flood for the Khadakhai Dam.
   b. To analyses uncertainty associated with estimation of design floods in view of future climate projections.
   c. To review and improvement of Khadakhai Dam operation rule curve.
   d. To prepare dam breach flood inundation maps for various scenarios.
   e. To access sensitivity of the flood inundation maps due to uncertainty in estimate of design flood, breach parameters and reservoir sedimentation.
9. Present state-of-art

   The Khadakhai Dam is an earthen dam of 365.4 m length build across Khadakhai river in 1981. The maximum height above foundation of the dam is 37 m. It has been constructed on two ends of hills i.e., Bhitarmda hill and Karanjharan hill end points. The reservoir is known as Suleipat reservoir, created mainly for irrigation purpose. In April 2012, Ministry of Water Resources, River Development & Ganga Rejuvenation through Central Water Commission with an objective to improve safety and operational performance of selected dams started the Dam Rehabilitation and Improvement Project (DRIP) with World Bank assistance. Design flood review and preparation of EAP are two important activity in DRIP. The older dams are designed with limited data and atmospheric realities of that period. Now, as those realities shift dramatically with the climate crisis, and need to be relooked. A dam operator has to manage the water release and storage cycle in such a manner that at the end of the monsoon period, its reservoir is at its full capacity. The storage and release schedule of a dam is governed by a rule curve. However, these rule curves are based on monsoon patterns of a time when such patterns were far more predictable, and less disrupted by climate change than they are today. Dam breach modelling is a key component to a well-rounded and robust dam safety program. Various researcher and guidelines recommended combination of breach parameters. The parameters are highly sensitive to peak flood and resulting flood inundation extent. This is further increased with uncertainty in design flood, reservoir operation policy, reservoir sedimentation etc. These needs to be addressed systematically while developing flood inundation map and EAP.

10. Methodology

It is proposed to develop a rainfall runoff model using HEC-HMS for estimating design flood hydrographs at the dam site. Design flood will be estimated using the recently developed PMP atlas. Further, the future climate projections (INCC), non-stationarity in the rainfall/ discharge pattern along with LULC changes will be analysed for assessing uncertainty in the design flood estimates. Based on the estimates of design flood it is proposed to evaluate and improve the existing rule curve in DSS(PM) platform. The dam break analysis will be carried out using HEC RAS. Sensitivity analysis will performed to access sensitivity of the flood inundation maps due to uncertainty in uncertainty in design flood, reservoir operation policy, reservoir sedimentation etc.

11. Research outcome of the project

- Revised design flood for the Khadakhai Dam.
- Flood inundation maps along with depth, velocity, time of flood arrival, combined flood hazard due to large controlled release and dam break of Khadakhai Dam.
- Capacity building in line with DRIP.
- Application of DSS (PM) developed under NHP

12. Work Schedule:

S.N.	Work Element	1st Year	2nd Year	3rd Year
12	Collection of basic data, topography, cross-section, satellite images, thematic maps etc.			
13	HEC-HMS model setup, review & estimate design flood			
14	Uncertainty analysis for design floods with future climate projections.			
15	Analysis of operation rule curve			
16	HEC RAS model setup for dam beach modelling			
17	Dam breach flood inundation modelling and combined general flood hazard classification			
18	Review and analysis of reservoir sedimentation and updating of EAC table			
19	Sensitivity of the flood inundation maps			
20	Workshop/ Training			
21	Report			

13. Cost estimate: Rs. 10,20,000 (NIH Internal Fund)

S. No.	**Sub-Head**	**Amount (Rs)**
1.	Travelling expenditure	3,50,000
2.	Data/ Equipment/ Consumable	1,10,000
3.	Training/ Workshop	5,00,000
4.	Misc. Expenditure	60,000
	Total	10,20,000

14. End Users/Beneficiaries of the study:

Department of Water Resources, Govt. of Odisha

NEW STUDIES (INTERNAL)
7. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

Title of the Project:	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin
Project Team:	Dr. Sunil Gurrapu, Scientist 'C' (PI), NIH Roorkee Dr. Y R S Rao, Scientist 'G', NIH Kakinada Dr. Nitesh Patidar, Scientist 'B', NIH Roorkee Dr. R Venkat Raman, Scientist 'D', NIH Kakinada
Type of Study:	Internal
Status:	New
Duration:	2 years
Date of Start:	1st April 2022
Scheduled Completion Date:	31st March 2024

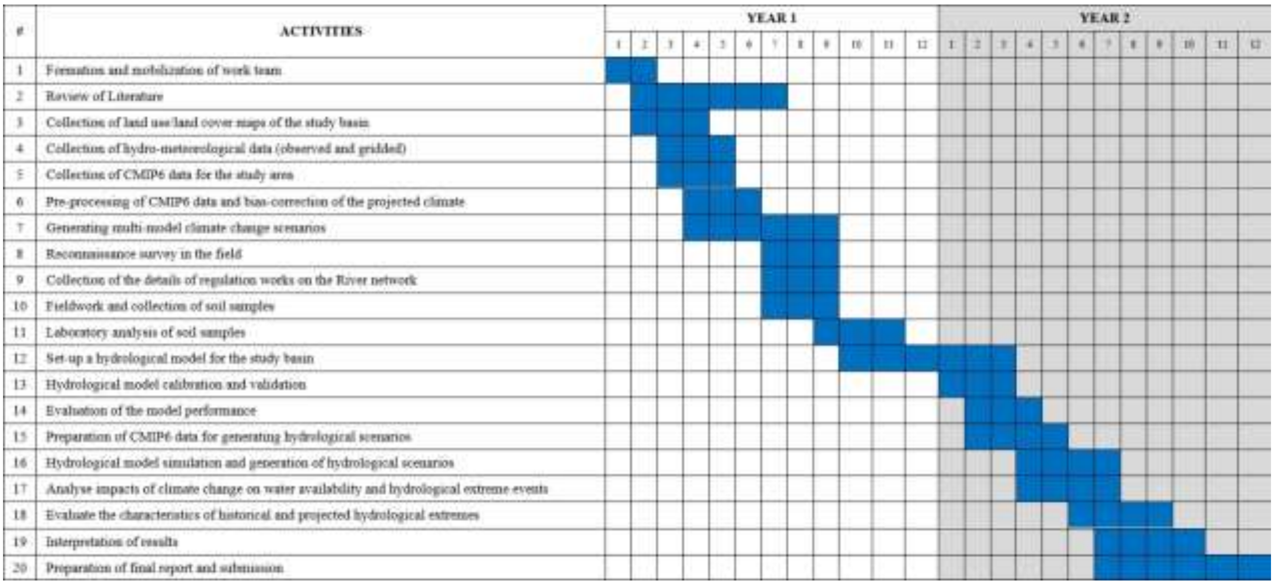
OBJECTIVES:

1. Analyse CMIP6 projected rainfall and temperature data for the state of Andhra Pradesh and generate multi-model scenarios of climate change.
2. Develop/calibrate and validate a hydrological model for surface water and groundwater levels for the Pennar River Basin.
3. Generate hydrological scenarios (i.e. streamflow and groundwater levels) using CMIP6 projected climate.

STATEMENT OF PROBLEM:

It has been globally accepted that the changing climate is imposing significant alterations in the hydrological systems, which eventually is leading to the changes in the characteristics of hydrological extremes (e.g. Liu et al., 2021; Tabari, 2020; Manfreda et al., 2018; Wang et al., 2016; Gossain et al., 2006). In a most recent special issue on the impacts of climate on hydrological extremes, the focus was on the historically observed hydrological extremes and how these extremes are linked to the changing climate in several watersheds across the globe (Manfreda et al., 2018). Therefore, to evaluate the impacts of changing climate on the basin hydrology and/or hydrological extremes, the knowledge of complex interactions between climate and hydrological systems is vital. In addition to the changing climate, the hydrological dynamics of a basin are affected by the changes in catchment characteristics and river flow regime, caused by the land-use/land-cover changes from anthropogenic activities. In brief, the on-going changes in the global climate and the anthropogenic effects on regional/local climate would trigger imbalance in the hydrological systems and eventually result in disproportionate changes in the hydrological extremes. Several studies from the recent past indicate that the hydrological extremes would be more frequent and widespread in future due to extreme weather events perceived to be induced by climate change (ICHARM 2009; Vogel et al. 2011). Therefore, information on the impacts of climate change on the basin's hydrology and the basin's hydrological projections of the 21st century becomes a vital information for water managers, irrigation engineers, city planners, hydro-electric engineers etc. The proposed project aims to analyse the projected rainfall and temperature data from CMIP6 GCMs and generate multi-model climate change scenarios for the state of Andhra Pradesh. The second major objective of the project is to generate hydrological scenarios using a calibrated and validated hydrological model and evaluate the impacts of climate change on the hydrology and extreme hydrology of a selected watershed. The generated hydrological scenarios and the results from impact assessment will benefit water managers, irrigation and hydro-electric engineers, to plan and allocate water appropriately for its effective use and reduce negative impacts of floods and droughts

TENTATIVE SCHEDULE



DELIVERABLES

1. Multi-model climate change scenarios for the state of Andhra Pradesh.
2. Calibrated and validated hydrological model for the Pennar River basin, ready to be used in the future studies on the assessment of climate change impacts.
3. Multi-model hydrological scenarios generated for the Pennar River Basin, ready to be used by the officials of Water Resources Department, Andhra Pradesh to make decisions on effective management of available water.

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NEW STUDIES (INTERNAL)

8. PROJECT REFERENCE CODE: NIH/SWD/NIH/22-25

Title of the Project: Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes

Thrust area under XIIth Plan: Impact of climate change on water resources and hydrology of extreme

Project team: Dr. Ashwini Ranade, Scientist 'D' (PI)
Dr. P.K. Mishra, Scientist 'D' (Co-PI)
Dr. Sunil Gurrapu, Scientist 'C' (Co-PI)

Type of Study: Internal

Status: New Study

Duration: 3 years

Date of Start: 1 April 2022

Scheduled date of completion: 31st Mar 2025

Objectives:

- To document broad features and unique characteristics of the large-scale and isolated heavy rainstorms/snowstorms across Northwest Himalaya
- To generate in-depth information about the location, shape, size, and intensity of the various rain-producing weather systems that are formed over the northwest Himalaya during different seasons of a year.
- To investigate the relationship among global atmospheric thermal structure and general and monsoonal circulation features and seasonal extremes over the NW Himalaya.
- To study the nature of mid/upper tropospheric tropical-extratropical interactions and different thermo-hydrodynamical processes causing isolated heavier rain/snow storms

Statement of the problem:
Heavy rain events over the northwest Himalayan region are becoming ferocious in recent years causing catastrophic disasters. Colloquially termed as the cloudburst has a potential to downpour over a smaller region in very short duration. International disaster database (http://www.emdat.be) has reported the substantial increase in the extreme rain events over the western Himalayas in recent 30-40 years. It is one of the most studied but less understood phenomena so far. Under the influence of highly complex terrain and tropical-extratropical interactive atmosphere, the northwest part of Himalaya becomes more prone to such types of extreme events, especially during the monsoon season. Other parts of the country also experiencing extreme rain events each year surprisingly even during large-scale droughts also. In addition, there is a widespread belief that, in a recent global warming period, due to the intensification of the hydrological cycle, extreme rain events are increasing (Senior et al. 2002, IPCC 2007). The sixth assessment report (IPCC, 2021) projected that, extreme rainfall are projected to be intensifies by 7% for each additional 1 ºC due to acceleration of hydrological cycle in warmer climate across the globe and become more frequent mostly in Africa and Asia.

Many more studies also supported this fact. In most of the studies, the rising frequency of extreme rain events in India has mostly attributed to the following conditions: i) a significant increase in synoptic activities over the Bay of Bengal and Arabian sea; ii) anomalous convective instability; iii) atmospheric conditions over the equatorial Indian Ocean; etc. Their conclusions are especially based upon, synoptic observations, satellite-radar output as well as numerical model simulations. Recently we have studied the heaviest monsoon rainstorm that occurred during 16-17 June 2013 over western slopes of Himalaya and concluded that, combined five factors: cool-low and warm-low regime contrast; squeezing of three different type of flows (deep warm-moist, cool-dry and warm-dry); orographic lifting; and pumping and suction effects produced unprecedented rains over Kedarnath range. In our earlier studies concerning about the variations in spatio-temporal extreme rainfall fields over the Indian region, we observe that the point/local, short-duration extreme rain events (EREs) are embedded in large-scale, long-period intense heavy to very wet spells, and rainwater generated during the main monsoon wet period is highly correlated with the Asia-Pacific monsoon intensity.

Since 2010, about 17 noticeable extreme events have been observed over Indian Himalayan region of Leh, Uttarakhand, Jammu and Kashmir and Himachal Pradesh, about 5 over subtropical Pakistan and 2 each over Nepal and China. Studies shows that, multiple visualizable factors operated in accord to produce extreme weather/rain events across subtropical Asia. Unprecedented interactions between deep westerly trough and cross-equatorial Indian Ocean south-westerlies as well as Pacific easterlies results in evolution of large and intense monsoon trough extending from Philippine through Indus basin. Arabian sea and Bay of Bengal provides the excessive moisture and numerous synoptic scales, mesoscale and microscale weather systems are evolved and interconnected in the anomalous monsoon trough along with topographical features results in increase in the severity of the events. Formation and intensification of troughs in the temperate westerlies is a short period phenomenon. Therefore, condensation and intense rainfall in subtropical mountainous terrain that involving confluence and convergence of huge airmasses of contrasting characteristics are short lived

Various studies have documented the precipitation characteristics in the Himalayan region during rainstorm periods, while the detailed understanding of the evolution and intensification of the rain-producing weather systems at the boundary of the tropical (barotropic) and extratropical (baroclinic) regime is missing. It has been observed that the circulation dynamics of monsoonal and non-monsoon weather systems are completely different from each other. Within monsoon season itself, early monsoon phase rainstorm dynamics are different than that during the established phase and withdrawal phase. So, it is a very challenging task to comprehend the common atmospheric pattern for all Himalayan extremes and reach any generalized conclusion. We, therefore, propose to study each type of extreme rain event that has occurred in different seasons of the year over NW Himalaya as a separate case study. In this study, we propose a detailed systematic analysis of various heavy rainstorm events over northwest Himalaya during winter, pre-monsoon, monsoon and post-monsoon seasons of a year on case by case basis by using the available station (hourly) and gridded (daily) rainfall observations and reanalysis atmospheric parameters (temperature, pressure, geopotential height, precipitable water, wind, absolute vorticity, cloud cover, vertical velocity, freezing level, OLR etc.)

Dataset used:

- Rainfall Data: Gridded rainfall products from IMD; hourly rainfall data of selected stations across NW Himalaya
- NCEP-CFSR dataset (2.5 degree): Temperature, geopotential height and wind at 12 isobaric levels, PPW, MSLP, OLR, Freezing level, lapse rate
- ERA-5 Reanalysis (0.25 deg): Divergence at all levels, Vertical Velocity, Vorticity, CAPE, Low, medium, high and total cloud cover, moisture convergence,

Deliverables

Our results are expected to provide in-depth information about the nature and types of EREs and location, shape, size, and intensity of the various rain-producing weather systems that are formed over the northwest Himalaya during different seasons of a year. The study also provides more information about the large-scale circulation dynamics, tropical-extratropical interaction mechanisms at different levels of the atmosphere, thermodynamical processes and the role of orography in the evolution and genesis of heavy rainstorms over Northern Himalaya. The results are helpful for the assessment and prediction of the rainstorms over northwest Himalaya well in advance.

Cost estimates

S. No.	Head	Amount
2	Travelling Expenditure	2,00,000
3	Consumables/contingency/Misc. expenditure	1,00,000
4	Capacity building/Technology transfer	3,00,000
5	Dataset purchase/software/hardware	4,00,000
	Total	10,00,000

a. Justification for traveling expenditure

Investigators may required to travel to collect station rainfall dataset and other meteorological dataset across study region. Fund will also be utilizing for presentation of project work in different conferences across India.

b. Justification for contingency

Funds will be required in order to purchase external hard drives in order to store the dataset collected and generated maps through project work. Some funds will also be used for the purchase of necessary furniture, stationary items, reference books, and preparation of research reports and training material.

c. Justification for Capacity building/Technology transfer

The results and knowledge gained from the project will be disseminated/exchanged with stakeholders and government officials and research students by organizing trainings/Workshops (2 nos) in the field of hydrometeorology and weather analysis.

d. Justification for Dataset purchase/software

It will be required to purchase hourly rainfall data and metrological parameters over selected stations across India in order to study extreme rain events in details. Funds will also be used to purchase necessary statistical and graphical analysis software as per requirement.

Work Schedule:

S.N.	Work Element	1st Year				2nd Year				3rd Year			
1	Identification of heavy rainstorms/snowstorms and associated weather systems	■	■	■	■								
2	Study of relationship of Global atmospheric thermal changes with monsoon circulation and EREs					■	■	■	■	■	■	■	■
3	Study of thermo-dynamical and hydro-dynamical processes for the weather systems occurrences					■	■	■	■	■	■	■	■
4	Report preparation											■	■

NEW STUDIES (INTERNAL)

9. PROJECT REFERENCE CODE: NIH/SWD/NIH/22-23

1. Title of the Study

Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics

2. Study Team

Dr. Archana Sarkar, Sc E, SWHD (PI)
Dr Jyoti Patil, Sc D, NIH New Delhi office (Co-PI)

Mr. Rohit Sambare, Sc B, RMOD (Co-I)

Mrs Charu Pandey, A.L.I.O., Library (Co-I)

3. Type of Study

Internal

4. Date of Start

1 May 2022

5. Scheduled date of completion

31 Oct 2023

6. Nature of Study

Scientific Analysis

7. Study Objectives:

- To study and analyze the growth and direction of research in the field of climate change impacts on hydrology and water resources in India during 1992-2021
- Identification of gap areas and emerging areas in the research on climate change impact on hydrology and water resources to address the water security issues in India
- Evaluation of research productivity of institutions engaged in research on climate change impact on hydrology and water resources in India through scientometrics
- Dissemination of study findings through workshop/training course, scientific documentation and other outreach means.

8. Background

Scientometrics is considered a powerful tool of tracing the development of a given scientific field, thereby revealing the gap areas and emerging research problems, and evaluation of scientific contributions and research productivity of research community, institutions, regions, countries, etc. As technological advancements occur, there is a paradigm shift in the working trends in any field. So it is recommended to look for emerging trends and propose new developments when the current trends of any research domain are studied. Bibilometric analysis and scientometric mapping can show the change in mindset of researchers by studying the research works over a time period. Also by identifying the research questions in the water sector today, one can have insight into the future of research in the field. As Boyack et al. (2005) stated that a correctly constructed science map help to understand the inputs, associations, flows and output of science and technology: “Just like in physical world, maps help us to understand our environment- where we are, what is around us and the relationships between neighbouring things”. In recent years, scientometrics has come to play a major role in the measurement and evaluation of research performance.

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to water resources throughout the world. As per the latest report of IPCC (AR6) released in August 2021, it is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost.

The effect of climate change on hydrology in tropical Asia has many facets. The Himalayas, which act as a mountain barrier on the earth, where polar, tropical and Mediterranean influences interact, play an important role in maintaining and controlling the monsoon system over the Asian continent. In the Himalayas, the storage of precipitation in the form of snow and ice (in glaciers) over a long period provides a large water reservoir that regulates annual water distribution. As a populous, tropical developing country, India faces a bigger challenge in coping with the consequences of Climate Change than most other countries. It is now clear that enhanced climate variability and climate change due to continued emission of greenhouse gases in the Earth’s atmosphere will alter the key characteristics of summer monsoon rainfall and could significantly impact water supply and demand throughout the Indian subcontinent. Continued global warming is projected to further intensify the global water cycle, including its variability, and the severity of wet and dry events. Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes. There is a strong need to reconnect climate science and policy development with the local context to generate relevant knowledge supporting future climate change adaptation and disaster risk reduction strategies on a local to national to international level. The ability to undertake policy action requires information, knowledge, tools, and skills.

9. Statement of the problem

Many researchers/academicians/policy makers in India have studied and published various aspects of climate change impact on hydrology vis-à-vis water resources and policy implications. However, such studies have been carried out in isolation focusing on specific region/river basin and specific aspect of climate change impact (floods/droughts/water availability/etc). As such, a scientometric analysis of research on climate change impact on hydrology and water resources by Indian scientists has not yet been carried out. The proposed study is expected to highlight the gap areas, emerging trends, and potential opportunities in taking forward the research on climate change impact on hydrology and water resources, which is gaining momentum in view of the looming water scarcity. The study will provide an insight into the dynamics of research on climate change impact on hydrology and water resources and also provide a roadmap to the policy planners in India to address the Sustainable Development Goals (SDG).

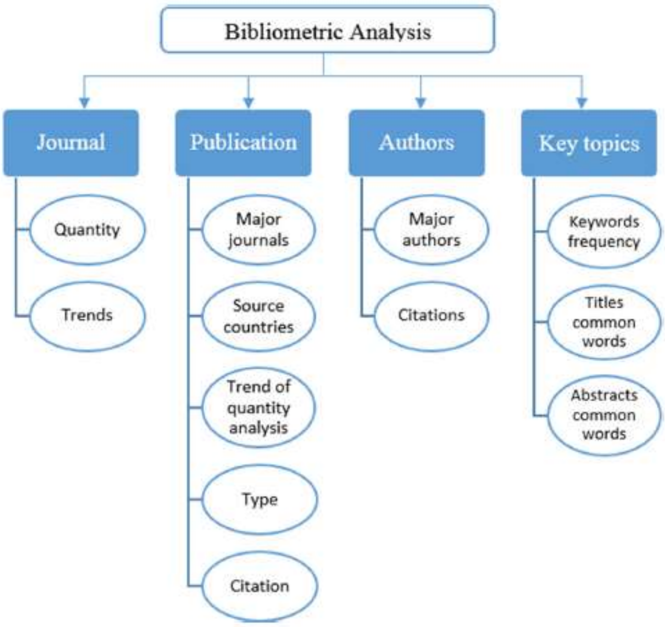
10. End users/beneficiaries of the study

Research Organisations, Academic Institutes, Central and State Government Agencies, Policy Makers, NGOs.

11. Methodology

1) Target population and sample size to be covered
   Research publications by Indian authors in hydrology journals covered under Scopus, 'Indian Citation Index', 'Indian Science Abstracts' and IWA's 'Water Intelligence Online' will be scouted for this study. Estimated sample size for the proposed 30-year period is 8,000-10,000 records.
2) Method of data collection
   The data element to be downloaded for the study include author(s), affiliation of authors, title of the paper, year of publication, source title (Journal title), citations received, keywords, publisher, language, and document type like research article, review, conference paper, editorial, meeting abstract, book review, letter and notes. Of these, only research articles, reviews, letters and notes will be subjected to detailed analysis.
3) Sources of the data
   The publication data on hydrologic climate change research by Indian researchers for the last 30 years (1992 to 2021) will be downloaded from 'Scopus' database of the Elsevier. Scopus's ability to manage bibliographic references and quantify citations makes it an essential instrument for analysis of any discipline. For expanded coverage of publications in Indian journals, efforts will also be made to explore availability of relevant publications in the 'Indian Citation Index', 'Indian Science Abstracts' and IWA's 'Water Intelligence Online'.
4) Reference period of the data to be covered
   The publication data on hydrologic research by Indian researchers for the last 30 years (1992 to 2021), which covers a significant period of the evolution of hydrologic research in India, is proposed to be used in the study.
5) Method of processing and analysing
   The publication data on climate change impact on hydrology and water resources by Indian researchers for the last 30 years (1992 to 2021) will be downloaded from 'Scopus' database of the Elsevier. Advanced search strategy available in Scopus database will be used to download the data. By using analytical functions available in the Scopus database, publications data will be further refined to get data distributed by subject, collaborating institutions, journal-wise, author-wise, organization-wise, State-wise etc. Complete counting method will be used wherein every contributing author or organization covered in multiple authorship papers will be fully counted. In order to address the issue of consistency of records, a standardization procedure will be applied. As an example, for the case of authors' names, the standardization criterion will address the coincidence in the affiliation of the institutional signatures associated with the different variants of names and surnames.

   After applying appropriate quality control procedures, the downloaded data from databases will be enriched through text enrichment techniques, which help to obtain better clustering that



represent the fields in the relevant topic. The downloaded articles considered irrelevant for the study shall be deleted from the database. Relevant data mining techniques, such as decision-tree and apriori algorithm, shall be used to analyze the data. There is a wide range of useful bibliometric methods to analyze the bibliographic data. The main bibliometric indicators proposed to be used in the study are described below:

- Total Number of Publications (TNP);
- Total Number of Citations (TNC);
- Citations Per Paper (CPP);
- Relative Citation Impact (RCI)

12. Action plan and timeline

S. No.	Work Element	First Year				Second Year	
		Q1	Q2	Q3	Q4	Q1	Q2
1	Identification of computational tools						
2	Identification of search strings relevant to research on climate change impact on hydrology and water resources in India						
3	Data collection from various sources						
4	Bibliometric analysis using bibliographic databases						
5	Manual analysis by searching and analyzing data from websites						
6	Scientometric mapping						
7	Interpretation of bibliometric analysis						
8	Preparation of research publications, outreach material, and synthesis report						

13. Data requirements

The publication data on hydrologic climate change research by Indian researchers for the last 30 years (1992 to 2021) from'Scopus' database and other relevant sources

14. Deliverables

Research papers, synthesis report, policy brief

15. Cost Estimate

I. Total cost of the project: Rs. 18,04,000/-

II. Source of funding: Internal funding from NIH

III. Sub Head wise abstract of the cost

S. No.	Head	Amount
1	Salary (Sr. Proj. Officer @Rs 28,000 p.m.)	5,04,000
2	Travelling Expenditure	3,00,000
3	Consumables	4,00,000
4	Technology transfer	2,00,000
5	Contingency and other costs	4,00,000
	Total	18,04,000

e. Salary

Full time one personnel (**Sr Project Officer**) for the project will be required for assistance in the data processing and technical analysis. A qualified person will be recruited as per the guidelines of Ministry of Water Resources on temporary basis (Sr. Proj. Officer @Rs 28,000 p.m. (01))

f. Justification for traveling expenditure

Investigators may require to travel to collect data, carry out academic discussions, interviews and a part of analytical work and reporting. Funds will also be utilized for presentation of project work in different conferences across India.

g. Justification for contingency

Funds will be required for: Stationary, printer cartridge, pen drives, books and journals, procurement of computation tools, preparation of research reports and training material etc.

h. Justification for /Technology transfer

The results and knowledge gained from the project will be disseminated/exchanged with stakeholders, government officials, researchers and policy makers by organizing trainings/Workshops.

i. Justification for Contingency and other costs

Funds will be required for: Fee for access of databases; thematic training of manpower; documentation and printing; payment of honorarium to experts; other contingent expenses

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sanjay K Jain	Scientist G & Head
2	Mrs. Deepa Chalisgaonkar	Scientist G
3	Dr. Manohar Arora	Scientist E
4	Dr. P K Singh	Scientist D
5	Dr. Manish Nema	Scientist D
6	Dr. P K Mishra	Scientist D
7	Dr. Vishal Singh	Scientist C
8	Sri P K Agarwal	Scientist B
9	Sri Yatveer Singh	Scientist B

APPROVED WORK PROGRAMME FOR THE YEAR 2021-2022

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
	Completed Sponsored/ Internal 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 (12/18-12/20)	NIH
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Singh; A. K. Lohani	2 years (12/18-12/20)	NIH
	Ongoing Sponsored/ Internal Studies			
1.	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; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra	5 years (01/16-03/21) (Likely to be extended till Sept., 2021)	DST (52.15)
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V. S. Jeyakanthan; L. N. Thakural;	5 years (01/16-03/21) (Likely to be extended till Sept., 2021)	DST (48.83)
3.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS)	5 years (01/16-03/21) (Likely to be extended till Sept., 2021)	DST (36.79)
4.	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 (Retd.) P. K. Mishra; M. Arora; AP Dimri (JNU)	5 years (01/16-03/21) (Likely to be extended till Sept., 2021)	DST 80.4 (NIH) + 73.2 (JNU)
5.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	M K Nema; Sharad K. Jain (Retd.); Renoj J.Thayyen; Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal AP Dimri (JNU)	5 years (01/16-03/21) (Likely to be extended till Sept., 2021)	DST (54.07)
6.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra; M. K. Nema; Renoj J. Thayyen; Pradeep Kumar	5 years (01/16-03/21) (Likely to be extended till Sept., 2021)	DST (90.99)
7.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore; (Now L. N. Thakural is PI); Sanjay Kumar; B. Venkatesh M. K. Jose; T.	3 years 2017-2020 (Recommended for extension up to June,	PDS under NHP (50.23 Lakh)

		Chandramohan	2021)	
8.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P. K. Singh; M. Arora ~~Renoj J. Thayyen;~~ A. K. Lohani; Vishal Singh;	3 years (11/19-11/22)	NMHS-MoEF (143 Lakh)
9.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	~~Renoj J. Thayyen~~ A. P. Dimri (JNU) Sanjay K. Jain Vishal Singh	3 years (06/19-11/22)	NRDMS-DST (23.19 Lakh)
10.	Permafrost mapping and characterization of Ladakh Region	~~Renoj J. Thayyen;~~ A. P. Dimri (JNU) will lead now; G. Jeelani (KU); V. Agnihotri (GBPNI)	3 years (11/19-11/22)	NMHS-MoEF (197.48 Lakh)
11.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh; P K Mishra; P K Agarwal	2 years (08/20-07/22)	NHP (14.50 Lakh)
12.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora P K Mishra Vishal Singh	3 years (04/18-03/21) (Extended for 12 months)	NIH
13.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	Vishal Singh; Sanjay K. Jain; Manohar Arora	2 years (08/20-07/22)	NIH (9.30 Lakh)
14.	Henval Experimental Watershed: Observations and modelling (Phase II)	M K Nema; Sanjay K Jain; ~~Renoj J. Thayyen;~~ P K Mishra; P K Agarwal	3 years (08/20-07/23)	NIH (10.22 Lakh)
15.	Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package	D. Chalisgaonkar M. K. Goel	1 year (08/20-07/21)	NIH
New Internal/ Sponsored Studies				
1.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh; P K Agarwal	2 years (04/21-03/23)	NHP (9.00 Lakh)
2.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	3 years (04/21-03/24)	NHP (25.00 Lakh)
3.	Monitoring of Hydrological Processes in Glaciated and Non Glaciated Watersheds of North-West Himalaya	M K Nema; Sanjay K Jain; Manohar Arora; Vishal Singh; Praveen Thakur (IIRS)	3 years (04/21-03/24)	IIRS (Total 701.37 Lakh)

PROPOSED WORK PROGRAMME FOR THE YEAR 2022-2023

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
Completed Sponsored/ Internal Studies				
1.	Upgradation of NIH_ReSyP to .NET Platform – a Reservoir Operation Package	D. Chalisgaonkar; M K Goel	1 year (08/20-03/22)	NIH
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V S Jeyakanthan; L. N. Thakural	5 years (01/16-03/21)	DST (48.83)
3.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain; A K Lohani; Sudhir Kumar; Praveen Thakur (IIRS)	5 years (01/16-09/21)	DST (36.79)
4.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	M. Arora; Sanjay K. Jain; Sharad K. Jain (Retd.) P K Mishra; AP Dimri (JNU)	5 years (01/16-09/21)	DST 80.4 (NIH) + 73.2 (JNU)
5.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	M K Nema; Sharad K. Jain (Retd.); Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal AP Dimri (JNU)	5 years	DST (54.07)
6.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra; M. K. Nema; Pradeep Kumar	(01/16-09/21)	DST (90.99)
Ongoing Sponsored/ Internal Studies				
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P K Singh; M. Arora A K Lohani; Vishal Singh	3 years (11/19-11/22)	NMHS-MoEF (143)
2.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Vishal Singh; Sanjay K. Jain; A P Dimri (JNU)	3 years (06/19-11/22)	NRDMS-DST (23.19)
3.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh; P K Mishra; Sanjay K Jain P K Agarwal	2 years (08/20-07/22)	NHP (14.50)
4.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh; Vishal Singh P K Agarwal	2 years (04/21-03/23)	NHP (9.00)
5.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	3 years (04/21-03/24)	NHP (25.00)
6.	Impacts of glacier and climate change on runoff for selected basins of Himalayan	Vishal Singh; Sanjay K. Jain;	2 years (08/20-07/22)	NIH (9.30)

	region	Manohar Arora		
7.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M K Nema; P K Mishra; P K Agarwal	3 years (08/20-07/23)	NIH (10.22)
8.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora; P K Mishra; Vishal Singh	3 years (04/21-03/23)	NIH
New Internal/ Sponsored Studies				
1.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M K Nema; P K Mishra	2 years (04/22-03/24)	NIH
2.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	Sanjay K Jain; M K Nema; P K. Mishra; Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS (30.91)
3.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	P K Singh; Vishal Singh; Sanjay K Jain;	3 years (04/22-03/25)	WRD, Karnataka (54.0)

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-22/01

1. **Thrust Area under XII five Year Plan**: Integrated water resources Management (Integrated operation of reservoirs)

2. **Project Team:**
   Mrs. D. Chalisgaonkar, Scientist 'G'
   Dr. M. K. Goel, Scientist 'G'

3. **Title of the Project:** Upgradation of NIH_ReSyP – A Reservoir Systems Package

4. **Objectives:**
   a. Upgradation of NIH_ReSyP to .Net Platform
   b. To carry out a number of modifications in various modules

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

In view of the importance of reservoir operation problem in Indian context and the non-availability of a generalized software for reservoir analysis, the National Institute of Hydrology (NIH), Roorkee had developed a generalized software named *"SRA – Software for Reservoir Analysis"* for reservoir analysis [Jain et. al (1996)] for carrying out various kind of reservoir analysis such as capacity computation, storage yield analysis, hydropower simulation, reservoir routing, EAC interpolation, inflow estimation using rate of rise method, initial rule curve derivation, and operation of a system of multiple reservoirs for conservation purposes. Subsequently, a WINDOWS based software named "NIH_ReSyP – Reservoir Systems Package" was developed [Goel and Chalisgaonkar (2011)]. The software was developed in Visual BASIC platform (VB6) and provided a user-friendly environment for carrying out various hydrological analyses related to reservoirs.

However, for some years there has been a threat hanging over legacy VB6 applications because the next version of Windows may not support VB6 and the applications are being developed on VB.NET platform which offers more features for application development and user-friendliness. Further, during the last decade, various technology transfer activities on the software have been organized and a number of suggestions have been made by field engineers.

6. **Methodology**

It is planned to upgrade the NIH_ReSyP software on the VB.NET form. Further it is planned to modify various modules as per the suggestions of field engineers. Some such modifications include:

a) To reduce the input variables for easy preparation of data minimizing the data entry errors.
b) Fixation of the units of different variables so as to avoid confusion and have a uniform input structure.
c) Improvement of menu structure
d) Modification of various programs for more detailed analysis

7. **Research Outcome from the project:**

Development of a user-friendly software for integrated operation of reservoir systems in accordance with the Indian practices. Since the help files for different modules are provided along with the software, no separate report will be prepared and the output will be only in the form of software.

8. **Cost estimates:**
No additional cost is envisaged.

9. **Work Schedule:**
   a. Date of commencement of the project: 01.08.2020
   b. Duration of the project: 1 year

10. Progress till date

Significant efforts have been made for the finalization of the revised version of NIH_ReSyP – 2022. All the 20 modules and their forms in .NET framework have been developed. Based on the inputs from the users, substantial improvements in the previous modeling system have been made, some of which include:

- Inputs reduced significantly. Fixed metric system being followed.
- Results up to accuracy of one cubic meter.
- Easier forms have been developed in .Net platform.
- Outputs also gives a detailed description of input.
- More time steps introduced for analysis, say daily or 10-daily.
- In rule curve derivation, desirable carryover storage added.
- Reservoir sedimentation is computed in a single step now.
- New modules added:
  - Storage-Yield-Reliability relationship
  - Instant estimation of reservoir inflow using rate of rise
  - Modules added to help operator in finding actual release to be made depending on the prevalent policy.
  - Instant estimation of release for flood control
  - Spillway discharge rating table
  - Instant spillway discharge estimation
- Significant modifications in Conservation Operation module:
  - Daily time step introduced. Now 100 reservoirs can be simulated for 50 years at daily time step.
  - Possible to revised demands in different years. Earlier, fixed demand pattern was possible
  - Tail-water rating curve introduced. Earlier, only fixed outlet level could be specified.
  - Reservoir sedimentation in real-time can be considered.
  - Rule curves for daily/10-daily time step are interpolated.
  - Total water balance is also computed annually for all projects in the system.
  - Total water balance in the whole system is computed.

Help files of most modules have been completed and these modules have been finalized. A few modules of the software will be demonstrated in the WG meet.

COMPLETED STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2016-21/01
NMSHE STUDIES

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

2. Project team

a) Project Investigator:	Deepa Chalisganokar D SRathore (retd.) PI
b) Project Co- investigators:	V. S. Jeyakanthan, Scientist 'E' L. N. Thakural, Scientist 'D'
c) Project Staff (JRF)	Ashish Bhandari, JRF Atul Bhardwaj, 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

6. 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.

7. Location map/ study area

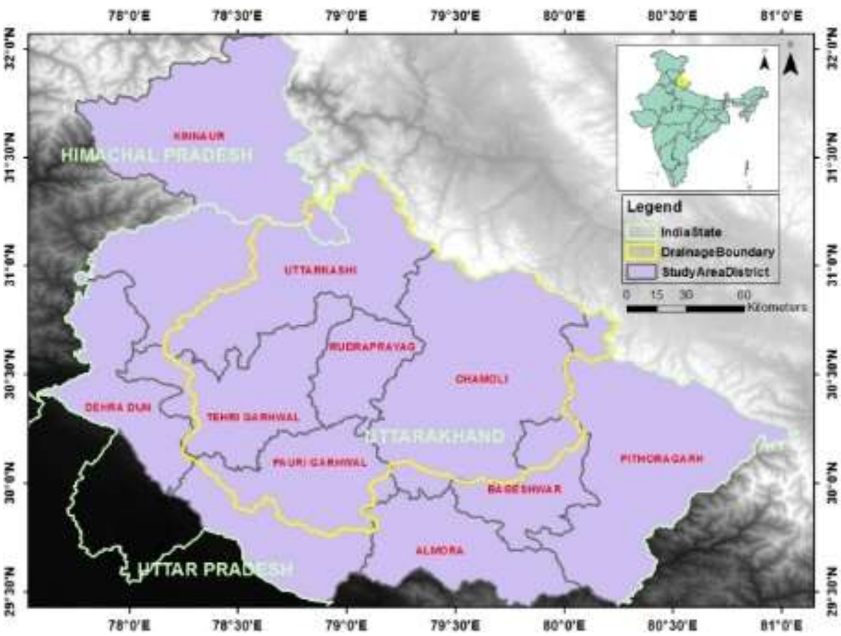


Figure 1: Upper Ganga basin

8. 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		↔		↔		↔		↔		↔

9. Recommendations/ suggestions in previous WG

Snow area should be displayed in the web application.

10. Achievements

Year	Objectives	Achievements
2020-21	Snow extent methodology	Post-processing of MODIS snow cover and computation of 8-day composite from MOD10A1 NDSI data was implemented in R and snow cover data were processed for Upper Ganga basin. Trend in seasonal maximum snow extent were not significant. Trend of seasonal average maximum snow extent was negative for autumn, early winter and spring and positive for summer in most altitudes. Autumn 2016 had large negative anomaly in the maximum snow extent. For snow survey, a Mt. Rose or Federal type snow sampler was fabricated. The survey was done at elevations between 1900 and 3200 m in Deorial Tal, Chopta, Tungnath and Dhanaulti/ Lal Tibba during January and February 2020. Snow water equivalent varied from one to 18 cm and increased with elevation. Observed densities for fresh and old snow were 0.07- 0.09 and 0.13- 0.29 respectively. A rule based classification is being developed utilizing NDSI, NDVI, B1, B2 and B4 of Landsat data for classification of snow, snow with vegetation, snow in shadows and discriminating snow from water and cloud.
2020-21	Web GIS application	More snow extent maps were added along with snow area table in the web application.

Final report has been prepared and submitted.

COMPLETED STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2016-21/02
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'
2. Dr. A. K. Lohani, Scientist 'G'
3. Dr. Sudhir Kumar, Scientist 'G'
4. Dr. P. Thakur, Scientist 'E', IIRS, Dehradun

Project Staff (JRF) Mr. Manish Rawat, 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 outburst.
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. 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 outburst 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.

7. Present progress

This project includes four study basins: Sutlej, Beas, Chenab and Ganga. Landsat imagery has been used for delineate the glacier boundary for the basin and Glacier maps have been prepared. The inventory of glacial lakes in the basins i.e. Satluj, Beas, Upper Ganga and Chenab have been prepared. The lakes have been categorised into Glacial-erosion, Moraine-Dammed and Ice-dammed lakes. These lakes were further classified on the basis of number frequency of lakes of different areas and different elevation. The Glacier lake inventory map and different bar chart figures of lakes type have been prepared. The vulnerable lakes in the basins have been identified. Vulnerable lakes in the basins have been identified on the basis of area change, location and other conditions.

The Geodatabase for hydrodynamic modelling for these lakes have been prepared. The geodatabase contain all the information related to river cross-sectional, bank stations, elevation, flow paths and lake information. Application of HEC-RAS 1D unsteady flow hydrodynamic model has been used for GLOF Simulation. Evaluation of the GLOF impacts has been analysed by flow depth, flow velocity, peak discharge and water surface elevation for all the affected locations The simulation of GLOF for all the four basin have been carried. The example of Chenab basins is given in Figures 1,2 and 3.

Objectives vs achievements

Sr.no	**Activity**	**Status**
1	Data base with regard to glaciers and glacial lakes in basins located in Western Himalayan region. Acquisition of Landsat data covering the study basin for the years 1990, 2000, 2008 and 2014 Preparation of glaciers and glacier lake inventory	Completed
2	Identification of potentially dangerous lake for GLOF simulation	Completed
3	Creation of Geodatabase for GLOF simulation Preparation of cross section, bank stations, flow paths along the river Preparation of lake information	Completed
4	GLOF modeling using the hydro-dynamic mathematical modeling Preparation of breach hydrograph for GLOF scenario based on the different parameter like breach width and breach formation time Application of HEC-RAS 1D unsteady flow hydrodynamic model for GLOF simulation	Completed
5	Evaluation of the GLOF impacts has been analysed by flow depth, flow velocity, peak discharge and water surface elevation for all the affected locations.	Completed
6	Preparation of Inundation maps for GLOF	Completed

Final Report has been prepared and submitted.

COMPLETED STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2016-21/03
NMSHE STUDIES

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

2. **Project Team:**
    1. Dr. M. Arora, Scientist 'E'
    2. Dr. Sanjay K. Jain, Scientist 'G'
    3. Dr. Sharad K. Jain, Retd.
    4. Dr. P. K. Mishra, Scientist 'D'
    5. Collaborator: Dr. A. P. Dimri, 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. Methodology

A) Discharge data of Maneri will be collected from the state agencies and interannual 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 is installed at Jhala near Harsil. Data from this weather station will be used for refining the runoff model.

C) 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. Historical and future climate scenarios will be bias corrected and tested.

D) Runoff modelling: Runoff modelling will be carried out by SPHY model as well with a temperature index model using snow cover depletion information. Using the SHPY model snow, glacier, rainfall and base flow components will be assessed. Using Climate downscaling and future predictions future runoff scenario will be generated.

6. Research Outcome from the project:

Understanding of the downstream impact of Gangotri glacier system with glacier, snow & rainfall component and its probable future variability.

7. 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

8. Progress of the project

During the reporting period focus of the project was on runoff modelling at Maneri using the bias corrected temperature and precipitation data received from JNU collaborator. Initial simulation done for the period of 30 years (1990-2020) using SPHY hydrological model has been improved.

Completed work:

1. Estimated snow cover change in the basin since 2001-2018 by developing a new cloud removal algorithm. Reducing snow cover in the lower elevations and slightly increasing snow cover during July/ August months at higher elevations were observed.
2. Runoff modelling by SPHY using CWC/ IMD ground data are carried out for 1980- 2018. Further, modelling is carried out for 1980-2100 using bias corrected REMO, Bias corrected RegCM.4.5, Various runoff/ water balance components such as rainfall, snow melt, glacier melt, base flow and evaporation are estimated. It is observed that high spatial variability of input variables in the complex mountain terrain is forcing significant uncertainty in the model output especially in the sub- basin scale.

3. Identification and characterization of Topoclimatic zone of Upper Ganga basin

4. Progress during the reporting period: Implemented the runoff model (SPHY) till Rishikesh and tried to achieve multi station calibration from basin outlet to glacier catchment. Runoff time series developed for 15 sub-catchments to assess the glacier catchment critical for runoff stability. Additionally, the catastrophic debris flow disaster event in the Rishiganga/ Dhauliganga river on 7th February is studied and role of recent warming of the area and related weather changes in the event is being established.

Objectives	Status
1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri	Completed
2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri	Completed
3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling.	Completed
4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change.	Completed

COMPLETED STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2016-21/04
NMSHE STUDIES

1. Thrust Area: Himalayan Hydrology

2. Project Team

Project Investigator	**:**	Dr. M. K. Nema, Scientist 'D'
Co-Project Investigator	**:**	Dr. Sharad K. Jain, Retd.
Project Co-Investigators	**:**	
	:	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. Surjeet Singh, Scientist 'F'
	:	Dr. P. K. Singh, Scientist 'D'
	:	Dr. P. K. Mishra, Scientist 'D'
	:	Mr. P. K. Agarwal, Scientist 'B'
	:	Dr. A. P. Dimri, Professor, JNU
	:	Dr. (Mrs.) Sangeeta Verma, RA

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. 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.

6. **Research Outcome from the Project:** Enhanced understanding of the Lesser Himalayan hydrology-atmospheric interactions and climate change forcing aiding water resources management.

7. **Cost Estimate: 134.32 lakhs**

Total cost of the project	:	Rs. 134.32 lakhs
Source of funding	:	NMSHE-DST

8. **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									↔	↔

9. **Progress of Work:**

During the period roughness length for momentum (Z_{0m}) is estimated using wind speeds for a valley bottom and a mountain ridge site in a lesser Himalayan experimental catchment. Results indicated that Z_{0m} is comparatively higher at the valley bottom site (Nagini) in the range of (0.010 – 0.497) than the values observed (0 - 0.069) for the ridge site (Kumargaon). Seasonal variations are observed at both the stations indicating its higher value for high LAI in the leaf-on season and lower values for low LAI in the leaf-off season. At valley bottom site, the seasonal increase is higher during kharif cropping as compared to the rabi cropping whereas, at Kumargaon, this increase is visible only in the rainy season due to natural vegetation growth. The changing height of vegetation and consequently LAI in different seasons is the most important factor for seasonal variations in Z_{0m}. On diurnal basis, Z_{0m}varies differently in different season due to changing wind speed and direction. Heterogeneity of the terrain causing fluctuations in Z_{0m} is more evident at Kumargaon. Atmospheric stratification and instability is another factor responsible for diurnal variation of Z_{0m}.

Final report has been prepared and submitted.

COMPLETED STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2016-21/05
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 'D'
2. Dr. M. K. Nema, Scientist 'D'
3. Dr. Pradeep Kumar, Scientist 'D'
4. Swagatam Das, JRF; Hemant Singh (JRF); Sanjay Kumar (PA); Pankaj Kumar (PA); 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

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. 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, etc. 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: (i) Consider all water resources; (ii) Address water demand as well as water supply; (iii) Address wastewater management as well as water supply; (iv) Involve all sectors and civil society stakeholders; (v) Promote access and gender equality: (vi) Recognize the economic (livelihood), social, and environmental value of water; (vii) Recognize the water related threat and hazards for preventive measures (adaptation and mitigation strategies)

7. Methodology
The project is executed as per the following roadmap:

Sampling

The upper Ganga is divided into two major zones comprising of Alaknanda basin and Bhagirathi basin. Each of this major zones are sub-divided into five sub-zones based on the elevation (altitude), climate etc. At least 10 villages have been screened from each sub-zones through scientific assessment and field visit as well as with discussion with other stakeholders.

Water census has been carried out by developing an elaborative matrix to capture various WRM components. A structured questionnaire and field mapping is used to gather the information.

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 - Stage I survey - Attributes for water census
5. Mid-term Workshop
6. Diagnostics report
7. Stage II survey
8. Finalization of Hotspot analysis
9. Development of adaptive strategies
10. Concluding workshop
11. Report preparation and submission

Activity chart

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

Sr.no	Activity	Status
1	To map water use pattern and livelihood linkages. • 231 villages surveyed (5 districts) • 526 households (5 districts) • GIS layers (maps) generated	Completed
2	To map potential water hazard zones in the catchment. • Reported cloud bursts (57 nos.) identified since 2010 • Potential hazard zones due to CBs identified and mapped	Completed
3	To identify hotspot matrix components, hotspots analysis and adaptation strategies. • IPCC's Livelihood Vulnerability Index based critical blocks identification for Uttarkashi, Tehri Garhwal, Pauri Garhwal, Chamoli and Rudraprayag districts.	Completed
4	Report preparation	Completed

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-22/01

1. Title - Snow and glacier contribution and impact of climate change in Teesta basin in Eastern Himalaya

2. Study Team

NIH Roorkee:

Dr. Sanjay K Jain, Scientist 'G'
Dr. P K Singh, Scientist 'D'
Dr. Manohar Arora, Scientist 'E'
Dr. A K Lohani, Scientist 'G'
Dr. Vishal Singh, Scientist 'C'

JNU, New Delhi:

Dr. A P Dimri, Professor

CAU Sikkim:

Dr. S R Yadav, Assistant Professor (SWCE)

IITM Pune

Dr. (Mrs) Nayana Deshpande, Scientist D

3. Objectives

The proposed project will adopt an inter-disciplinary approach to address the following objectives, in particular for the Teesta basin within the eastern Himalayas:
The objectives of this study are:

- Assessment of recent changes in snow, glacier, rainfall and its impact on the hydrology of the Teesta basin through Hydrologic modelling.
- To understand the influence of glacier size, debris cover, topographic (i.e., altitude, aspect, and slope) and climatic variables on recent glacier changes?
- Sediment transfer characteristics of Teesta River at selected sites and identification of major drivers.
- Assessing climate change in the basin and future scenarios and resultant hydrological responses
- To understand and simulate the magnitude of the GLOF hazard of glacial lakes formed due to glacier recession using MIKE-II breach modeling.
- Identification of key change indicators for water resources of the region and their impact on local communities
- To develop a comprehensive and interactive web-enabled database repository of the hydro-met database and modelling spatial outputs with basic GIS functionalities.

4. Sponsored by NMHS, MOEF & CC
5. Project Cost Rs. 143 Lakhs

6. Methodology

In the present study, modelling of snow/glacier melt runoff, sediment sampling and modelling, climate change studies, impact of climate change and glacier lake outburst flood are proposed to achieve the objectives.

- Snow/glacier melt runoff modelling will be done using SNOWMOD and VIC models. Landuse/landcover, snow/glacier maps etc. will be prepared for the study basin using standard RS and GIS techniques. Hydro-meteorological data will be collected from different sources such as CWC, IMD, NHPC and state agencies.
- Sediment yield modelling and assessment will be done using Delivery Ratio and GIS coupled empirical models, SWAT model and conceptual SCS-CN based sediment yield models.

- Many methods have been developed for generating climate scenarios for the assessment of hydrologic impacts of climate change, which include downscaled general circulation model (GCM) simulations. Data and knowledge generated will be used to implement a sub-grid scale parameter scheme for Regional Climate Model using RegCM4 model with sub-grid parameterization and refined future projections for climatic variables.
- The satellite data along with field investigations will be used to assess glaciers and glacial lakes. MIKE 11 model will be used for GLOF simulations.
- A comprehensive web enabled database repository will be developed based on information from the field data collection and modelling results.

7. Time-Line and Activities

	Activities	1st Year		2nd Year		3rd year	
NIH	Hiring Manpower	■					
	Procurement of the instruments	■	■				
	Data collection and database preparation		■	■	■		
	Model data need and requirement by other PIs			■	■	■	
	Model simulations and sensitivity analysis			■	■	■	
	Study of impact of climate change			■	■	■	
	Sediment studies				■	■	
	GLOF studies			■	■	■	■
	Development of a comprehensive and interactive web-enabled database repository			■	■	■	■
	Workshops/Trainings				■	■	■
	Report writing					■	■
CAU	Hiring Manpower	■					
	Procurement &installation of Met. stations	■	■	■			
	Data collection and Data synthesis		■	■	■	■	
	Sediment studies			■	■	■	■
	Report writing						
JNU & IITM	Hiring of manpower	■					
	Climate modelling work		■	■	■	■	
	Report writing					■	■

8. Progress till-the-Date

Following two tasks have been completed:

1: SWAT model for streamflow simulation up to Teesta Lower Dam Stage-IV gauging site.

2: RUSLE model in GIS environment for assessing the soil erosion severity using the IMD, TRMM and CHIRPS datasets.

<u>Streamflow simulation using SWAT model</u>:
The Soil & Water Assessment Tool (SWAT) 2012 model is used to simulate the streamflow up to Teesta Lower Dam Stage-IV gauging site Teesta River basin for the period of 2004-2019. For single-site model calibration and validation at daily time steps, SWATCUP's Sequential Uncertainty Fitting 2 (SUFI-2) approach is used in this study. The calibration findings for daily simulation for the period

(2004–2016) revealed a very good model performance for flow rates, with an R^2 of 0.76, a PBIAS of 20.3, and a Nash–Sutcliffe efficiency (NSE) of 0.70. The validation findings for daily simulation for the period (2017–2019) revealed good model performance for flow rates, with R^2 values of 0.69, PBIAS of 23.3, and NSE of 0.64. In the calibration process a total of seventeen parameters were optimized. Snowfall temperature (SMTMP), Temperature lapse rate (TLAPS), melt factor for snow (SFTMP), and initial SCS curve number value (CN2) were found to be the most sensitive parameters in this work.

Soil erosion using RUSLE and Satellite precipitation datasets:

Quantitative assessment of soil erosion and its spatial variation is very important for designing effective erosion control measures for any basin. In this study, the popular erosion prediction model i.e., Revised Universal Soil Loss Equation (RUSLE) have been applied to the Teesta basin using two satellite datasets, i.e., CHIRPS and TRMM along with the latest IMDAA dataset for quantifying the average annual soil loss and its spatial variation. Thematic maps of land use land cover (LULC), soil map, slope map and other maps were developed to generate input maps of various parameters of RUSLE model for quantifying soil erosion and its spatial distribution for the period of 2000-2018. The erosion severity maps are also prepared along with the area under each class. The results show the area under extremely severe erosion class (>80 t/ha/year) due to CHIRPS, TRMM and IMD is found to be 38.17%, 41.81% and 39.52%, respectively. The results show that both the CHIRPS and TRMM datasets perform equally well across the Teesta basin and these satellite precipitation datasets can be effectively utilised for erosion modelling in the Teesta basin.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-22/02

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

   Dr. Vishal Singh, Scientist 'C'
   Dr. Sanjay K. Jain, Scientist 'G'
   Collaborator: Dr. A. P. Dimri, Professor, SES, JNU, New Delhi

3. **Title of the Project:** Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin

4. **Objectives:**

   a. Seasonal Snow loading and unloading estimation from GRACE and comparison with other RS products
   b. Seasonal mass fluctuation of glacier regime and regional mass balance assessment
   c. Seasonal soil moisture fluctuation in the basin with an emphasis to ISM (JJAS) and IWM (DJF)
   d. Inter-comparison between seasonal river runoff and basin scale mass anomaly from GRACE

5. **Methodology**

In the high mountain regions of the Himalaya, winter time water fluxes are minimum for stream discharge, Groundwater (base flow) and evaporation (low temperature). This condition ensures a high amplitude GRACE- TWS anomaly due to seasonal snowfall (Snow loading) which sustain and build up through winter months till March. Building on this opportunity, the assessment will focus on the time period from the start date (t_0) of snow accumulation to the breakup date (t_b) snowfall. The first snowfall precipitation event is determined by the daily snow cover assessment. Total basin water storage (TWS_o) at start date of accumulation at t_0 and TWS_b at breakup date of accumulation t_b will be estimated by the GRACE TWS data. From winter peak (March) to summer low (October) cryospheric mass changes will be resulted in marked depletion in TWS detected by GRACE over the glacier area specific region. The TWS change will be represented the integrated change of soil moisture, Snow water equivalent (SWE), and glacier mass change in the region. The remotely sensed data will be used such as MODIS snow cover product (SCA) (https://reverb.echo.nasa.gov/). These snow data (SCA and SWE) will be used to provide information regarding the distribution of snow in the basin. The runoff modelling will be carried out up to Rishikesh and various water balance components will be estimated which together force the change in GRACE-TWS on a monthly basis. The GRACE data will be downscaled for snow/glacier regions and snow/glacier water equivalent changes will be estimated the total monthly GRACE anomaly.

6. **Research Outcome from the project:** A) Development of expertise in GRACE –TWS data analysis and manpower development B) Regional assessment of snow water equivalent/ glacier change assessment through the monthly variation of TWS.

7. **Cost Estimate:**

Total cost of the project:	Rs. 23.19 lakhs
Source of funding:	NRDMS-DST

8. **Progress till date**

a.Snowmelt-glacier melt induced runoff modelling using SPHY model

8.1.1 Brief on SPHY model and its methodology

SPHY is a spatially distributed leaky bucket type of model, and is applied on a cell-by-cell basis. SPHY is written in the Python programming language using the PCRaster dynamic modeling framework. For glaciers, sub-grid variability is taken into account: a cell can be glacier free, partially glacierized, or completely covered by glaciers. The cell fraction not covered by glaciers consists of either land covered with snow or land that is free of snow. Land that is free of snow can consist of vegetation, bare soil, or open water. The dynamic vegetation module accounts for a time-varying fractional vegetation coverage, which affects processes such as interception, effective precipitation, and potential evapotranspiration. SPHY simulates for each cell precipitation in the form of rain or snow, depending on the temperature. The snow storage is updated with snow accumulation and/or snowmelt.

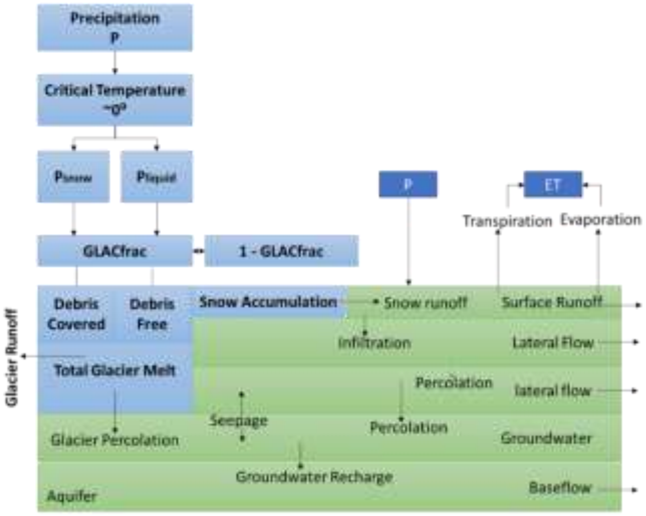


Figure 1: Water balance and snow-glacier runoff computation in SPHY model.

A part of the liquid precipitation is transformed in surface runoff, whereas the remainder infiltrates into the soil. Melting of glacier ice contributes to the river discharge by means of a slow and fast component, being (i) percolation to the groundwater layer that eventually becomes baseflow, and (ii) direct runoff. The cell-specific runoff, which becomes available for routing, is the sum of surface runoff, lateral flow, baseflow, snowmelt and glacier melt. Figure 1.2 represents an overview of the six modules available: glaciers, snow, groundwater, dynamic vegetation, simple routing, and lake/reservoir routing. All modules can run independently of each other, except for the glacier module. As input, SPHY requires static data as well as dynamic data. For the static data, the most relevant are digital elevation model (DEM), land use type, glacier cover, lakes/reservoirs and soil characteristics. The main dynamic data consist of climate data, such as precipitation, temperature, and reference evapotranspiration. Since SPHY is grid based, optimal use of remote sensing data and global data sources have been utilized. To undertake a proper calibration and validation procedure, observed flow data has been used at the outlet and other few locations in the upstream.

8.2 Works Done

1. Downloading and processing of hydro-meteorological datasets such as precipitation, temperature, discharge, soil moisture, evapotranspiration
2. Preparation of thematic datasets (e.g. DEM, LULC and SOIL maps) to setup the hydrological model for the assessment of snow-glacier induced melt runoff.
3. Preparation of decadal glacier change maps and their validation and comparison with RGI 06 glacier inventory (reference standard data)

4. Downloading of GRACE data i.e. Total water storage anomalies (TWSA) has been done for the year 2002-2020 at 25km^2 grid scale.

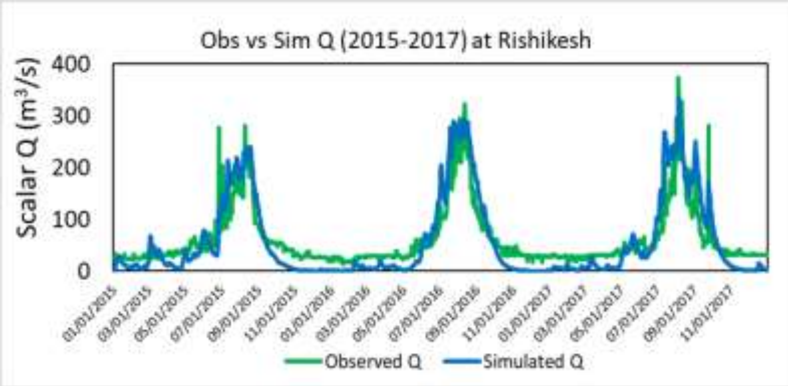


Figure 1: Comparison of observed vs simulate runoff at Rishikesh.

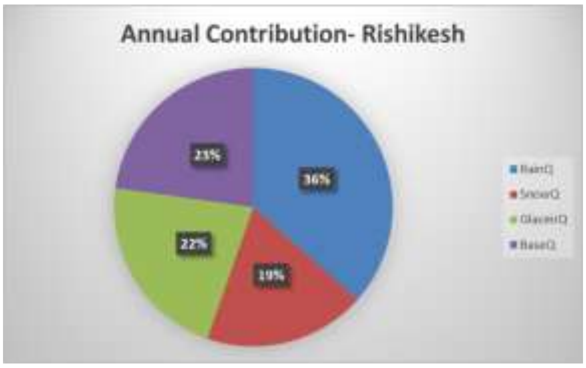


Figure 2. Annual contribution of runoff components at Rishikesh in the terms of percentage for base, rain, snow and glacier.

Table 1: GRACE Data Resolution.

Spatial Resolution	300 -400 km grids (~150,000km^2)
Gridded Resolution	0.5^{o}X0.5^o

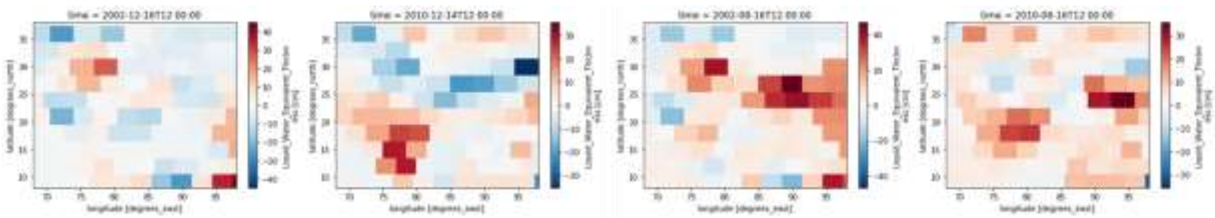


Figure 3: Showing variations in GRACE TWSA in different times.

8.3 Work in Progress

- Downscaling of Grace data and its validation with other relevant parameters to compute the snow water equivalent
- Modeling of snowmelt and glacier melt using GRACE
- Refinement of snowmelt and glacier melt runoff modelling using SPHY
- Processing of soil moisture and its utilization in snowmelt and glacier melt runoff modelling

ONGOING STUDIES

SPONSORED RESEARCH PROJECT: NIH/WRS/2020-22/3

1. Title: Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.

2. Project Team:

Dr P. K. Singh, Scientist 'D'
Dr P. K. Mishra, Scientist 'D'
Er P. K. Agarwal, Scientist 'B'

3. Project Duration: 02 Years (08/20 – 07/22)

4. Objectives

The major objective of this study is to apply newly developed WA+ framework for sub-basins of Brahmaputra and Barak basins in the state of Meghalaya.

a) To develop water accounts for the study basins/sub-basins.
b) To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
c) To develop accounts for agricultural services (i.e., land productivity and water productivity).
d) To prepare the detailed WA+ report for study basins/sub-basins.
e) To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

5. Present state-of-the-art

Water accounting (WA) can provide a coherent and consistent solution to the spatial & temporal assessment of WP and the allocation of water across various competing sectors to avert the looming water crisis. WA also considers the consumption of water and the benefits and services - including ecosystem services - that result from that consumption, including the return flow of non-consumed water. 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 WA frameworks. FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, however, it does not distinguish between consumptive use and non-consumptive use. The System of Environmental Economic Accounting for Water (SEEA-WATER) of the United Nations Statistics Division (UNSD) (UN, 2012) requires a variety of data from numerous sources, which are unlikely to be available at many times (Dimova et al., 2014; Perry, 2012). It does not distinguish between the green and blue water resources (Falkenmark and Rockstr¨om, 2006; Rockstr¨om and Gordon, 2001). The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) accounts for water withdrawals rather than consumptive use. However, AWAS 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 in India (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and at the 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 (WA+) Framework 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 understood by 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) (Figure 1) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certain area of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies land use land cover (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) (Figure 2). 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.

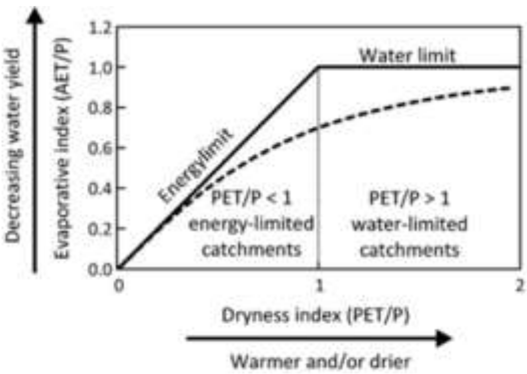


Figure 1: Budyko Framework **Figure 2: WA+ Based WMC**

6.1 Study Area and Major Input Data

The state of Meghalaya is the north eastern part of India and is bounded in the north and east by Assam plains and in the south and west by Bangladesh plains. In the north, it is bounded by Kamrup and Goalpara districts of Assam and on the east by Karbi Anglong and North Cachar. The southern border is the international border with Bangladesh which is about 496 km long. Meghalaya is located between 25º01’51.58” N to 26º07’10.31” N latitude and 89º49’10” E to 92º48’04” E longitude with altitude ranging from 50 to 1966 meters. The State covers geographical area 22,429 km^2. Figure 3 shows the basin map of the Meghalaya state.

The WA+ framework makes use of open source remote sensing data in an effort to maintain a high level of transparency. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study:

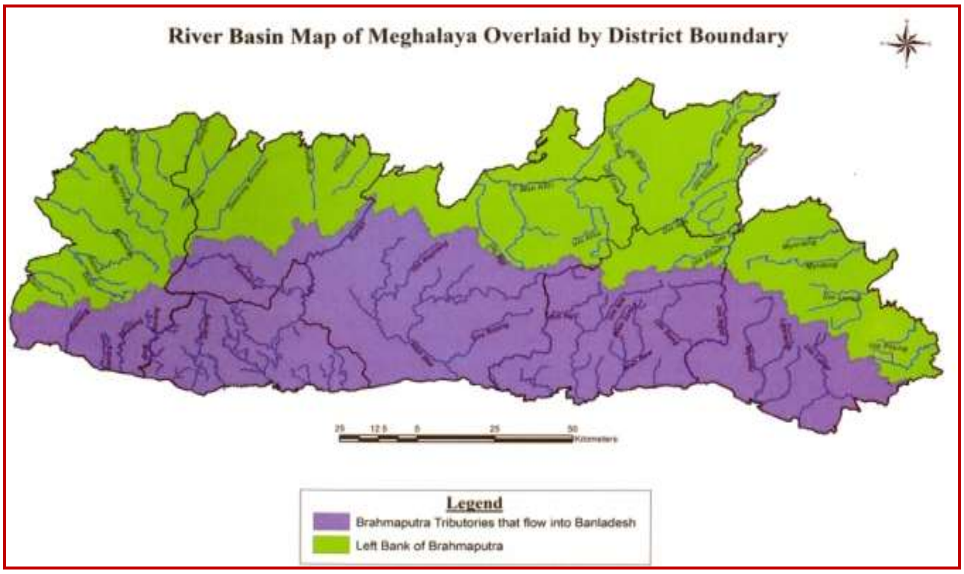


Figure 3: River basin map of Meghalaya overlaid by district boundary
(Source: WRD, Meghalaya)

- Precipitation (CHIRPS - or TRMM rainfall)
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- WA+ system based Land Use / Land Cover (WALU using GlobCover, IWMI crop maps, MODIS, FAO, etc.)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- Vegetation, leaf area index (MODIS)
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.
- GRACE (Gravity Recovery and Climate Experiment) dataset
- GMIA (Global Map of Irrigated Areas) dataset
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Grey Water Footprint/WPL datasets

7. Research Outcome from the Project:

- Water Accounts: Supply-Demand and Consumptions and Water Availability
- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Accounts for Land Productivity and Water Productivity.
- LULC map, soil maps, and river networks.
- WA+ Report and Recommendations.
- Training modules on WA+ Framework.

8. Cost Estimates:

The total cost of the project: **₹ 14.50 Lakh**

a. Source of funding: NHP
b. Sub-head wise abstract of the cost:

Head	Amount (in Lakh)		
	1st Year	2nd year	Total
1: Manpower: JRF @31,000/ + HRA and others	5.00	5.00	10.00
2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
3: Travel Expenditure	1.00	1.00	2.00
4: Contingency	0.25	0.25	0.50
Grand Total			14.50
	Rs. Fourteen Lakhs Fifty Thousand Only		

9. 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	**Aug. 2020-July 2021**				**Aug. 2021-July 2022**			
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. Development of Water Accounts					⟷	⟷	⟷	
e. Detailed Analysis of Water Accounts and Validation and research paper publications						⟷	⟷	⟷
f. Final report writing recommendations and Training							⟷	⟷

10.Progress till date:

The estimates of the water and land productivity were refined based on the discussions held during the second WA+ training to the WRD state officials of the North-Eastern states including Meghalaya. Green and blue water consumptions were estimated for all the districts of the Meghalaya using Budyko theory. The results show that the Garo Hills districts have more blue water consumptions than the other districts such Khasi Hills in the Meghalaya. A comparison was also made between various gridded precipitation datasets such as IMD, APHRODITE, CHIRPS, and TRMM. The goodness-of-fit statistics was evaluated in terms of RMSE, R2, MAE and Mean Bias. The results show that the TRMM datasets have lower bias as compared to CHIRPS and APHRODITE datasets with IMD. CDD and CWD were also evaluated in comparison to the IMD datasets. The work is under progress for generating supply-demand statistics and water availability in the different sub-basins of the Meghalaya. A stakeholder workshop/meeting is also planned during the month of April-May, 2022 to discuss the major findings with this study.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-23/4

1. Title of the Project

Development of Water Accounts for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland using Water Accounting Plus (WA+) Framework.

2. Project Team:

Dr P. K. Mishra, Scientist 'D'
Dr P. K. Singh, Scientist 'D'

3. Project Duration: 02 Years (04/21 – 03/23)

4. Objective of the Study

The major objective of this study is to apply the newly developed WA+ framework for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland for estimating the status of the water resources. This will generate useful base data to help development of proper water management strategies and decision processes. The specific objectives are:

1. To set-up WA+ Framework for the selected study basins/sub-basins.
2. To estimate ET consumption patterns for the selected basins/sub-basins.
3. To estimate land and water productivity for the selected basins/sub-basins.
4. To develop Resource Base (Surface water & Groundwater) for the selected basins/sub-basins.
5. To develop capacity on WA+ to the State Govt. officials from WRD, Nagaland through training programmes

5. Scope of the Study:

The scope of this study is as follows:

a. To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
b. To develop accounts for agricultural services (i.e., land productivity and water productivity).
c. To collect hydrological and meteorological data.
d. To collect data on topography, soils, river networks, drainage networks and land-use & land-cover.
e. To validate, analyze and process the data collected and give necessary inputs.
f. To develop water accounts for the study basins/sub-basins.
g. To prepare the detailed WA+ report for study basins/sub-basins.
h. To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

6. Study Area and Input Data

The state of Nagaland is a north eastern state of India and is surrounded by the states of Assam, Manipur, Arunachal Pradesh and also by Myanmar in the East. The state covers a geographical area of approximately 16580 km^2. The major part of the State is drained by the Brahmaputra basin (~10881 km^2, 65.6%) followed by Barak basin (~814 km^2, 4.9%) and by Irrawady-Chindwin basin (~4884 km^2, 29.5%). The state of Nagaland is divided into three river basins viz, rivers flowing to Brahmaputra, rivers flowing to Barak and the rivers flowing to the Irrawady-Chindwin basin.

Input Data

The WA+ framework focuses on the use of open source and remote sensing satellite datasets in an effort to maintain a high level of transparency and applicability in ungauged basins. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and many other agencies are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study. Data sources are given in Appendix 1.

- Precipitation: Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)/ Tropical Rainfall Measuring Mission (TRMM)
  [now available as Global Precipitation Measurement (GPM)]
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- GMIA (Global Map of Irrigated Areas)
- IWMI LULC map
- GlobCover LC v2
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Leaf area index (LAI) and NDVI
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- GRACE (Gravity Recovery and Climate Experiment) dataset
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.

The resolution of the above datasets varies from 250 m (MODIS) to 300 km (GRACE). However, all the dataset will be re-sampled to 250 m x 250 m resolution to develop water accounts of the study sub-basins/basins.

7. Project Budget

Head	**Amount (in Lakh)**		
	1stYear	2nd year	Total
1: Manpower: JRF@31,000/ + HRA and others	-	-	-
2: Work Station-high configuration	3.50	-	3.50
2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
3: Travel Expenditure	1.50	1.50	3.00
4: Contingency	0.25	0.25	0.50
Grand Total			**9.00**
	Rs. Nine Lakhs only		

8. Expected Deliverables

- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Land Productivity and Water Productivity.
- Basin/sub-basin wise Water Accounts: Supply-Demand and Consumptions and Water Availability
- WALU map, soil maps and river networks.
- WA+ Report and Recommendations of best practices suitable for the catchments
- Trainings on WA+ to the officers from Meghalaya WRD and other Implementing Agencies of the NHP.

9.Expected Timeline against the Deliverables:

Project Year	**Apr. 2021-Mar. 2022**				**Apr. 2022-Mar. 2023**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments	↔	↔						
b. Data analysis in WA+ Framework, and		↔	↔					
c. Water Consumption Patterns and beneficial non-beneficial consumptions			↔	↔				
d. Accounts of Land Productivity and Water Productivity				↔	↔			
e. Catchment wise Water Accounts: Supply-Demand and Consumptions and Water Availability					↔	↔	↔	
f. WA+ Report and Recommendations of best practices suitable for the catchments							↔	↔
g. Training modules on WA+							↔	↔

10. Progress till date:

Particulars	**Work Done**
Procurement of High Configuration System	Completed
Generation of GIS layers for 3 basins and 9 sub-basins in Nagaland	Completed
Data downloading and processing from open sources viz. CHIRPS, GMIA, LAI, GPP, NPP, Globcover, MIRCA (Rainfed and Irrigated), WDPA, Population, etc.	Completed
Development of Water Accounting based Land use (WALU)	Completed.
Setting up of WA+ model for Sheet 2 (Evapotranspiration) and Sheet 3 (Agricultural Services including Land and Water Productivity) Generation	Ongoing
Setting up of Water Pix model for Supply Generation	Ongoing
Generation of Sheet 4 (Utilized flow), Sheet 5 (Surface water), Sheet 6 (Groundwater), Sheet 1 (Resource base)	Yet to be done
Training on WA+ to selected WRD officials	Planned during the month of April/ May 2022.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-24/5

1. **Project Title:** Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram.

2.	**Duration of the project**	**:**	**3 years (04/21-03/24)**
3.	**PI and Co-PI from Lead Organization**	**:**	PI: Dr. Vishal Singh, Scientist- C Co-PI: Dr. M.K. Nema, Scientist- D Dr. P. K. Singh, Scientist-
4.	**Investigators from Partner Organization**	**:**	1. Mr.K. Hamlet, Sr.E.E 2. Mr. Vanlalpekhlua Sailo, AE

5. Objective of the Study

The major objective of this study is to apply the advance modeling framework for Barak, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA) sub-basins in the state of Mizoram for water security plan. This will generate useful base data to help development of proper water management strategies and decision processes. The major objectives of the study area as follows:

a. To collect, prepare and evaluate various thematic datasets such as digital elevation model, land use/Land cover (LULC) map, soil map, population data (census) and hydro-meteorological data-sets such as precipitation, temperature, discharge etc.
b. Long-term Rainfall trend analysis based on rainfall frequencies and intensities to analyse the effect of climate change as per the standard guidelines.
c. Hydrological modelling, calibration and parameterization over Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar subbasins in the state of Mizoram for the assessment of watershed components (including surface and groundwater) and water availability using SWAT and SWATCUP models (Arnold et al., 2012).
d. Analyzing the effect of LULC changes on the hydrological scenarios such as water availability (or water yield) at sub-catchments scale and discharge at the outlets.
e. Analyzing the effect of climate changes on the hydrological systems, with possible thresholds for resilience under different conditions and combinations anticipated.
f. To setup WEAP model (Levite et al., 2003) for calculating water demand of Mizoram state subject to mid-term water availability (say up to 2050) to increase water use efficiency and maintaining the adequate water supply sustainable development.
g. To prepare the detailed report for study basins/sub-basins in Mizoram state as per the mid-term hydrological assessment with the guidelines of water security plan with particular reference to demand points (domestic, irrigation or others) identified by the Water Resources Department, Government of Mizoram.
h. To impart training on “hydrological modelling” to the state officials of Water Resources, Agricultural and other related Depts, as well as officers from other implementing agencies of the National Hydrology Project.
i. Selection of dam sites with suggested capacity to meet the growing demand of water in the state.

6. Study area

Mizoram, with an area of 21,087 km^2 is largely divided into three major river basins: one is the Barak basin (8,935 km^2) in the central to northern part of the state, the second is Kolodyne basin (8,144 km^2) in the southeastern part, and the third is Karnaphuli basin (3,999 km^2) in the southwestern part, as shown in Figure 1.

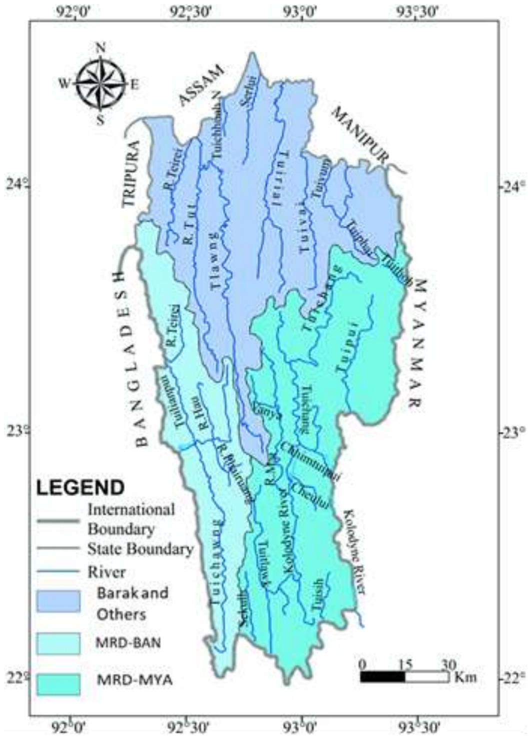


Figure 1: River basin map of the Mizoram showing river basins namely Barak and Other, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA).

7. Brief Methodology

7.1 Processing of meteorological datasets

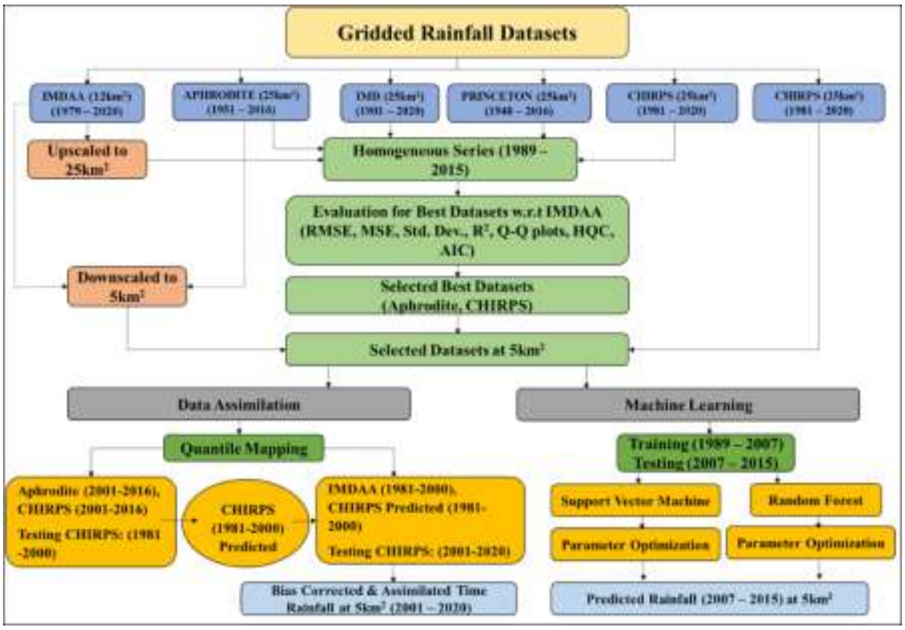


Figure 2: Processing of meteorological datasets and generation of new hybrid gridded rainfall.

7.2 Climate projections and rainfall indices

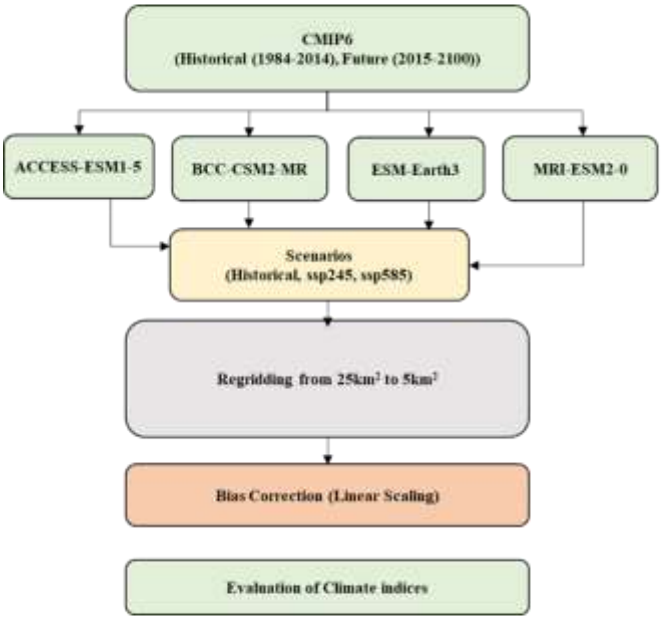


Figure 3: Analysis of rainfall indices to analyse changes in rainfall.

7.3 Overall modeling methodology

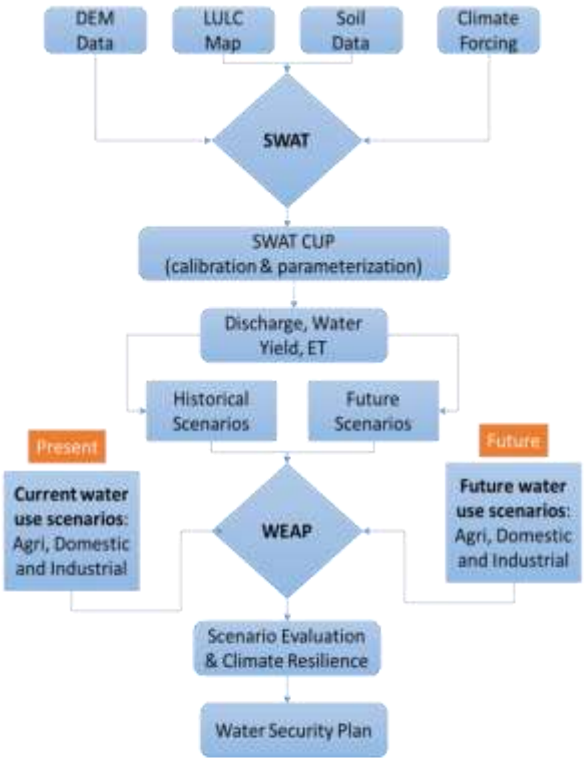


Figure 4: Overall modeling methods.

8. Expected Deliverables

- A detailed outcome of water balance components including surface and groundwater.
- Rainfall extreme trends discharge scenarios (up to 2050), with possible plans and thresholds for resilience with and without structural interventions under the anticipated conditions and combinations thereof.

- Basin/sub-basin wise water availability: Supply-Demand and Consumptions and Water Availability, considering a development period of 5 years and a planning horizon of 30 years.
- LULC change maps, soil maps and river networks.
- Guidelines and schema of water security plan, with particular reference to identified locations with significant demand. Planned developments will be taken into consideration.
- Report and Recommendations of best practices suitable for the catchments
- Trainings on hydrological models to the officers from Mizoram IWRD and other Implementing Agencies of the NHP.

9. Expected Timeline against the Deliverables

Project Year	**Mar 2021-Feb 2022**		**Mar 2022-Feb 2023**		**Mar 2022-Aug 2024**	
Project Quarter	**M 1-6**	**M 7-12**	**M 13-18**	**M 19-24**	**M 25-30**	
a. Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments	⟷	⟷				
b. Data analysis, Trend generation, SWAT setup		⟷	⟷			
c. Hydrological Assessment & Calibration		⟷	⟷			
d. Projected Scenarios using GCMs and Climate Resilience Analysis		⟷	⟷	⟷		
e. WEAP setup and water availability and demand assessment			⟷	⟷	⟷	
f. Report and Recommendations of best practices suitable for the catchments					⟷	⟷
g. Training modules on Hydrological Model				⟷	⟷	⟷

10. Progress till date

10.1. Generation of new gridded high resolution rainfall datasets

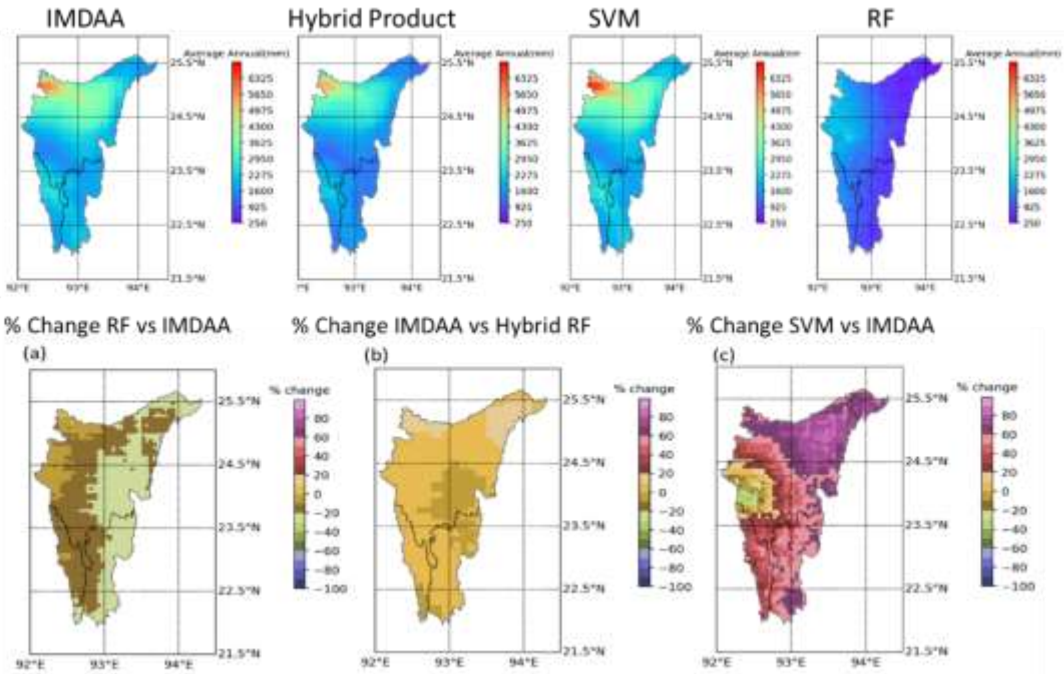


Figure 5: Hybrid rainfall datasets.

10.2. Preliminary SWAT Modeling Water Balance outcome

Water Balance Ratios

- Streamflow/Precip = 0.62
- Baseflow/Total flow = 0.40
- Surface Runoff/Total Flow = 0.60
- Perc/Precip = 0.17
- Deep Recharge/Precip = 0.01
- ET/ Precipitation = 0.36

10.3 Evaluation of SWAT modeling outcome (prior to calibration)

Site	Lon	Lat	Observed discharge Duration (days)	Annual Mean Discharge			Standard Deviation			Maximum Discharge			R^2 (Q_{obs} vs Q_{sim})
				Q_{obs}	Q_{sim}	% change		Q_{sim}	% change	Q_{obs}	Q_{sim}	% change	0.27
Tlabung site at River Karnaphuli	92.47	22.89	2014 - 2018 (441)	179.15	141.80	20.85	0.27	213.26	10.04	1303.935	1585	-21.55	0.41
Tlawng (near Lunglang village)	92.66	23.62	2015 - 2017 (348)	60.96	47.43	22.19	0.41	49.54	-4.15	160.721	346.7	-115.71	0.15
Tuipui D Site at River Kolodyne	92.93	22.90	2015- 2017 (593)	403.72	297.10	26.40	0.15	465.84	42.68	8701	6430	26.10	0.22
Mateswari Site at River De	92.52	22.94	2015 - 2017 (629)	39.00	43.33	-11.11	0.22	62.74	-5.49	333.33	480.8	-44.24	0.27

Q_{obs} = Observed Discharge, Q_{sim} = Simulated Discharge

11. Work in Progress

- Calibration and Validation using Stochastic Modeling and Optimization Methods
- Generation of Projected Scenarios of Various Watershed Components to Setup WEAP model

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-22/1

1. **Title:** Impacts of Glacier and Climate Change on Runoff for Selected Basins of Himalayan Region

2. **Project Team:**

   Dr Vishal Singh, Scientist 'C'
   Dr Sanjay K Jain, Scientist 'G'
   Dr Manohar Arora, Scientist 'E'

3. **Project Duration: 02 Years (08/20 – 07/22)**

4. **Objectives**

   1. To apply a data assimilation technique and bias correction methods for constructing more accurate high resolution gridded (i.e. approximately at $0.05^0 \times 0.05^0$) hydro-meteorological data sets (e.g. precipitation) over the selected river basins.
   2. To develop a novel Integrated approach for snowmelt and glacier melt runoff modeling by incorporating SWAT and SPHY hydrological models with special emphasis on uncertainty estimation utilizing real time remote sensing and hydro-observation datasets.
   3. To study the impact of snow and glacier changes on the runoff.
   4. To analyze the impact of climate change and the long-term (21^{st} century) variability in snow and glacier melt runoff utilizing latest CMIP6 GCMs datasets.

5. Present state-of-art

A limited number of studies have been carried out related to the separation of snow and glacier melt contributions, especially in the Himalayan region under glacier and climate changing conditions. The computation of snowmelt induced runoff from the glaciered catchment has always been a key hydrological issue, especially over high mountainous regions like Himalaya. Climate change studies resulted that around 1ºC temperature has been increased in Himalayan regions, which have been identified as one of the most vulnerable glaciated regions to climate change. The conservation of Himalayan freshwater reserves is necessary for the design and management of hydropower plants, supply of drinking water, agricultural management practices and flash flood risk assessment. This study has been proposed to carry out a research analysis over Himalayas to assess the impact of glacier and climate change in the long-term time frame (e.g. 21st century). For snow and glacier modelling, a novel approach based on snow-glacier hydrological model such as SPHY will be incorporated. SPHY model is a grid-based model and uses multiple thematic and meteorological datasets. In this study, we will use a temperature index model utilizing variable degree-day factors (uses separate factor for snow, clean ice glacier and debris glacier) in SPHY at each grid scale for analyzing snow and glacier melt runoff, especially designed for the Himalayan conditions. No such variable degree-days factors have not been applied for each grid. For climate change analysis, latest CMIP5/CMIP6 GCMs coupled with SWAT model will be utilized. SWAT model has been widely utilized in the simulation and projection of various hydro-meteorological components.

6. Methodology: In the present study four Himalayan river basins such as Baspa, Parbati, Lachung and Subanshiri will be taken up.

6.1 Data assimilation and bias correction

For meteorological datasets, a high resolution gridded daily precipitation dataset (0.05º×0.05º) will be constructed for the historical time by assimilating IMD precipitation, TRMM based precipitation, GPM based precipitation and CHIRP precipitation datasets as per their availability. The bias correction will be done using advanced bias correction methods (such as Quantile mapping, Linear scaling etc.) (Singh and Xiaosheng, 2019).

6.2 Integrated Hydrologic Modelling:

The Soil and Water Assessment Tool (SWAT) and SPHY model, will be used for the estimation of snowmelt and glacier runoff over the selected Himalayan river basin such as Parbati, Baspa, Lachung and Subansiri.

6.3 Snow and Glacier runoff changes

For snow-covered areas (SCAs) and glacier mapping, MODIS, LISS 3, LISS 4, and Sentinel satellite sensors data will be utilized. For snow cover extraction Normalized Difference Snow Index (NDSI) based on cloud removal technique will be utilized as previously used by various researchers. For the computation of snow and glacier melt a variable degree day factors based Temperature ndex model will be applied.

6.4 Validation of Satellite-based Snow Covers with SPHY model derive Snow Covers and Model calibration

Various satellite-sensor based remote sensing products MODIS will be used to validate the SPHY derived snow covers. A detail calibration will be performed to calibrate/validate the SWAT derived stream flows at the available gauges.

7. Progress till date:

7.1 Preparation and processing of hydro-meteorological datasets and thematic datasets such as LULC maps, DEM derived maps, Soil map, Glacier change maps and snow cover area maps.

7.2 Snow and glacier melt runoff modeling using SPHY and results have been calibrated and validated.

7.3. Assessment of snowmelt and glacier melt runoff changes at subbasin and seasonal scales in the Baspa river basin.

7.4 SPHY Model based simulation of snow-glacier melt induced discharge at the outlet gauge i.e. Sangla.

7.5 SPHY Model based simulation of snow-glacier melt induced discharge for Upper Ganga River Basin (up to Devprayag)

7.6 Modeling of snow/glacier induced runoff and glacier changes for Upper Ganga River Basin (up to Devprayag)

For the assessment of glacier changes and corresponding melt runoff from high (upstream) to moderate (downstream) elevation ranges, decadal glacier-change maps (1990, 2000, 2010, 2020) have been prepared utilizing the RGI glacier inventory (RGI06) data and by processing the LANDSAT satellite images.

Table 2: Showing changes in snow and glacier runoff components in intra-decadal (mean) scenarios

Components	Scenarios	Bhagirithi	Alaknanda	Devprayag
Glacier Q (Mean)	1986-1995	58.685230	75.612448	134.297651
	1996-2005	62.754126	78.616867	141.370997
	2006-2015	62.590482	78.385543	140.976009
	2011-2020	63.382801	79.230132	142.612946
Snow Q (Mean)	1986-1995	97.273781	139.561971	236.839060
	1996-2005	86.398220	121.692763	208.094795
	2006-2015	88.486988	121.914880	210.404877
	2011-2020	87.844005	122.330329	210.177880
Rain Q (Mean)	1986-1995	154.073537	274.432808	429.439567
	1996-2005	160.544640	295.227510	456.819414
	2006-2015	176.990498	317.926959	496.026979
	2011-2020	160.918805	287.552351	449.425606
Base Q (Mean)	1986-1995	34.453273	54.367486	88.909510
	1996-2005	36.502612	58.057554	94.666650
	2006-2015	38.769161	60.974558	99.855288
	2011-2020	37.305955	57.664187	95.064272
Total Q (Mean)	1986-1995	344.485716	543.974540	889.485507
	1996-2005	346.199598	553.594693	900.951855
	2006-2015	366.837033	579.201771	947.263023
	2011-2020	349.451474	546.776835	897.280474

8. Work in Progress

- Assessment of snowmelt and glacier melt runoff changes at subbasin and seasonal scales in the Teesta river basin.
- SPHY Model based simulation of snow-glacier melt induced discharge at Teesta river basin

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-23/2

1. **Title:** Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya
2. **Project Team:**

   Dr Manish Kumar Nema, Scientist 'D'
   Dr Sanjay K Jain, Scientist 'G'
   Dr P. K. Mishra, Scientist 'D'
   Er. P. K. Agarwal, Scientist 'B'

3. **Project Duration: 03 Years (08/20 – 07/23)**
4. **Objectives**
   a. To develop a baseline runoff and meteorological data of Henval watershed with the established experimental setup.
   b. To carry out Hydrological modelling of Henval river
   c. To model the spatial-temporal variability and temporal-stability of the soil moisture
   d. To compare and validate the satellite soil moisture data with the in-situ observations
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. Experimental hydrology still has a unique place with no alternative for testing and developing new research hypotheses and models. Given the importance of experimental hydrology, NIH has initiated an experimental hydrologic project for a small lesser Himalayan watershed, namely, Henval. In the first phase of the project, a state-of-art field observatory was established with various instruments and sensors during 2016-2019. Preliminary data analysis on the estimation of evapotranspiration by various methods and water balancing of the watershed was performed. The field station developed at Henval watershed is envisaged to operate for long-term monitoring of different hydro-climatic variables. This study is supposed to be the second phase of the project.

The field monitoring of the various variables and development of baseline datasets for the Henval watershed shall be a continuous process in this study. Hydrological modeling of the stream is planned to understand the catchment characteristics and runoff behaviour of the watershed. Soil moisture is the crucial variable for partitioning rainfall into infiltration and runoff, thus playing a fundamental role in runoff modelling and flood forecasting. Recently, the scientific community is making an excellent effort to address soil moisture estimation over large areas through in situ sensors, remote sensing, and modelling approaches. There is sizeable spatial-temporal variability of soil moisture that exists in field conditions. Currently, we are able to estimate soil moisture accurately at the point scale through in-situ sensors.

Moreover, satellite sensors can obtain less accurate measurements at a coarse scale (~20 km). Finally, spatial downscaling/upscaling approaches can be used to integrate the different techniques and observations with modelling. Data assimilation and merging methods can also be considered to integrate in-situ, satellite and modelled data optimally.

6. **Methodology**

In the present study, meteorological variables, soil and runoff monitoring shall be done within the established experimental watershed. Modelling of runoff, soil moisture monitoring and modelling and comparison and validation of satellite soil moisture product with in-situ sensors are proposed. The methodology for these is described in the following sections.

Hydrologic modelling:

Several models are available for runoff modelling. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used for the estimation of streamflow in the basin.

Soil moisture modeling

The SWAT, Soil Water Balance Model, etc. shall be applied to carry out soil moisture modelling. The observed soil moisture data shall do the calibration and validation of soil moisture model. Study of the effects of static factors such as land-use, topography, soil texture, etc. on the spatial variability of soil moisture also envisaged in this study.

Validation of Satellite-based Soil moisture products

Various satellite-based soil moisture products such as ASCAT, SMAP, SMOS, etc. with different resolution shall be validated and compared against the in-situ soil moisture sensor. The interrelation of soil moisture and surface runoff shall be performed.

7. **Research Outcome from the project:**

- Validation of the SWAT model for a lesser Himalayan watershed.
- Assessment of the spatial-temporal variability and temporal-stability the soil moisture
- Validation of satellite-based soil moisture product for Himalayan watershed.
- The error characterization of the satellite-based soil moisture products.

8. **Cost estimates:**

The total cost of the project: **₹ 10.2236 Lakh**

a. Source of funding: NIH

b. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)			
		Year - I	Year - II	Year - III	Total
1	Salary (Part-Time Field Staff)	156000	171600	188760	516360
2	Travelling expenditure	78000	78000	78000	234000
3	Experimental/ Rental Charges	66000	76000	76000	218000
4	Misc. expenditure	18000	18000	18000	54000
	Sub- Total:	318000	343600	360760	
	Grand Total:				**1022360/-**

9. **Work Schedule:**

SN	Description of Activity	2020-21			2021-22				2022-23				2023-24	
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1	Data Collection and up-keeping of the instruments	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Hydrological modelling		■	■	■	■	■							
3	Soil Moisture modelling				■	■	■	■	■	■				
4	Satellite data acquisition, assimilation and		■	■	■	■	■	■	■	■	■	■		

	processing		■	■	■	■	■	■	■	■	■	■		
5	Validation and comparison of satellite and in-situ data							■	■	■	■	■	■	■
6	Report writing				■				■					■

10. Progress till date:

The PI has visited the various instrumented sites in the experimental catchment during the last six months to collect the data and maintain the systems. In the previous working group meeting, the results related to hydrological modelling were shared with the members. In pursuance of the study's second objective, an empirical model is formulated using available parameters in this study, i.e., rainfall, wind speed, air temperature, and near soil surface temperature. This model was calibrated and validated using the Kumargaon, Kanataal and Nagini sites in the lesser Himalayan region. The results indicated the best performance of the model at Kumargaon with high R^2 in calibration and validation. These results are further supported by lower values of RMSE, ubRMSE, MAE and Pearson's correlation coefficient for this site. The model performed good at the other two sites of Kanataal and Nagini, but the results are comparatively inferior to Kumargaon. Furthermore, this model is simplified using the averaged values of optimized parameters and tested using the data used for validation. The results indicate that the simplified model also performed best at Kumargaon for all the soil depths with high R^2 values which are obtained as 0.86 for 2 cm, 0.83 for 6 cm and 0.64 for 25 cm depths, respectively. Whereas for the similar soil depths at Kanataal, the performance was good only for the topmost layer of 2 cm with a high R^2 value of 0.82. For the deeper soil layers at Kanataal, lower values of R^2 (0.50 for 6 cm and 0.33 for 25 cm) indicates relatively average performance. Once again, the simplified model performed well at the site of Nagini with high R^2 (0.81) value for the soil depth of 6 cm. It is also found that the model's performance decreases with increasing soil depth which indicates that the effect of meteorological variables decreases with the increasing soil depth. Yet, no ideal model would precisely predict soil moisture; hence, this quest emergence of deep learning models makes the process efficient and reliable. In the later part of the study's second objective, two deep learning hybrid models based on long-short term memory, namely, CNN-LSTM and RNN-LSTM, were developed and tested to model the sub-surface soil moisture at three stations located in a Lesser Himalayan catchment. The work is still ongoing, and findings will be shared in future working group meetings.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2021-23/3

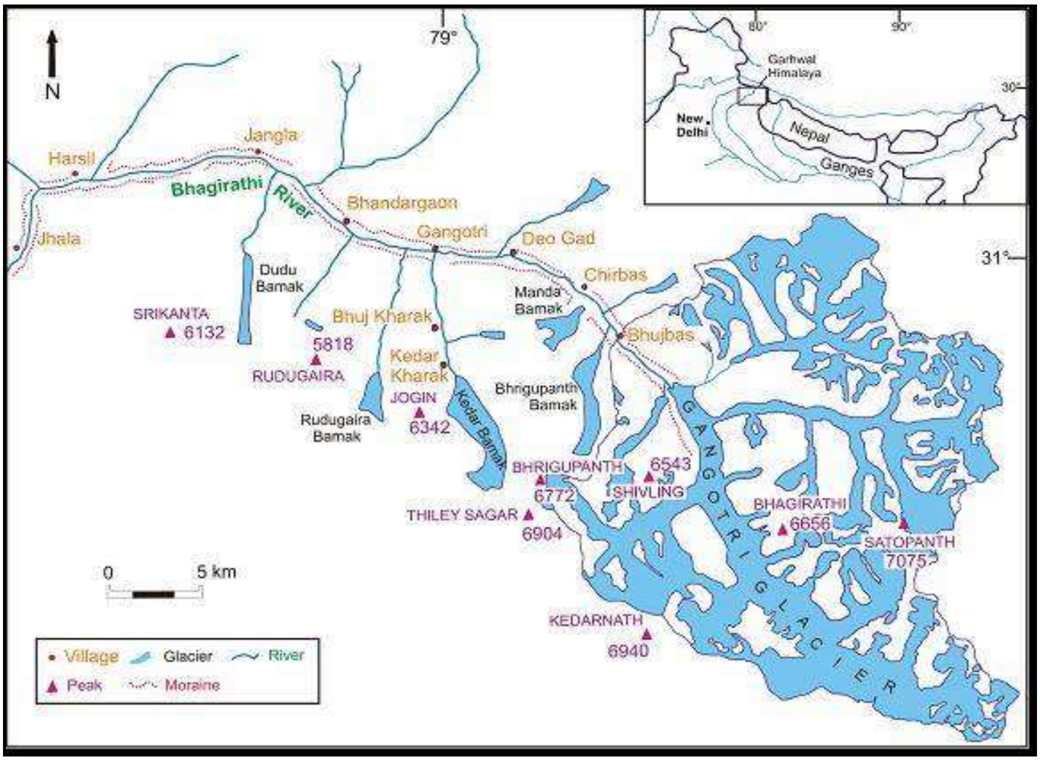
1. Title of the Study: Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

2. Study Group: Dr Manohar Arora, Scientist 'E'
Dr P K Mishra, Scientist D
Dr. Vishal Singh, Scientist C

3. Type of Study: Internal Project

Date of start: 01.04.2018
Scheduled date of completion: 31.03.2023

4. Location Map:



5. 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.

6. 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

9. Objectives vis-à-vis Achievements

Objectives	Achèvements
Continuous monitoring of meteorological and hydrological data for monthly and seasonal specific water yield and its variability from the year to year	Due to Covid 19 no field investigations was carried out for ablation season 2021. The field investigations for 2022 will be started in the first week of May 2022.
Characterization of Suspended sediment in the Gangotri Glacier Melt Stream	Particle size analysis was carried out from the samples collected. The results indicate a clear dominance of silt size particles (65–78%) in suspended sediment throughout the melting season followed by sand (15–30%) and clay (4–7%). These results were further sub-classified into six size categories for more detailed analysis of the silt and sand particles. These sub-classification results indicate that, in the case of silt particles, medium (25–30%) and coarse (27–34%) silt provided the maximum contribution; whereas in the case of sand particles, fine sand (14–20%) dominated the suspended-sediment concentration. between 2% and 7% with an exception in the case of medium sand (10%), which happens to be the coarsest particle size of our study.
Seasonal Distribution of Cold Katabatic and Warm Anabatic Wind.	The percentage of Cold katabatic and Warm anabatic wind in the years 2016-2019 is 56% and 44% respectively.
Simulation of Streamflow for the Gangotri Glacier Melt Stream.	HBV model was used for the simulation of streamflow. The model was calibrated for the years 2016-17 and validated for the year 2018-19. Different functionalities, such as an automatic calibration using a genetic algorithm or a Monte Carlo approach, as well as the possibility to perform batch runs with predefined model parameters make the HBV model interesting especially for estimating streamflow. The coefficient of determination R^2 for the calibration period and validation period were 0.77 and 0.71 respectively.

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2022-24/1

1. **Title:** Spatio-temporal Water Availability under Changing Climate and Land-use Scenarios in Wainganga River Basin

2. **Project Team:**

   Dr Manish Kumar Nema, Scientist 'D'
   Dr P. K. Mishra, Scientist 'D'

3. **Project Duration: 02 Years (04/22 – 03/24)**

4. **Objectives**

   Wide-scale interventions and other water-related activities have occurred in the Wainganga River Basin (WRB), which sustain the northern industrial region of Nagpur and large expanses of highly irrigated rice-growing districts. The water demands of the basins have steadily increased over time, and among the diverse nature of the purposes driving such a continually growing demand for drinking water, an increased reliance on irrigated agriculture, as well as numerous developmental projects such as thermal power plants, are expected to intensify competition for the limited water resources. As a result, the study's goal is to examine the basin's water resources availability and, more importantly, to estimate the influence of current and future changes of climate and landuse on the Wainganga river basin's water balance. The specific objectives of the study are as follows:

   a. To study the historical climate change, morphological properties and land use/land cover change pattern over the Wainganga river basin
   b. To calibrate and validate a hydrological model at different spatial scales for the river basin using current land use and observed climatic conditions
   c. To develop future expected land-use change and climate change scenarios (CMIP6) for the base period and compare them with the observed period
   d. To model spatial and temporal future water availability using climate and land-use change scenarios
   e. To quantify the uncertainty in modeling analysis arising from model parameters and input conditions
   f. To prepare adaptation/management strategies under changing climate and land-use scenarios

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

   Presently, the total water availability of the Wainganga basin is 9225 MCM (325.89 TMC). The various sectoral demands such as domestic, industrial and agricultural for the basins water resources have grown steadily over the years, leading to an intensification of competition and conflicts for the limited water resources. Therefore, the study aims to assess the basin's water resources availability and, further, to evaluate the impact of existing and other prospective water resources developmental initiatives on the overall water balance of WRB. It is an interstate river, and the water is being shared based on the Water Dispute Tribunal Award for the Godavari Basin (Eastern Godavari Basin (EGB)). The majority of the inhabitants in this basin depend on farming, fisheries, and forest-dependent livelihood activities. The WRB fall under the parts of the Eastern Vidarbha region of Maharashtra has been in the news for many farmer suicides for more than a decade due to crop failures and increasing debts. While most districts in Vidarbha are known for cotton and soybean cultivation, eastern-Vidarbha, through which Wainganga flows, is historically known for its paddy cultivation. Bhandara and Gondia districts are known as the 'rice bowls' of Maharashtra. The rice and sugarcane production in the region was supported by the Maji-Malguzari (MM) tanks, which needs to be rejuvenated. The MM tank system, albeit feudal, was a well-designed decentralized system for irrigation and could have served as a hallmark of development in eastern Vidarbha.

6. Methodology

Study Basin:

The Wainganga rises in the Seoni District of Madhya Pradesh at an elevation of 640 m above M.S.L. Wainganga basin extends over approximately 50,000 square kilometres up to the Ashti gauging site, which spreads across the States of Madhya Pradesh and Maharashtra. The total length of this river is ~638 km up to the Ashti gauging site just before the confluence with the Wardha River. In the beginning, it flows eastward for a distance of about 175 km and then Southward for a length of about 100 km in Seoni and Balaghat District of Madhya Pradesh. It also serves as a border between Madhya Pradesh and Maharashtra state for 32km. Before joining the Godavari, it flows about 479 km in the Bhandara, Chandrapur, and Gadchiroli District of Maharashtra. The Wainganga basin lies in the medium rainfall zone, situated between 900 mm and 1600 mm. Most of the rainfall is received during the southwest monsoon from June to October. In the winter, the minimum temperature varies from 7^0 C to 13^0 C. Maximum temperature ranges from 39^0 C to 47^0 C. Month of May is the hottest month, and December is the coldest month.

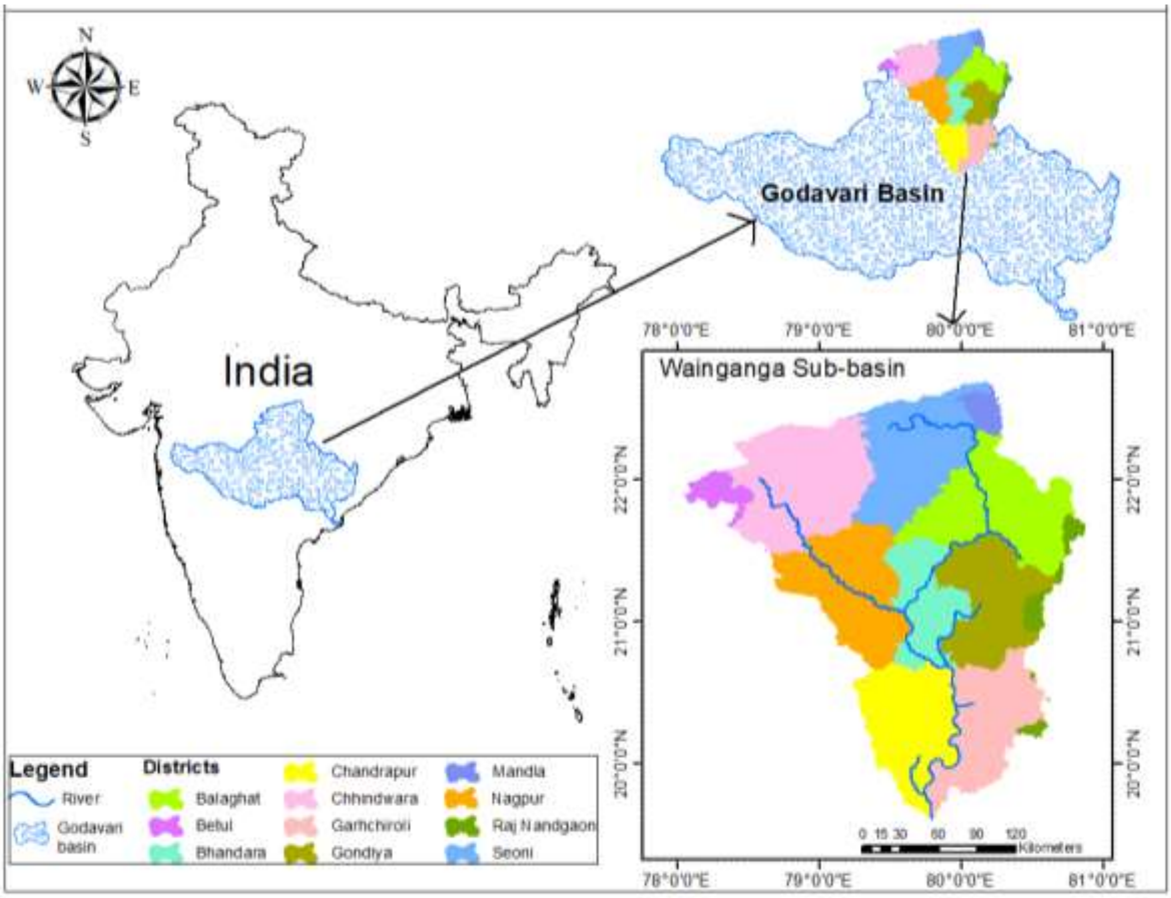


Fig. 1 Location Map of Wainganga River sub-basin of Godavari Basin in India

Research Approach:

A few activities/tasks have been defined to accomplish the study's research objectives, including collecting the data sets, field visits, surveys, analysis of collected data, model setup, scenario-based analysis, assessment of water availability, etc. The task-wise methodology proposed for analyzing the impact of climate change on the hydrology of Wainganga Basin is described below:

Task 1: Data collection, pre-processing and development of digital database including DEM, LULC, SOIL, Climatic time series, etc.

Task 2: Analysis of Trends for the climatic and hydrological extremes

Task 3: Modeling of surface hydrology and assessment of climate change impacts. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used to estimate streamflow in the basin.

Task 4: Water resources availability under changing climate & landuse scenario using the FDC based analysis. Uncertainty analysis shall be performed for the water availability assessments made using these scenarios

Task 5*:* Preparation of adaptation/management strategies /plans

7. **Research Outcome from the project:**

Assessment of the spatial-temporal water availability under the different climatic and land-use scenarios.
Future Land-use scenarios for the study region.
Climate change adaptation plan for the Wainganga river Basin

8. **Cost estimates:**

The total cost of the project: **₹ 10.2236 Lakh**

a. Source of funding: NIH
b. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)		
		Year - I	Year - II	Total
1	Salary (Part-Time Field Staff)	156000	156000	312000
2	Travelling expenditure	150000	150000	300000
3	Data /Infrastructure/Equipment	50000	50000	100000
4	Workshop/ Meeting / Experimental Charges	20000	200000	220000
5	Misc. expenditure	20000	20000	40000
	Sub- Total:	396000	576000	
	Grand Total:			**972000**

9. **Work Schedule:**

SN	Description of Activity	2022-23				2023-24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Data Collection, pre-processing and development of digital database	■	■	■					
2	Analysis of trends for the climatic and hydrological extremes	■	■	■	■				
3	Landuse modeling and predictions for the future periods			■	■	■			
4	Modeling of Surface Hydrology and Assessment of Climate Change Impacts			■	■	■	■		
5	Water Resources availability under changing climate & landuse scenario			■	■	■	■		
6	Uncertainty Analysis					■	■	■	■
7	Adaptation/management Strategies /Plans					■	■	■	■
8	Stakeholder's Workshop							■	
9	Report Writing					■			■

NEW STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2022-25/2

1. **Title:** Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya

2. **Project Team:**

   Dr. Sanjay K. Jain, Scientist 'G'
   Dr Manish Kumar Nema, Scientist 'D'
   Dr P. K. Mishra, Scientist 'D'
   Dr. Praveen Thakur (IIRS)

3. **Project Duration: 03 Years (04/22 – 03/25)**

4. **Scope of the Work**

The scope of the work to be carried out in the project includes:

a. Characterizing spatial extent and patterns of hydrological cycle components in selected watersheds in Western Himalaya (Uttarakhand) using multi-scale EO data;
b. Assessment of watershed's topographical, morphological and hydro-meteorological spatio-temporal dynamics using a systematic and multi-site sampling using ground observations and EO inputs;
c. Determining the EO-based land surface parameters and hydrological cycle variables of the watersheds and its dynamics;
d. Developing hydrological models for multi-scale assessment of hydrological cycle components and water availability linking natural hydrological processes and anthropogenic water use under present and future climate scenarios;
g. Developing a web-based hydrological information system, supporting hydrological and spatial database, web analytics and data/information dissemination for water resources planning and management.

5. **Deliverables**

- Establishment of long term, experimental watershed monitoring sites with field instrumentation for understanding various hydrological and snow/glacier processes which are important in overall water balance studies.
- The updated geospatial-database on hydrological sources and water resources of the selected watersheds.
- Quantification of hydrological response of the selected watersheds and assessment of basin level water availability in the Upper Ganga Basin of NWH region under present and future climate change scenarios.

6. **Cost estimates:**

   The total cost of the project: **₹ 30.91 Lakh**

   a. Source of funding: IIRS
   b. Sub-head wise abstract of the cost:

Head	**Total grant (Lakh)**
Recurring	
(i) Salary + HRA: 01 JRF or Project Fellow	**10.88**
(ii) Field work and Travel (Domestic)	**6.5**
(iii) Services (Field activities & other project costs: Field sampling for hydrological data collection and lab analysis of soil/water samples; contingency/consumables, skilled/non-skilled labor hiring for watersheds data collection), data, printing of project report/outputs and other charges.	**9.5**
(vi) Institutional charges/ Overhead	**4.03**
Grand Total*	**30.91***

Say **Rupees Thirty Lakh Ninety-One Thousand and Two Hundred only** from IIRS. *This is the maximum amount, which can be transferred during project duration. Actual budget transfer to be as per actual funds availability from ISRO, progress of work and utilization of given funds by the collaborating institute.

8. Project Schedule

Duration of project shall be **Three (03)** years from the date the project has been sanctioned by ISRO and approval of budgetary provisions.

<table>
<tr><th>Activity</th><th>Year I</th><th>Year II</th><th>Year III</th></tr>
<tr><td>Project initiation, Inception workshop</td><td style="background:#c0c0c0"></td><td></td><td></td></tr>
<tr><td>Recruitment of project personnel</td><td style="background:#c0c0c0"></td><td></td><td></td></tr>
<tr><td>Permission for field studies</td><td style="background:#c0c0c0"></td><td></td><td></td></tr>
<tr><td>Workshop for field training</td><td style="background:#c0c0c0"></td><td></td><td></td></tr>
<tr><td>Field instrumentation/sampling</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Acquisition of Satellite based Earth Observation data</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td></td></tr>
<tr><td>Progress review/workshop</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Hydrological data collection, development of web based data repository and information system</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Development of hydrological models for multi-scale water resources availability</td><td></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Generation of spatial layers on hydrological fluxes for present and future climate scenarios</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Progress review and stakeholder workshop</td><td></td><td></td><td style="background:#c0c0c0"></td></tr>
<tr><td>Final Report generation</td><td></td><td></td><td style="background:#c0c0c0"></td></tr>
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NEW STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2022-25/3

1. Title of the Project

Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka

2. Objectives of the Study

The major objective of this study are as follows:

1. To collect, prepare and evaluate various thematic datasets such as DEM, land use/Land cover (LULC) map, soil map, and hydro-meteorological data-sets such as precipitation, temperature, discharge (if available) etc.
2. To analyze long-term hydro-meteorological variables such as precipitation, evapotranspiration, and water consumption patterns in the basin and assessment of their possible impacts on water management in the basins.
3. To estimate water potential of the west-flowing rivers, i.e., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins using hydrological models and Frameworks.
4. To assess the effects of climate and landuse changes on the water yield using Budyko conceptual framework.
5. To analyze the hydrological sensitivity and resilience capacity of the basins under adverse climatic impacts.
6. To impart training on the hydrological models to the state officials of the water resources department including IAs of NHP.
7. To prepare the detailed sub-basin wise project report for the state water resources department for planning purposes.

3: Research Team:

PI:	Dr P K Singh, Scientist D, WRS Division, NIH Roorkee
Co-PI:	Dr Vishal Singh, Scientist C, WRS Division, NIH Roorkee
Co-PI:	Dr Sanjay K Jain, Scientist G and Head, WRS Division, NIH Roorkee

4: Project Duration: 03 Years (04/22 – 03/25)

5: The Study Area and Input Data

Figure 1 shows the map of the west flowing rivers in the state of the Karnataka. As discussed above, this study is aimed to assess the water potential yields and other hydro-meteorological analysis of the six sub-basins, e.g., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins.

Figure 1: West-flowing Rivers in Karnataka (Source: IndiaWRIS).

6: Input Data

Looking into the un-availability of the measured/monitored hydro-meteorological datasets in these basins, it is planned to utilize the earth observation and satellite datasets for calibration and validation purposes and yield estimation in this study. Following datasets (not limited to) will be used in this study:

SI. No.	Data-sets/Name	Availability/Source/Resolution	Time-Period
1	DEM	SRTM/CARTOSAT – 30 m/ALOS-PALSAR 12.5 m.	
2	Daily Rainfall and Temperature Gridded (Observed)	IMDAA –12 km^2	1979-2020
3	Daily Rainfall Gridded (Satellite based-open sources)	CHIRPS – 5 km^2; TRMM+GPM -25 km2;	1991-2020
4	Other Hydro-Meteorological Datasets	NOAA/NASA/ ESA/ISRO	1991-2020
5	Population Data and population growth Data	As per census	2011 and older
6	LULC maps	Glob cover, NRSC, IWMI, ESRI	For different time periods
7	SOIL Maps	FAO, USGS, Water Base, Future Water Group Netherlands	As per availability

A detailed information about the data sources and their resolution can be had from their respective sources.

7: Methodology

The modelling tools/framework such as SWAT, HEC-HMS, WA+ and Budyko based approach will be applied for quantifying the water yield potential of these basins. The study will also assess the effects of climate and landuse changes on the water yield. Along with this, the hydrological sensitivity and resilience capacity of these basins will also be assessed using the Budyko framework. For climate change analysis CMIP5/CMIP6 projections will be used in this study. For LULC change and impact assessment, decadal and projected LULC maps will be prepared and analyzed accordingly. For future projection of LULC change Markov chain based approach will be applied in this study. Figure 2 shows the flow chart of the methodology.

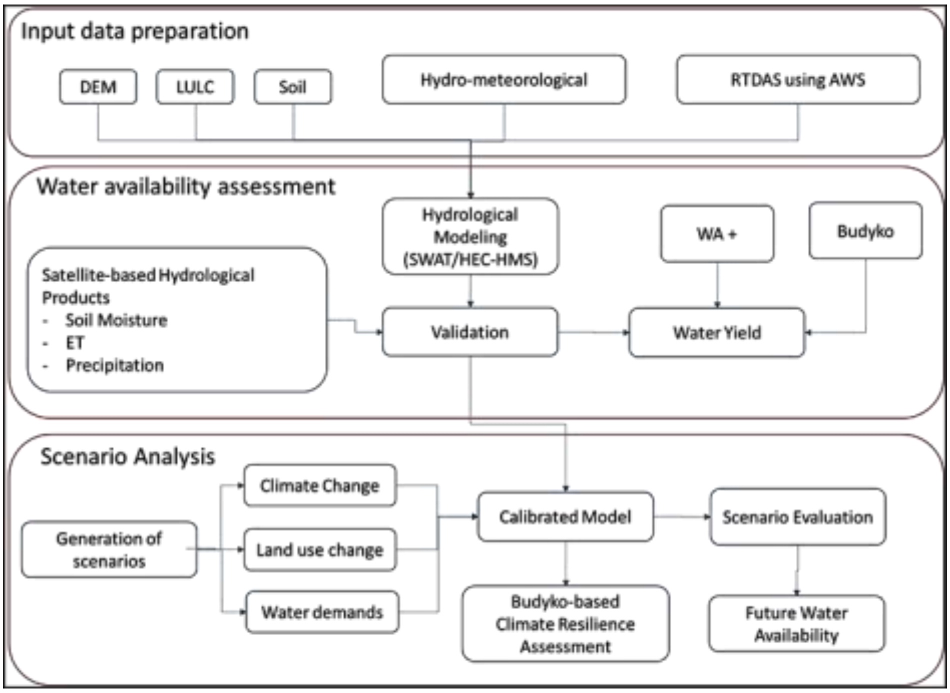


Figure 2: Modelling Steps

8. Project Budget: Year-wise breakup of the budget:

Sl. No.	Head	Amount (in Lakh)			
1:	**Manpower (Salaries/ wages of project staff)**	**1st Year**	**2nd Year**	**3rd Year**	**Total**
	JRF (02 nos.) as per DST Norms	8.50	8.50	8.50	25.50
2:	Travel Expenditure	2.00	2.00	2.00	06.00
3:	Meetings/Workshop	1.50	1.50	1.50	04.50
4:	Others (Hiring of services, field works, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	3.00	5.00	5.00	13.00
5:	Contingency	2.00	2.00	1.00	5.00
	GRAND TOTAL	**17.00**	**19.00**	**18.00**	**54.00**

9. Expected Deliverables

- Thematic maps: DEM, soil and LULC, stream network maps
- Improved and bias free high resolution gridded precipitation and ET datasets
- Basin wise water availability estimates: Historical (BAU)
- Revised basin-wise water availability estimates: CC with no LU change
- Revised basin-wise water availability estimates: LU change with no CC
- Revised basin-wise water availability estimates: both CC and LU change
- Resilience and Non-resilience basins under changing climates
- Sub-basin wise project report for the state water resources department for planning

- Training on the modelling frameworks to the state officials of the water resources department and other Implementing Agencies of the NHP.

10. Advantages, Challenges and Limitations

- The proposed modelling frameworks/tools will be very useful for estimating the water yield potential for ungauged basins using satellite and open data sources including the datasets obtained from the field.
- All satellite data products have some level of uncertainty and error which will be effectively taken care of in this study for generating error free and bias corrected datasets for future use.
- The hydrological resilience analysis will be an effective criterion to understand the historical as well as future changes in the basin to ensure the sustainability of the water resources.
- The main challenge of this study is that the study basins are ungauged hence the dependability on the satellite datasets will be on the larger side. Therefore, the alternative hydrological calibration strategies can be accounted utilizing the relevant hydrological variables such as ET and soil moisture which can be measured/estimated in the absence of the observed discharge datasets.

11. Period of Project:

- Three years from the date of the start of the project

Expected Outcome (Quantifiable Deliverables) of Key Activities with Timeline (Tentative):

Sl. No.	Expected Outcomes/Quantifiable Deliverables	1st Year				2nd Year				3rd year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1:	Hiring Manpower	■	■										
	Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments	■	■	■									
4:	Analyse long-term hydro-meteorological variables			■	■	■							
5:	Hydrological Modelling: SWAT model Setup			■	■	■							
6:	Hydrological Modelling: HEC-HMS model Setup												
7:	WA+ and Budyko Frameworks:		■	■	■	■							
8:	Model's validation using satellite and observed (if available) datasets				■	■	■	■					
9:	Water potential of the west-flowing rivers							■	■	■			
10:	Hydrological sensitivity and resilience capacity									■	■		
11:	Training on the hydrological models										■	■	
12:	Detailed basin wise project report for the state water resources department and Regional Conference with NHP											■	■

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 F
4	Dr. (Mrs.) Jyoti P. Patil	Scientist D (LCU)
5	Er. Digambar Singh	Scientist D
6	Sri. Rohit Sampatrao Sambare	Scientist B
7	Sri Subhash Kichlu	PRA
8	Sri Rajesh Agrawal	SRA
9	Sri N. R. Allaka	RA

APPROVED WORK PROGRAM FOR THE YEAR 2021-22

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	NIH	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020- Feb 2023	On-going
2	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Sep 2020- Aug 2023	On-going
3	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	NIH	A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Sep 2020- Aug 2022	On-going
Sponsored Projects					
1	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	DST-NMSHE	A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora	Mar 2016-Sep 2021	completed
2	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI)	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	On-going

Proposed Training/Webinar/Outreach Activities of RMOD (2021-22)

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Recorded webinar on ‘Water for Public Health (W4PH): Preparing for Disasters and Pandemics’ (33 presentations from 35 speakers)	26 August 2021 to 06 October 2021	NIH Roorkee	Researchers, Professionals, Health workers, and NGOs	V.C. Goyal, J. P. Patil, Varun Goyal
2	Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands	Sept. 2021	NIH Roorkee	R&D Institutes/University/Govt. Organizations	NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst

3	Awareness Programme for School Children	July-Sep 2021	2 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
4	3-days training workshop on Eco-hydrology for Sustainable Development	06-08 Oct 2021	HRRC-NIH, Belgavi	Researchers, Professionals, Scholars	B Venkatesh, J P Patil, V C Goyal, Amrendra Bhushan
5	NIH-IWP joint state level workshop on 'Enhancing Capability to Address Climate Change in Integrated Water Resources Management (IWRM) in Uttarakhand State'	07 Dec 2021	NIH Roorkee	Officials from state departments, Researchers, NGOs	NIH: V.C. Goyal, J. P. Patil, Varun Goyal, Amrendra Bhushan IWP: Veena Khanduri, Aditi Tallu Kaul

Other Outreach Activities:

S.N.	**Activity**
1	• Lecture on 'Why and how of patenting for Indian academicians and R&D Institutes', delivered by Ms Sangeeta Nagar, Scientist F, Patent Facilitating Centre, DST-TIFAC on 29-09-2021 • 'Guidebook on S&T interventions for ponds rejuvenation', Sponsored by DST, Government of India • Brochure on 'Water for public health' released on 22nd March 2022 (World Water Day)
2	• Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi
3	• Coordination of 75 planned Activities at HQ & RCs under Azadi Ka Amrut Mahotsav @ India 75 • Organizing activities as per mandate of Division under Azadi Ka Amrut Mahotsav @ India 75
4	• Any other Outreach activity on demand/assigned

PROPOSED WORK PROGRAM FOR THE YEAR 2022-23

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	NIH	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020- Feb 2023	On-going
2	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Sep 2020- Aug 2023	On-going
3	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	NIH	A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Sep 2020- Aug 2022	On-going
4	Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun	NIH	Omkar Singh (PI) V.C. Goyal, Rajesh Singh (Co-PI), Jyoti Patil, Rohit Sambare, N.R. Allaka; Team from SRHU-HIHT, Dehradun	April 2022- Mar 2024	New Study
Sponsored Projects					
1	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI)	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	On-going

<u>Proposed Training/Webinar/Outreach Activities of RMOD (2022-23)</u>

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Brainstorming session on 'Water Security in a Changing Environment-Focus on Indian Himalayan Region (IHR)', during 16th Uttarakhand Science and Tech	April 2022	UCOST, Dehradun	Conference participants	V. C. Goyal, J P Patil, Amrendra Bhushan
2	5-days training on 'Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based Solutions' sponsored by National Water Mission	April 2022 May 2022 June 2022 July 2022	Bhopal Belgaum Kakinada Roorkee	R&D Institutes/ University/ Govt. Organizations	Bhopal: T Thomas Belgavi: B Venkatesh Kakinada: YRS Rao Roorkee: J P Patil, Omkar Singh, Rohit Sambhare

	(4Nos)				
3	Training on GEM	April 2022	NIH Roorkee	Admn and finance staff of NIH	A. R. Senthil kumar Omkar Singh
4	Webinar on ecohydrological functioning of wetlands	April 2022	NIH Roorkee	Students and researchers	Rohit Sambare V C Goyal
5	Stakeholders workshop for Upper Dhasan Basin water resources assessment	May 2022	Bhopal	CWC, CGWB, State departments (Irrigation, WRD, Agril etc)	J P Patil, T Thomas, P K Mishra, Rohit Sambhare
6	Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands	May/Jun 2022	NIH Roorkee	R&D Institutes/University/Govt. Organizations	NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst
7	Five-day training program on "Hydrology of water bodies and their development under climatic uncertainty"	May/Jun 2022	NIH Roorkee	Engineers in Irrigation/PHE/SWC departments	A. R. Senthil kumar, Rohit Sambare, Santosh M Pingale, N R Allaka
8	E-course on Urban hydrology	June 2022	NIH, Roorkee NIUA, Delhi	Researchers, academicians, scholars	NIH: V C. Goyal, J. P. Patil NIUA: Victor Shinde
9	Awareness Programme for School Children	July-Sep 2022	3 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, A. R. Senthil kumar, Rajesh Agarwal, N R Allaka

<u>Other Outreach Activities:</u>

S.N.	**Activity**
1	• Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi • River Walk of Solani River • Short video on Hydrology for People @district level • Short video on vulnerability assessment under Hydrology for People series
2	• Coordination of 75 planned Activities at HQ & RCs under Azadi Ka Amrut Mahotsav @ India 75 • Organizing activities as per mandate of Division under Azadi Ka Amrut Mahotsav @ India 75 • Compendium of NIH activities on the activities under Azadi Ka Amrut Mahotsav @ India 75
3	• Any other Outreach activity on demand/assigned

1. **Title of the Study:** Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand Region, Central India.

2. **Project team:**

   a. Project Investigator: Dr. Jyoti P. Patil

   b. Project Co-Investigator(s):

      Dr. T. Thomas (RC-Bhopal)

      Dr Prabhash K Mishra

      Er. Rohit Sambhare

3. **Type of Study:** Internal; **Budget**: 41.0 Lakhs

4. **Date of start:** 01.09.2020

5. **Scheduled date of completion:** 28.02.2023

6. **Duration of the Study:** 2.5 years (30 months)

7. **Study Objectives:**

The major objective of the study is to assess the demand and availability of water in Upper Dhasan basin located in the drought prone Bundelkhand region in Central India, and to develop a plan for the optimal water allocation using WEAP model and WA+ framework. The following are the sub-objectives of the study:

a. Estimation of water balance components of Upper Dhasan basin using WEAP and WA+ outputs.
b. Estimation of water productivity and land productivity of Upper Dhasan Basin using WA+ framework.
c. Vulnerability assessment of Upper Dhasan Basin using IPCC approach.
d. Assessment of future water supply-demand scenario in the light of upcoming projects, inter-basin transfers and climate change.
e. Development of water allocation plan for the optimal use of water resources in the study area.

8. **Statement of the Problem:**

The Dhasan River is a major tributary of the Betwa river system which originates in Raisen district of Madhya Pradesh and flows through the various drought prone districts in Central India viz., Tikamgarh, Chhatarpur districts in MP and Lalitpur, Jhansi and Hamirpur districts in UP. It is one of the important rivers in Bundelkhand region which has off late become a drought prone region due to the various issues facing the region including the overexploitation of the natural resources and changes in the weather pattern. The frequency of occurrence of droughts is once in 4 years. The variability of rainfall is the main reason for the regular water stress. However, the limited groundwater availability in the hard rock region coupled with low water holding capacity soils further aggravate the water stress thereby creating livelihood issues for the local population.

Due to the limitations of groundwater development in the basin, thrust is towards developing surface water resources in the region. Few projects have come up viz., Bansujara Multipurpose Project, the Banda Irrigation Project. The Bansujara Multipurpose Project has been completed, whereas the construction of the Banda Irrigation Project is in progress. The Banda Irrigation Project located in Banda block of Sagar district has a CCA of 80000 ha and involves providing micro-irrigation. Apart from this there is a proposal to transfer surplus water in Dhasan basin to the water deficit Bina River (Bina Complex Irrigation & Multipurpose Project) by constructing four dams for irrigating 84200 ha and generation of hydropower.

This study aims to have a holistic look into the overall water availability in the Dhasan basin, in the light of the committed storages of the planned projects and realistic assessment of the planned projects. The estimation of the water availability and water productivity using both the WEAP model and the Water Accounting+ framework in totality will help to understand the supply of available water along with the demands from various sectors in the drought prone region in Bundelkhand. The assessment of the reliability of these projects in the light of the climate change, based on scenario analysis for the estimation of the future water supply-demand and development of an optimal water allocation plan for the basin, shall provide a useful tool in the hands of the decision makers to fine-tune the water resources development and management policies accordingly. The State Government is interested in taking up such a project as this will provide them with an optimal water allocation plan in the present time as well as into the future. The Chief Engineer, BODHI, MP Water Resources Department has given the consent in this regard.

Very few studies related to the water resources have been carried out in Dhasan basin, viz., water balance (Thakural et al., 2009) and drought (Kar et al., 2016). The Water Evaluation and Planning System (WEAP) is one such tool which can be effectively used for devising optimum water allocation policies based on the appraisal of water management strategies at the basin scale. The model has the capability of carrying out scenario based analysis which will provide multiple options for the water resources managers and decision makers for taking effective decisions.

Increasing competition for land and water resources is expected in the coming future due to rising demands for food and bioenergy production, biodiversity conservation, and changing production conditions due to climate change. Growing competition for water in many sectors reduces its availability for irrigation. In this situation, land productivity and water productivity increment is the most efficient solution for meeting increasing food demand and climate variation. For communicating water resources related information and services obtained from consumptive use in a geographical domain to users, water accounting (WA) is the best process. WA+ is a modified and upgraded version of water accounting which has been developed by IWMI (Karmi et al., 2013) based on original initiatives taken by the Delft University of Technology (Bastiaanssen, 2009). Water accounting plus (WA+) is a framework designed to provide explicit spatial information on water depletion and the net withdrawal process from river basins. It provides the link between water balance, land use, and water use as well as management options to modify it by grouping land use classes with common management characteristics. The major landuse of Dhasan basin is agriculture. Therefore, land productivity and water productivity assessment using WA+ framework will be useful for making sound water management strategies in the Upper Dhasan basin.

The ever-growing population and a parallel increase in the demand for natural resources have left agricultural and water resources of the region susceptible to increasing climate change risks. Vulnerability assessment (VA) is, therefore, considered as a useful tool for planning of climate change adaptation and risk management strategies in water challenged areas. 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. The drought frequency has been increased in Bundelkhand region due to climate variability. Therefore, focus of this study will be on generating vulnerability index of Upper Dhasan basin, by IPCC approach, with main focus on indicators like annual rainfall, number of rainy days, number of dry days, flood frequency, drought frequency, variation in temperature (max, min) etc. The assessment would facilitate the identification of areas, which are vulnerable to climate change and need special attention towards adaptation.

The water availability needs to be assessed for multiple scenarios of new and upcoming water storage infrastructure, plans for out of the basin water transfers as well as the highly uncertain impacts of the climate change on the water availability scenario in the basin. This will provide as realistic assessment of the present and future water availability scenario in the basin based on optimal water allocation policies and plans can be devised. Such an integrated effort will go a long way in managing the available water resources in the present and future and managing the demands in tune with the availability and constraints. This will result in the development of WEAP and WA+ based water allocation plan for the optimal use of water resources in the study area, which will be useful to the line departments and stakeholders including the Agriculture Department (agriculture), Water Resources Department (better water distribution for irrigation by integrated operation of projects), Public Health Engineering Department (water supply for domestic use) and Industries that may be benefitted, ultimately leading to the development of the region resulting in improved livelihood options for the local population.

9. Methodology

Study area:

The study has been selected in Upper Dhasan basin upto Garrauli G/D site on Dhasan river falling in Chhatarpur district (Figure 1). The area of Upper Dhasan Basin is 3565 sq. km.

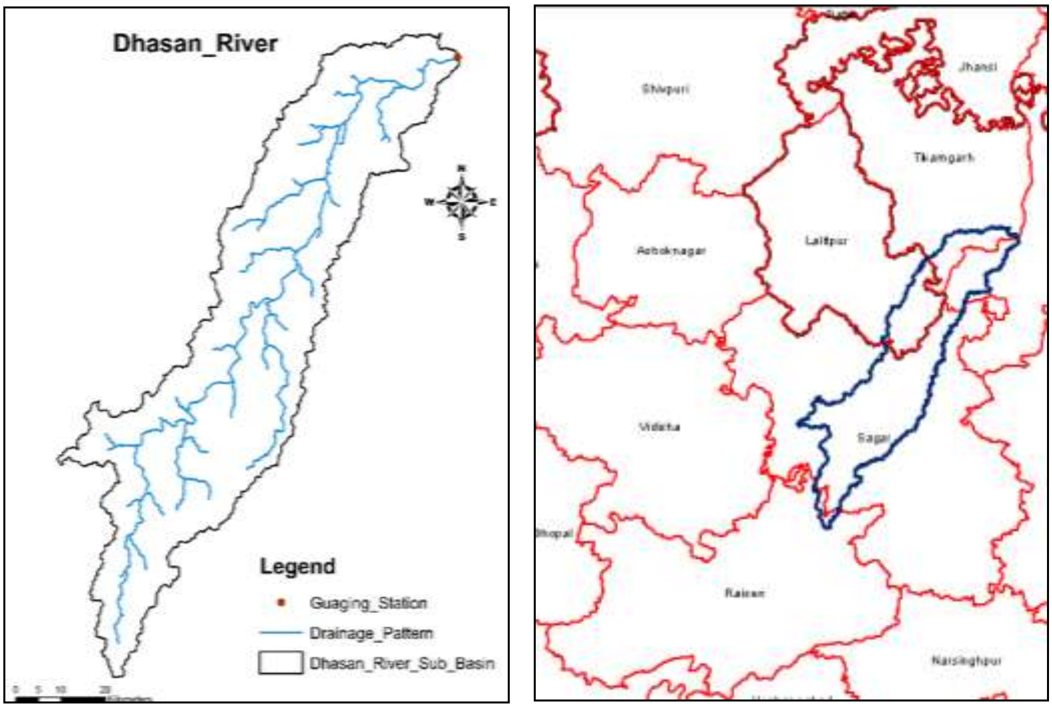


Figure 1 Location of study area (Upper Dhasan basin)

Detailed Methodology:

1. Preparation of data inventory including climatic, hydrologic, demographic and socio-economic data.
2. Processing and analysis of data.
3. Trend analysis of meteorological and hydrological variables.
4. Customization, calibration and validation of WEAP model for runoff simulation.
5. Estimation of water productivity and land productivity using WA+ framework
6. Assessment of environmental flow requirement using established techniques and water balance and supply demand scenario using WEAP and WA+ outputs.

7. Vulnerability assessment using IPCC approach
8. Assessment of climate change on the future water availability.
9. Water allocation planning for the present and future under alternate scenarios of upcoming water resource infrastructure, population growth, inter-basin water transfer and climate change using WEAP.
10. Stakeholder workshop and Final Report.

10. Approved Timeline:

Sr. No.	Work Component	2020-21			2021-22				2022-23		
		II	III	IV	I	II	III	IV	I	II	III
1.	Preparation of data inventory including climatic, hydrologic, demographic and socio-economic data.	■	■								
2.	Processing and analysis of data.	■	■								
3.	Trend analysis of meteorological and hydrological variables.	■	■	■							
4.	Customization, calibration and validation of WEAP model for runoff simulation.		■	■	■	■					
5.	Estimation of water productivity and land productivity using WA+ framework		■	■	■	■					
6.	Assessment of environmental flow requirement using available techniques Assessment of water balance and supply demand scenario using WEAP and WA+ outputs		■	■	■	■	■	■			
7.	Vulnerability assessment			■	■	■	■	■			
8.	Assessment of climate change on the future water availability.						■	■	■	■	■
9.	Water allocation planning for the present and future under alternate scenarios						■	■	■	■	■
10.	Stakeholder interaction and Final report								■	■	■

11. Objective and achievement

Objective	Achievement
Data collection and analysis	Trend analysis of meteorological and hydrological variables is completed
Estimation of water balance components of Upper Dhasan basin using WEAP	WEAP model is formulated for complete Dhasan Basin and preliminary results were shared during last WG meeting
Estimation of water productivity and land productivity of Upper Dhasan Basin using WA+ framework	The WA+ is run for Betwa river basin. The results will be presented
Vulnerability assessment of Upper Dhasan Basin using IPCC approach	List of indicators is finalised. Vulnerability assessment is under progress

12. Recommendation / Suggestion: NA

Recommendation / Suggestion	Action taken
No specific comments	NA

13. Analysis & Results

i. Collection of information and Hydro-meteorological Data

a. The gauge and discharge data of Garaulli site, Madhya Pradesh was collected from Yamuna Basin Organization (YBO), Central Water Commission (CWC), Government of India from 1991-92 to 2019-20.
b. The daily meteorological data [Rainfall, Temperature (maximum and minimum)] of 17 grid points have been collected from IMD, Pune for 50 years (1971-2020).

The details of hydro-meteorological, spatial, and agriculture data is given in the following table1.

Table 1 Details of hydro-meteorological data

Data	Details	Source
Discharge data (Daily)	1991-92 to 2019-20	CWC
Rainfall (Daily)	0.25^o X 0.25^o ; 1971-2020	IMD
Temperature (Daily)	1^o X 1^o; 1971-2019	IMD
Geospatial Maps	Land use Land Cover (LULC) River and Water bodies Soil type	USGS earth explorer, NRSC
Agriculture	Major crops (kharif/ rabi), area under each crop, water requirements, irrigated area	Respective District Administrations, District Irrigation Plans (DIP)
Demand data	Population Livestock Industries	Census/ District Administration websites / District reports
Supply information	Water Supply, Groundwater source Tank capacity	IMD/ district authorities CGWB district reports Minor irrigation census

ii. Spatial database

The spatial database of the basin such as Digital Elevation Map (DEM), LULC map, Drainage Network were created. The landuse of the basin is predominantly agriculture (58%). The area under each landuse is given in Table 2.

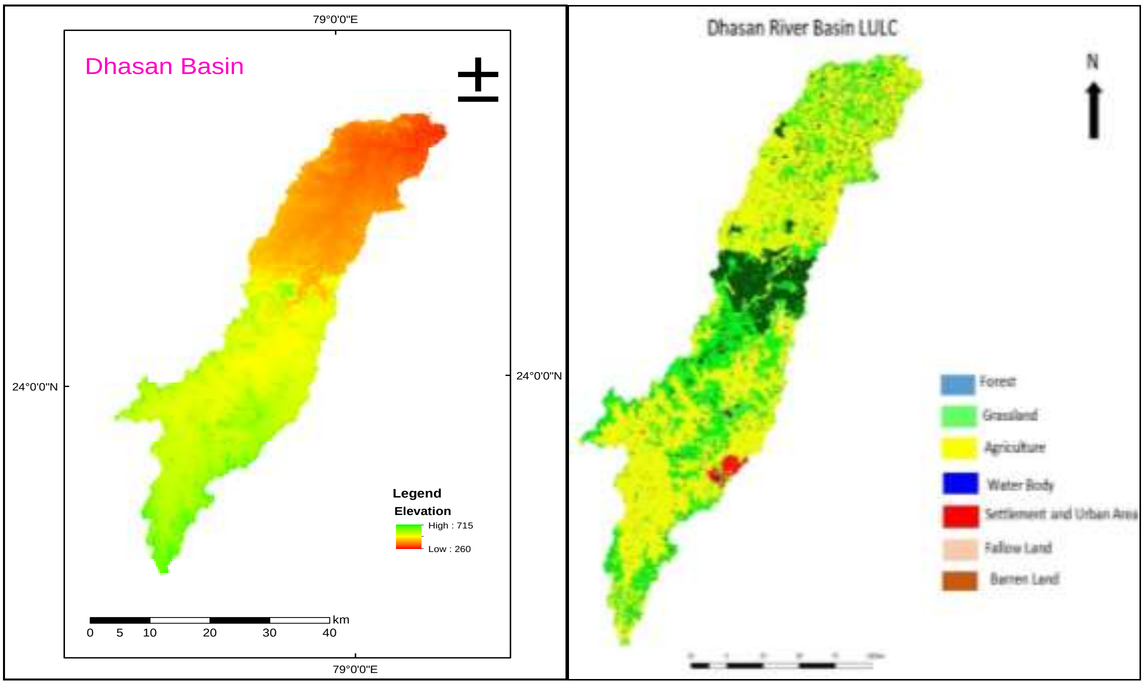


Figure 2 DEM and LULC maps

Table 2 Land use/land cover statistics of Dhasan river basi**n**

Land use/cover categories	**Area (km^2)**	**Percentage (%)**
Agriculture Area	1982.23	58
Grassland	959.58	28
Forest Area	304.91	9
Barren land	74.02	2
Fallow land	58.20	2
Urban area	29.41	1
Water bodies	18.04	1

iii. Analysis of meteorological and hydrological variables

For modeling purpose, the basin is divided into two catchments. The sub-watershed 1 (SW1) is upto Banda Irrigation project and sub-watershed 2 (SW2) is downstream of the Banda irrigation project, upto the outlet of the basin. The Table-3 summarizes indices estimated for SW1 and SW2 alongwith their trend using Kendall-tau significance test.

Table 3 Indices estimated for SW1 and SW2

Index	SW1		SW2	
	Value	Trend statistics	Value	Trend statistics
Mean Tmax (^{0}C)	32.56	0.0226	32.52	0.0172
Mean Tmin (^{0}C)	18.43	0.0193	18.96	0.0161
Mean Rainfall (mm/day)	2.91	-0.0044	2.78	-0.0082
No. of days RF>= 10mm	28.96	-0.0742	29.80	-0.1205
Max no. consecutive dry days (during Jun, Jul, Aug)	15	-0.1838	15	-0.1021
Max no. consecutive wet days (during Jun, Jul, Aug)	8	-0.0323	10	-0.0249

Greatest 3-day total rainfall (mm)	183.72	0.3426	170.82	-0.1295
Greatest 5-day total rainfall (mm)	219.28	-0.2357	210.08	-0.3429
Greatest 10-day total rainfall (mm)	301.61	-0.5746	282.53	-0.677

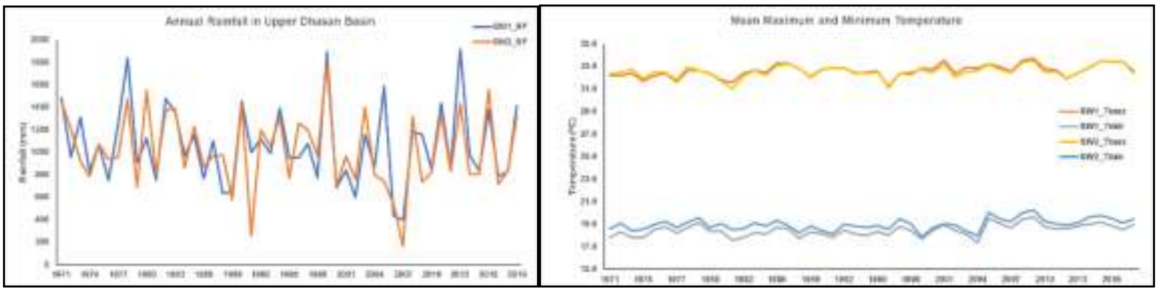


Figure 3 Annual rainfall and mean temperature variation in basin

iv. WEAP model formulation

The WEAP model for formulated for complete Upper Dhasan Basin for the current account year 2015 by considering demands (agriculture, forest, domestic, industrial), supply resources (rainfall, groundwater, river and major surface reservoirs). The scenarios like population growth, increased irrigation efficiency, industrial growth and incorporation of rainwater harvesting structures were run in the WEAP to observe the unmet demands of the basin during 2021-2050.

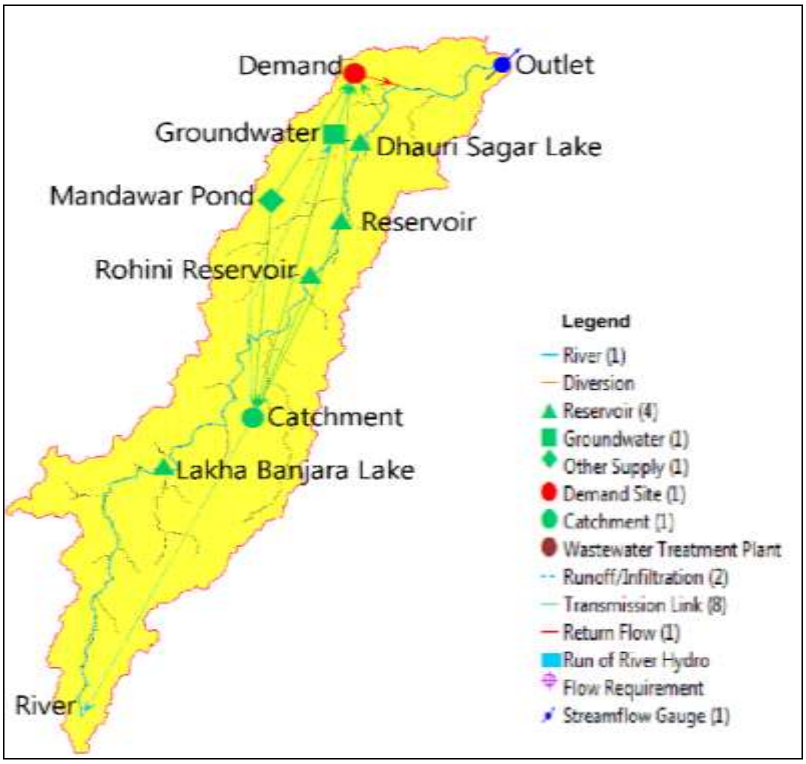


Figure 5 WEAP model formulation for Dhasan Basin

For detail analysis of water balance components and impact of proposed dams in the basin, the WEAP model will be formulated for two sub-catchments.

v. WA+ Framework

Precipitation and Evapotranspiration Variability

A preliminary analysis was carried out to understand the precipitation and evapotranspiration variability across the Betwa basin. Figures 6a shows the spatial variation of precipitation obtained from CHIRPS data (developed by the Climate Hazards Group InfraRed Precipitation with Stations) for the period of 2003-2014. It can be observed that the eastern and southern parts of the Betwa basin receives higher rainfall as compared to the rest part of the basin. Overall, the basin receives less rainfall with an annual average of 958 mm. In the contrary, the mean monthly ensemble ET is higher in the northern and central parts of the basin as shown in Figure 6b.

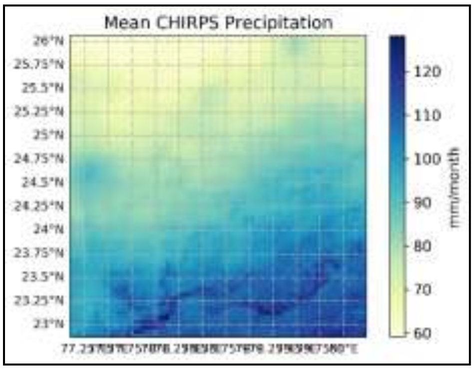


Figure 6a Spatial variation of mean monthly CHIRPS precipitation

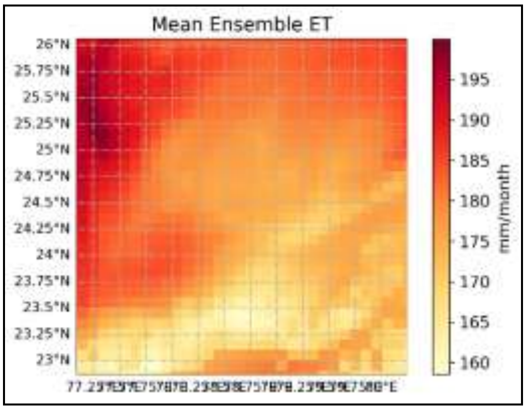


Figure 6b: Spatial variation of mean monthly ensemble ET

WA+ based land use land cover (WALU)

WA+ recognizes the influence of land use on water cycle and provides the link between water balance, land use and water use as well as management options to modify it, by grouping land use classes with common management characteristics. WA+ classifies LULC in to four major LULC classes segregated from 80 global land use classes based on the land use and water management practices as: (1) Protected Land Use (PLU); (2) Utilized Land Use (ULU); (3) Modified Land Use (MLU); and (4) Managed Water Use (MWU). PLU represents areas set aside for minimal disturbance by humans e.g. National Parks & Wildlife Sanctuaries, etc. ULU represents a land use that provides a range of ecosystem services and which has had little interference by man with less exploitation e.g., Grasslands, forest land, natural pastures, etc. MLU refers to land that is significantly modified by human activity. Here only the land use is modified e.g., Rainfed cropping systems, creation of plantation forests, etc. MWU represents the land use classes in which both the land use and water is managed with significant exploitation, e.g. Irrigated cropping systems. The WA+ based land use for the Betwa basin is shown in Figure 7. The land use distribution is presented in Table 4.

Table 4: Land use distribution for the Betwa basin generated using 8 different datasets

LULC	**Area (Km^2)**	**% area**
Forest	3828.25	10.62
Grassland	3756.81	10.42
Waterbody	1330.06	3.69
Barren/waste	2892.94	8.02
Builtup	6223.25	17.26
Agriculture	18018.44	49.98

Note: Distribution has been generated using 8 global datasets.

Development of Evapotranspiration Sheet [Sheet 2]

Sheet 2 presents provides information on water consumption in a basin as a total value and per water sector (land use type). Major inputs for the generation of Sheet 2 are RS-based evapotranspiration maps (ET), Leaf Area Index (LAI), Net primary production (NPP), Gross primary production (GPP), daily precipitation and a LULC map. Developed Sheets for wet and dry year for the Betwa basin is shown in Figure 8a and Figure 3b, respectively. The total water consumptions of the basin for the wet year, i.e., 2013-14 is found to be 41.5 km^3/year with further partitioning of ET into evaporation (E) from soil and Transpiration from different LULC. The total water consumptions of the basin for the wet year, i.e., 2013-14 is found to be 25.8 km^3/year. Sheet 2 also shows that the non-beneficial consumptions in the basin indicating further scope for water conservation practices to be adopted in the basin to minimize non-beneficial consumptions.

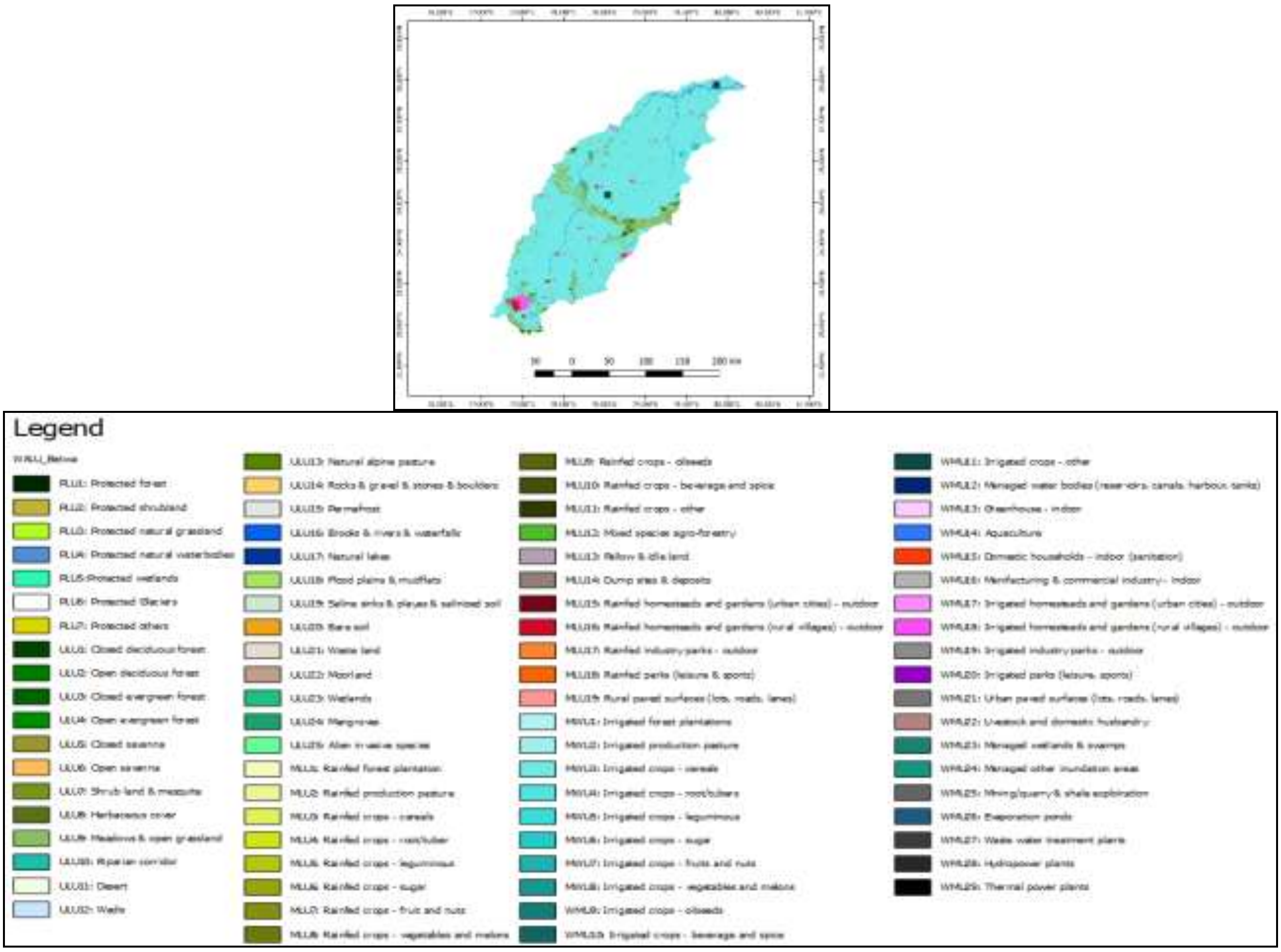


Figure 7: LULC map of Betwa basin generated using WALU

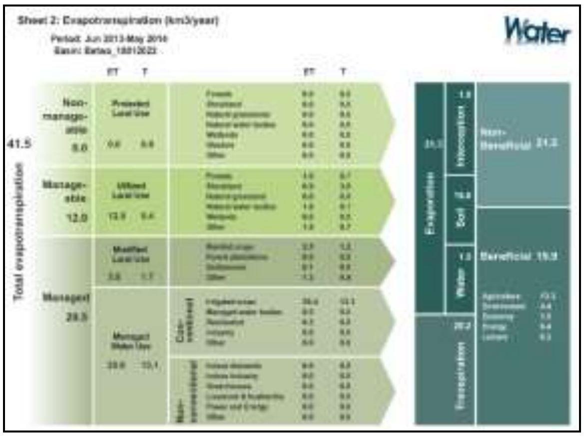


Figure 8a: Evapotranspiration Sheet: Sheet 2 for wet Year 2013-14.

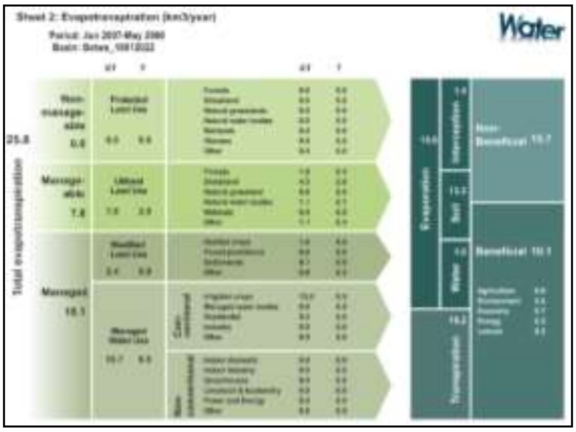


Figure 8b: Evapotranspiration Sheet: Sheet 2 for Dry Year 2007-08.

15. **End Users / Beneficiaries of the study:** Agriculture Department (agriculture), Water Resources Department (better water distribution for irrigation by integrated operation of projects), Public Health Engineering Department (water supply for domestic use) and Industries.

16. **Deliverables:** Development of Water Management Plan for Upper Dhasan Basin.

17. **Major items of equipment procured:** None.

18. **Lab facilities used during the study:** None.

19. **Data procured or generated during the study:** None.

20. **Study Benefits / Impacts:** Outputs of the study will be used in preparation of 'Integrated Water Management Plans at Sub-basin level and District level.

21. **Involvement of end users/beneficiaries:** Local stakeholders, District Administration of Sagar, Chhatarpur and Tikamgarh; Chief Engineer, Bodhi, Ken-Betwa Basin, WRD & Deputy Director, Agriculture of Sagar, Chhatarpur and Tikamgarh.

22. **Specific linkage with Institution and /or end users/beneficiaries:** Various line departments (KVKs, Irrigation, WRD, Agriculture, Industry).

23. **Shortcoming / Difficulties: NA**

24. **Future Plan:** Possible up-scaling to other water stressed regions/basins.

1. **Title of the study:** Establishing hydrological regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District)

2. **Study Group:**

   Project Investigator:
   Rohit Sambare, Scientist B, NIH, Roorkee

   Co Project Investigators:
   Dr. V.C. Goyal, Scientist G, NIH, Roorkee
   Dr. Suhas Khobragade, Scientist G, NIH, Roorkee
   Dr. Gajendra Singh, Scientist, USAC, Dehradun
   Sh. Nageswara Rao Allaka, RA, RMOD, NIH Roorkee
   Scientist from HESCO, Dehradun

3. **Nature of Study:** Interdisciplinary

4. **Date of start:** September 2020

5. **Expected date of completion:** August 2023

6. **Weather externally funded or not:** No

7. **Objectives:**

- To study the hydrological regimes (e.g. water balance, water inflow-outflow, connectivity with aquifer and/or streams) and establish ecohydrological functions
- To assess the impact of climate variability and anthropogenic activities (e.g. local Gujjar community)
- To assess the floral diversity, invasion by invasive, temporal changes in the wasteland and establishing long term monitoring plots.
- To support in developing the long term monitoring and management plan for conservation of Jhilmil Jheel wetland.

8. **Statement of the Problem:**

Wetlands are facing country's ever increasing population and their economic aspirations and subsequent anthropogenic pressures. Monitoring and conservation of large wetlands such as all Ramsar sites are done regularly. But wetlands which is having relatively smaller area of influence get very little attention. There are many pristine wetlands which are needs to be monitored and should be kept from any external significant disturbances. As last inventory of wetlands in country was conducted in 2011, and it is very difficult to update all the information on regular basis. India's past forestry practices have often considered grasslands as "wastelands". The resultant plantation of exotics and other indigenous tree species in grasslands has converted several grassland habitats into woodland (Rahmani et al. 1988). The ruthless destruction of terai ecosystem for agriculture and human settlements has led to large-scale fragmentation, shrinkage, and degradation of these unique habitats. High resolution remote sensing coupling with field surveys plays important role in monitoring purpose. The regular monitoring (covering all seasons) of wetlands is very important to understand all the functions and ecological linkages of the concerned wetland. The lack of temporal and spatial extent (swath) of the satellite data can be also very problematic as wetlands are relatively very small water bodies. Wetlands are also susceptible to climate change impacts. Varying rainfall and rising temperature also affecting health of wetlands.

Jhilmil lake wetland is situated (78013'17.50" E; 29047'49" N, 240m msl) between the Haridwar–Najibabad Highway with the natural course of the Ganga to the south of it. It is surrounded by the Reserve Forest of the Chidiyapur Range. It is permanent freshwater lake spread over 148ha (WWF 2012). The catchment area of the wetland consists dry plain Sal forests and northern dry mixed deciduous forest. The temperature in summer season varies from 290C in March to 390C in May, however in winter season 6 to 100C. Annual average rainfall in the region is 1174mm with 84% precipitation occurring in monsoon season. Jhilmil lake is home of one of the most charismatic faunal species of Terai landscape Swamp Deer and also corridor for various animals of Rajaji Tiger Reserve as both shares common boundaries. It is a main source of water for animals in the surrounding forests. It also helps to stabilize micro-climate of area of the surrounding region.

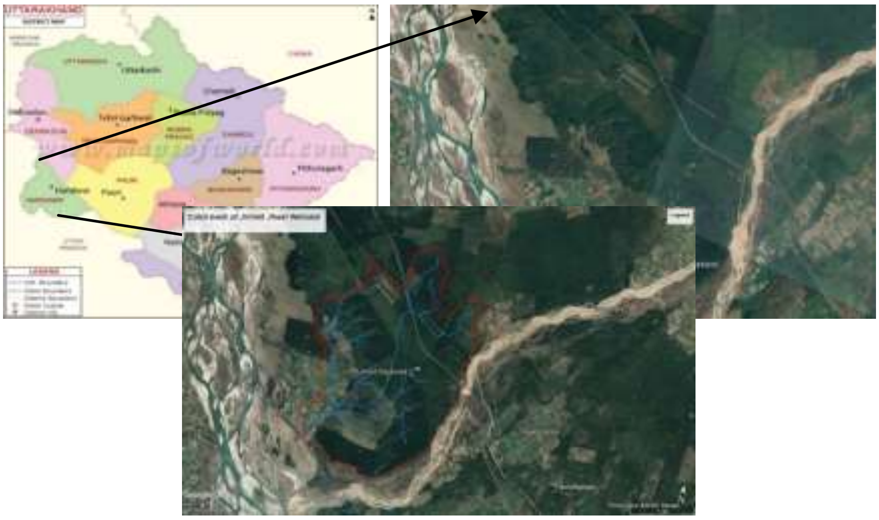


Figure 1: Catchment of Jhilmil Jheel Wetland (Catchment derived from NRSC's high resolution CARTODEM)

9. Brief methodology:

- Mapping of the wetland will be carried out using high resolution satellite images and LULC will be generated by supervised classification. Also NDVI and NDWI maps will be generated for estimating vegetation distribution and hydroperiod of the wetland an its catchment. With the help of parameters derived from satellite images and high resolution DEM disturbance features such as crop plantation, reduction of water during various seasons, increasing tree or vegetation population in the wetland area shall be analysed. It can be vital for the deciding future conservation strategies. HGM functional assessment methods will be adopted to analyse the health score of wetland.

- SWIM (Soil and Water Integrated Model) is a semi distributed ecohydrological model, integrating hydrological processes, vegetation growth (agricultural crops and natural vegetation), nutrient cycling (nitrogen, N and phosphorus, P), and sediment transport at the river basin scale with the daily time step. SWIM will be set up for estimating ecohydrological functions of the wetland's catchment such as lateral water flows in the catchment, vegetation growth, sediment transport at desired time scales. The outputs of the model may be used in the deriving water balance of the wetland's catchment.

- Seasonal sampling of the water from the wetland, River Ganga, its two adjoining tributaries and groundwater will be done for the stable isotope analysis. Temporal hydrologic connectivity will be established between all waterbodies through laboratory analysis. Seasonal water table variations in the catchment will be analysed hence the contribution of the wetland to groundwater or vice versa can be quantified. Water quality analysis including anion, cation analysis; heavy metal analysis will be done.

The graph theory will be attempted for establishing connectivity between various ecological and hydrological components of the wetland.

- RAWES (Rapid Assessment of Wetland Ecosystem Services) tool will be used to assess the wetland's ecosystem services through community surveys. Various wetland's health indicators will be developed such as Change in wetland area, Change in land cover, Wetland Stress Index, Productivity of the wetland, Hydroperiod. Floral diversity and Invasive species assessment will be done by detailed floral inventorisation (list) for various seasons from the wetland, its upstream and downstream. Lon term monitoring plots will be established for regular monitoring of the grassland and invasive species. Wetland monitoring and management plan will be generated for its conservation keeping all the aspects such as spatial extent, catchment characteristics, hydrology, biodiversity and ecosystem services of the wetland. The plan will be conveyed to state forest department and state wetland authority.

10. Timeline

Sr. No.	Work Component	FY 2020-21				FY 2021-22				FY 2022-23			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1	Hiring of project staff, identification and procurement of equipment	■	■	■	■								
2	Collection of data from various sources	■	■	■	■								
3	Field data collection	■	■	■	■	■	■	■	■	■	■		
4	Satellite data preparation (LULC and soil data testing)	■	■	■	■								
5	Finding effect of disturbance features		■	■	■								
6	Setting up of SWIM model and its calibration and validation.			■	■	■	■	■	■				
7	Water sample collection from wetland and Ganga river and testing them stable isotope laboratory and water quality analysis	■	■	■	■	■	■	■	■	■	■		
8	Water balance study of catchment								■	■	■	■	
9	Inventorisation of plant's diversity				■	■	■	■			■	■	
10	Preparation of detailed vegetation map and habitat assessment (field sapling)				■	■	■	■	■	■	■		
11	Establishing long term plots and monitoring				■	■					■	■	

12	Preparation of conservation strategies												
13	Preparation of wetland management plan												
14	Report writing												
15	National workshop												

11. Achievements

- Several field tours have been done, sites for sample collection and water table measurement has been done.
- Collection of isotope samples for estimating the connectivity and water level measurement for post monsoon period has been done.

Sample Code	**Source**	**$\delta^{18}O$ (Oct 2020)**	**δD (Oct 2020)**	**$\delta^{18}O$ (Jan 2021)**	**δD (Jan 2021)**
JJ-1	Hand Pump	-7.69	-50.14	-7.79	-52.20
JJ-2	Open well	-4.42	-24.57	---	----
JJ-3	Tube well	-7.79	-50.28	-7.85	-48.83
JJ-4	Artesian Well	-7.21	-47.01	-6.99	-47.01
JJ-5	Artesian Well	-7.11	-47.29	-7.12	-46.35
JJ-8	Wetland stream	-7.84	-50.35	-7.92	-54.23
JJ-9	Hand pump	-7.73	-49.84	-7.96	-53.73
JJ-10	Hand pump	-7.46	-47.61	-7.56	-48.03
JJ-11	Hand pump	-8.95	-59.10	-9.04	-59.80
JJ-13	Hand pump	-7.61	-49.52	-7.21	-48.40
JJ-15	River	-11.07	-69.77	-10.68	-68.35
JJ-16	River	-7.17	-46.60	-9.96	-60.05
JJ-17	Hand pump	-6.95	-43.88	-6.81	-43.09

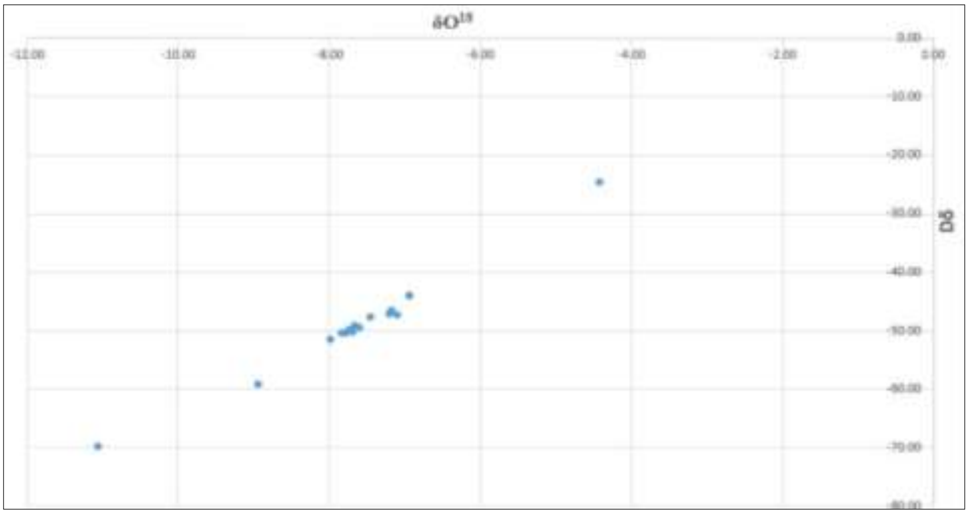


Figure 2: Isotopic composition of collected water samples from different sources (Oct 2020)

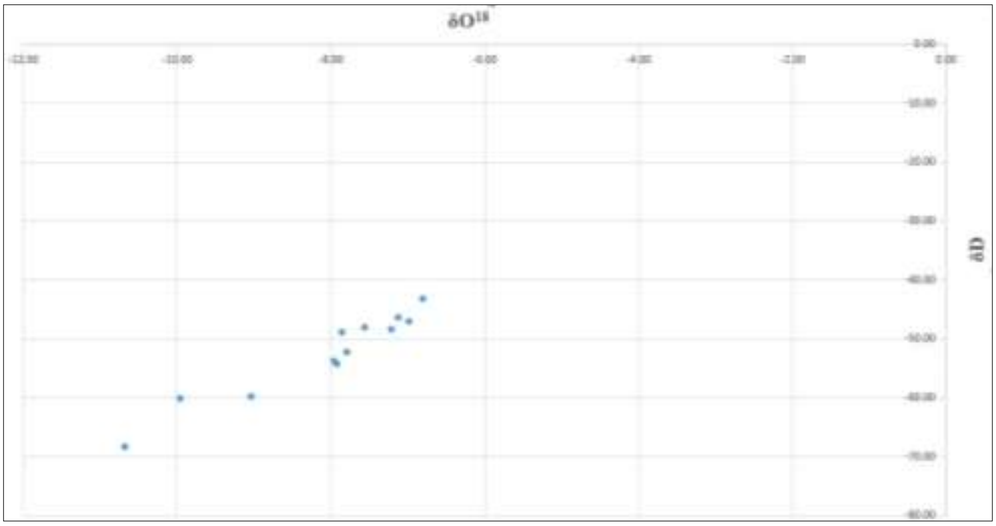


Figure 3: Isotopic composition of collected water samples from different sources (Jan 2021)

- Collection of water quality samples for post monsoon period has been done. Cation and anion analysis has been performed.
- High resolution Carto DEM and High Resolution Cartosat 3 image has been has been procured from NRSC Hyderabad.
- Available data from the forest department’s Automatic Weather Station (AWS) has been collected.
- Analysis of season wise variations in the vegetation features and water availability has been done using satellite images of different years.
- HGM approach has been performed for the functional assessment of the wetland using field data and remote sensing products. Effects of the various disturbance features have been analysed through this approach and health of wetland has been determined. Wetland health index has been generated. Future projection of health of wetland has also been analysed with this approach.
- The study has been interrupted since last working group because, project investigator Rohit Sambare had been on the leave since September 2021 due to his health reasons. As he joined office after his recovery, this study will be continued in coming months and further achievements will be presented in next working group agenda.

1. **Title of the Study:** Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana

2. **Study group:**
Dr A. R. Senthil kumar, Sc “F” RMOD
Sh. Omkar Singh, Sc “F”, RMOD
Sh. Rajesh Agarwal, SRA, RMOD
Sh. Nageswara Rao Allaka, RA, RMOD

3. **Date of start: September 2020**

4. **Duration of the study: 2 Years**

5. **Whether externally funded or not: Internal**

6. **Objectives:**
   a. To evaluate the existing cropping pattern and farming practices for estimation of farmer’s income
   b. To carry out scenario analysis considering combinations of crop types and cropping pattern, land allocation, water allocation under climatic variability, etc.
   c. To develop plan for optimized income from farming practices encompassing food and water security.

7. **Statement of the problem**

The rising population and industrial growth with climate change makes difficult to meet the demand of agricultural activities. Continuous over exploitation of ground water under uncertain occurrence of rainfall is inevitable to continue the traditional cropping pattern. Traditional cropping pattern is neither good for soil health nor for food security. Farmer’s income is often below optimal. Scientific planning considering cropped area, climate smart crop types, crop productivity, cropping pattern, farming input costs, and crop revenues, will evolve optimal utilization of available water and optimize farmer’s income from farming practices. Scenario analysis with projected population growth, landuse changes, climatic conditions, water-efficient irrigation technologies, etc. shall provide a canvas of options to be considered for optimal income from farming practices in future. A scientific plan is needed to guide the farming community about optimizing their income from farming practices that lead to food and water security.

8. **Methodology**

The optimal income from agricultural for various scenarios of crop types and land resources in Mewat region, Haryana is evolved by setting up of WEAP tool with the combination of LINGO. 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 and census department. The future climatic scenarios will be downscaled from GCM models for RCP4.5 and RCP8.5. 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 optimum income for agricultural sector will be arrived by LINGO using the input variables obtained from the scenario analysis of WEAP model for crop types and land resources. The optimization functions such as maximizing the net income from agriculture, minimizing the water usage, minimizing the cost of cultivation with the constraints of land area for crops, water availability based on the scenario analysis and cost of cultivation are considered for achieving the objectives. The scenarios such as change of cropping pattern (crop diversity) considering food security, change of cropping area with allowable limits, availability of water (normal, dry, very, wet and very wet), industrial and population growth and climate scenarios RCP4.5 and RCP8.5 from GCM models

9. Results achieved with progress/present status:

Three blocks, Nuh, Nagina and Punhana of Mewat District have been selected for the setup of WEAP model based on the drainage network created from the toposheets of Survey of India. The Schematic diagram of WEAP model is given in Fig. 1. The total area of three blocks is 957.78 Sq.km. The total population by the end of 2020 is 7,71,093 (Urban- 80101 and rural - 69)based on the 2011 census and the population projection of Haryana State by National Commission on Population. The gridded data of rainfall, maximum and minimum temperature have been obtained from IMD. The evapotranspiration has been estimated by Hargreaves method using the average maximum and minimum temperature and extra terrestrial radiation obtained from https://www.engr.scu.edu/~emaurer/tools/calc_solar_cgi.pl and is given in Fig. 2

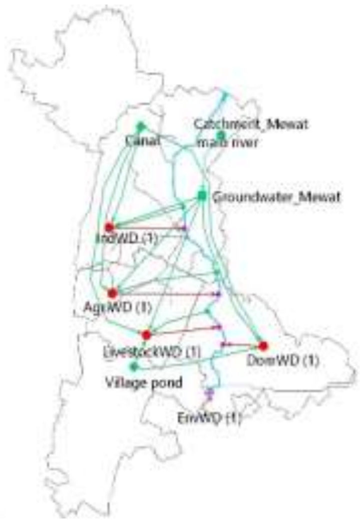


Fig 1 Schematic diagram of WEAP model for Mewat (Nuh, Punhana, Nagina)

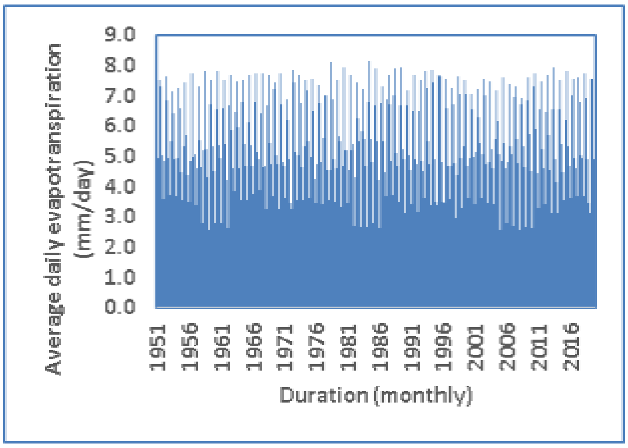


Fig 2 Evapotranspiration by Hargreaves equation

The study team visited district head Quarter Nuh, Agriculture department and Animal Husbandry and Dairying Department on 24.09.2021 and collected crop and livestock details and given as follows:

Table 1. Crop area and water requirement for Kharif season

Crop	Area (ha)	Crop water requirement (mm)	Crop water requirement (m^3/ha)
Sorghum	4843	300	3000
Millet	18639	150	1500
Cotton	4900	420	4200
Paddy	7994	1200	12000
Fodder	19614	225	2250
Sugar cane	310	1500	15000
Legumes	49	200	2000
Vegetables	170	400	4000
Garden mango	38	1000	10000
oil seed	52	300	3000

Table 2. Crop area and water requirement for Rabi season

Crop	Area (ha)	Crop water requirement (mm)	Crop water requirement (m3/ha)
Wheat	56152	400	4000
Mustard	11846	240	2400
Barley	252	300	3000
Chick pea	314	150	1500
Lentil	439	200	2000
Tomato	489	500	5000
Vegetables	531	400	4000
Barseem Fodder	98	900	9000
Garden mango	17	1000	10000
Sugar cane	5	1500	15000
Nursery	15	1000	10000

Table 3. Livestock population for Nuh, Nagina and Punhana blocks

SL No.	Block Name	Buffalo	Cattle	Goat	Rabbit	Sheep	Horses	Mules	Ponies	Pigs	Dogs	Camels	Donkey	Poultry
1	Nuh	47255	13704	9409	1920	2369	80	13	4	611	158	1	1	0
5	Nagina	11522	1152	1714	6	214	7	0	0	0	26	67	5	0
6	Punhana	54028	3727	6067	30	1191	15	7	0	107	53	6	1	0

The monthly water consumption urban (135 lpd) and rural (70 lpd) population and livestock palpation are given as follows:

Table 4 Monthly water consumption for rural and urban population (m^3)

Month	Urban	Rural
Jan	4.185	2.17
Feb	3.915	2.03
Mar	4.185	2.17
Apr	4.05	2.1
May	4.185	2.17
Jun	4.05	2.1
Jul	4.185	2.17

Aug	4.185	2.17
Sep	4.05	2.1
Oct	4.185	2.17
Nov	4.05	2.1
Dec	4.185	2.17

Table 5 Monthly water consumption for livestock (m^3)

Month	Buffalo/ cattle	Goat	Rabbit	Sheep	Pig	Dog	Horse family	Camel
Jan	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325
Feb	2.465	0.29	0.0435	0.29	0.435	0.0348	1.16	2.175
Mar	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325
Apr	2.55	0.3	0.045	0.3	0.45	0.036	1.2	2.25
May	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325
Jun	2.55	0.3	0.045	0.3	0.45	0.036	1.2	2.25
Jul	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325
Aug	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325
Sep	2.55	0.3	0.045	0.3	0.45	0.036	1.2	2.25
Oct	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325
Nov	2.55	0.3	0.045	0.3	0.45	0.036	1.2	2.25
Dec	2.635	0.31	0.0465	0.31	0.465	0.0372	1.24	2.325

The percentage share of landuse for agricultural land, forest land, settlement, fallow land and water bodies are 74, 8, 12, 5 and 1 respectively. The monthly crop coefficient (Kc) for different landuses and crops (FAO) and the effective precipitation for evapotranspiration are given as follows:

Table 6 Monthly crop coefficient for Kharif and Rabi crops

Landuse	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural Land	0.98	0.41	0.25	0.36	0.35	0.79	0.51	1.09	1.00	0.53	0.77	1.12
Forest land	0.75	0.75	0.75	0.75	0.95	0.95	0.95	0.95	0.95	0.85	0.85	0.85
Settlement	0.08	0.08	0.08	0.08	0.12	0.12	0.12	0.12	0.12	0.09	0.09	0.09
Fallow land	0.15	0.15	0.15	0.15	0.19	0.19	0.19	0.19	0.19	0.17	0.17	0.17
Water bodies	0.90	0.90	0.90	1.05	1.05	1.05	1.05	1.05	1.05	1.00	1.00	1.00

Table 7 Monthly crop coefficient for Kharif and Rabi crops

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sorghum (Jwar)	0	0	0	0	0	0	0.3	1.1	1	0.55	0	0
Millet	0	0	0	0	0	0	0.3	1	1	0.3	0	0
Cotton	0.5	0	0	0.35	0.35	0.35	1.2	1.15	1.15	1.15	0.7	0.7
Paddy	0	0	0	0	0	1.05	1.2	1.2	0.9	0.9	0	0
Fodder (Sorghum)	0	0	0	0	0	0	0.3	1.1	1	0.55	0	0
Sugar cane	0.75	0.55	0.4	0.4	0.4	1.25	1.3	1.25	1.25	0.75	0.75	0.75
Vegetables (Brinjal)_kh	0	0	0	0	0	0.6	1.1	1.05	1.05	0.8	0	0
Wheat	1.15	0.4	0.25	0	0	0	0	0	0	0	0.7	1.15
Mustard	0.35	0	0	0	0	0	0	0	0	0.35	1.15	1.15
Barley	1.15	1.15	0.4	0	0	0	0	0	0	0	0.3	1.15

Chickpea (Chana)	1	0.35	0	0	0	0	0	0	0	0.4	1	1
Lentil (Masoor)	1.1	1.1	0.3	0	0	0	0	0	0	0	0.4	1.1
Tomato	0.9	0.7	0	0	0	0	0	0	0	0.6	1.15	1.15
Vegetables (Cauliflower)_Rb	0.95	0	0	0	0	0	0	0	0	0.7	1.05	1.05
Berseem Fodder	0.9	0.9	0.85	0.85	0	0	0	0	0	0.4	0.4	0.9

Table 8 Effective precipitation for evapotranspiration

Landuse	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural land	60	60	60	50	50	70	70	70	70	60	60	60
Forest land	65	65	65	60	60	80	80	80	80	65	65	65
Settlement	50	50	50	40	40	65	65	65	65	45	45	45
Fallow land	60	60	60	50	50	70	70	70	70	55	55	55
water bodies	18	18	18	15	15	25	25	25	25	20	20	20

The yield and market price for Kharif and Rabi crops are given as follows:

Table 9 Yield and market price for Kahrif crop

Sl.no	Crop	Yield (kg/ha)	Market Price (Rs/quintal) for 2020-21
1	Sorghum (Jwar)	1890	2640
2	Millet (Bajra)	2592	2150
3	Cotton	574	5515
4	Paddy	2337	1868
5	Fodder (sorghum)	35,000	500
6	Sugar Cane	70,000	362
7	Vegetable (Brinjal)	24700	2000

Table 10 Yield and market price for Kahrif crop

Sl. No.	Crop	Yield (kg/ha)	Market Price (Rs/quintal) for 2020-21
1	Wheat	3903	1975
2	Mustard	2141	4650
3	Barley	3085	1600
4	Chickpea (chana)	1666	5100
5	Lentil (Masoor)	1,800	5100
6	Tomato	21,500	750
7	Vegetable (cauliflower)	16300	1300
8	Berseem Fodder	75000	500

Initial run has been carried in WEAP model with above mentioned inputs and some of the results are given as follows:

Fig 3. Monthly Inflows to area from 2020 to 2030

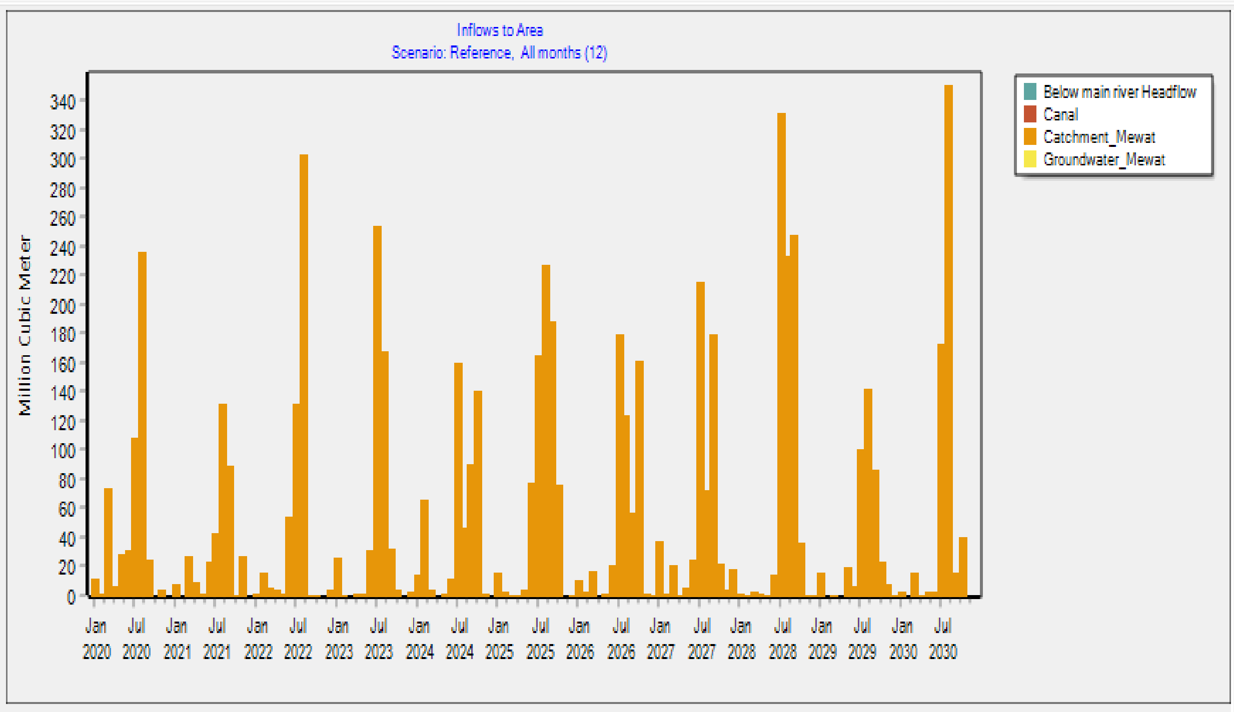


Fig 4. Monthly ground water storage from 2020 to 2030

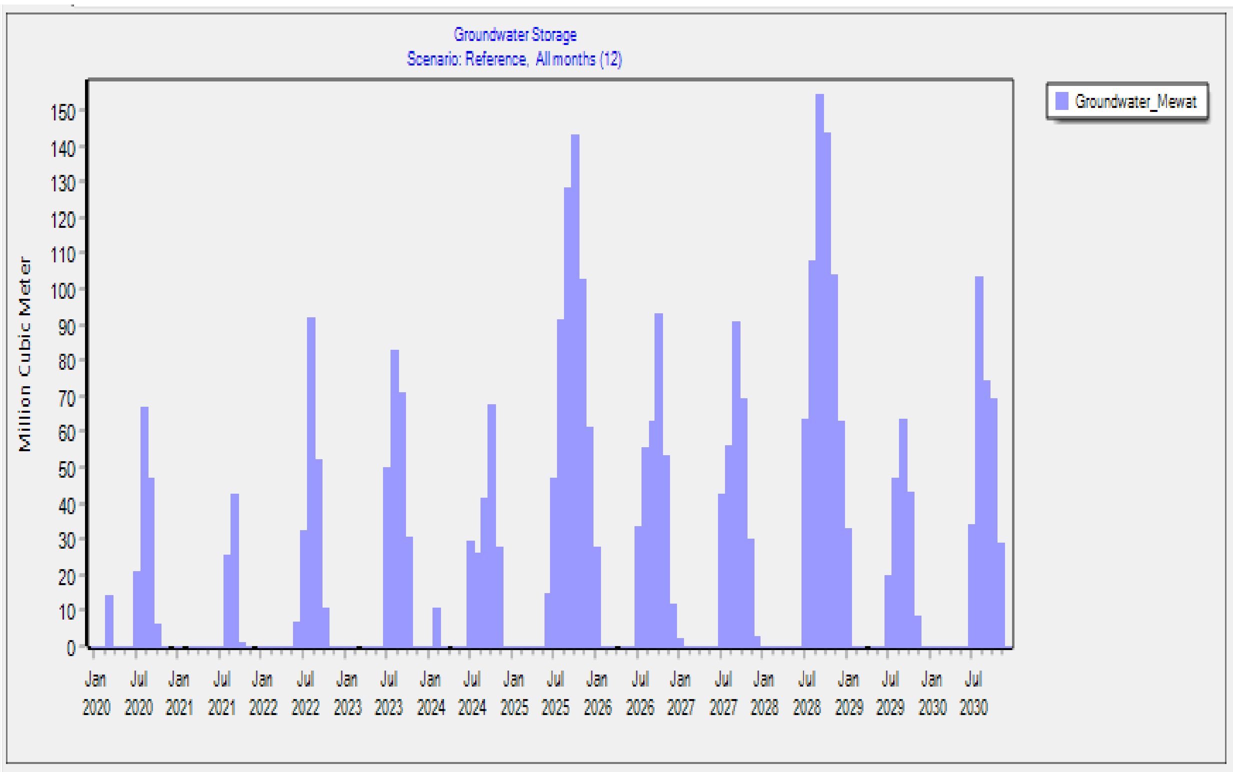
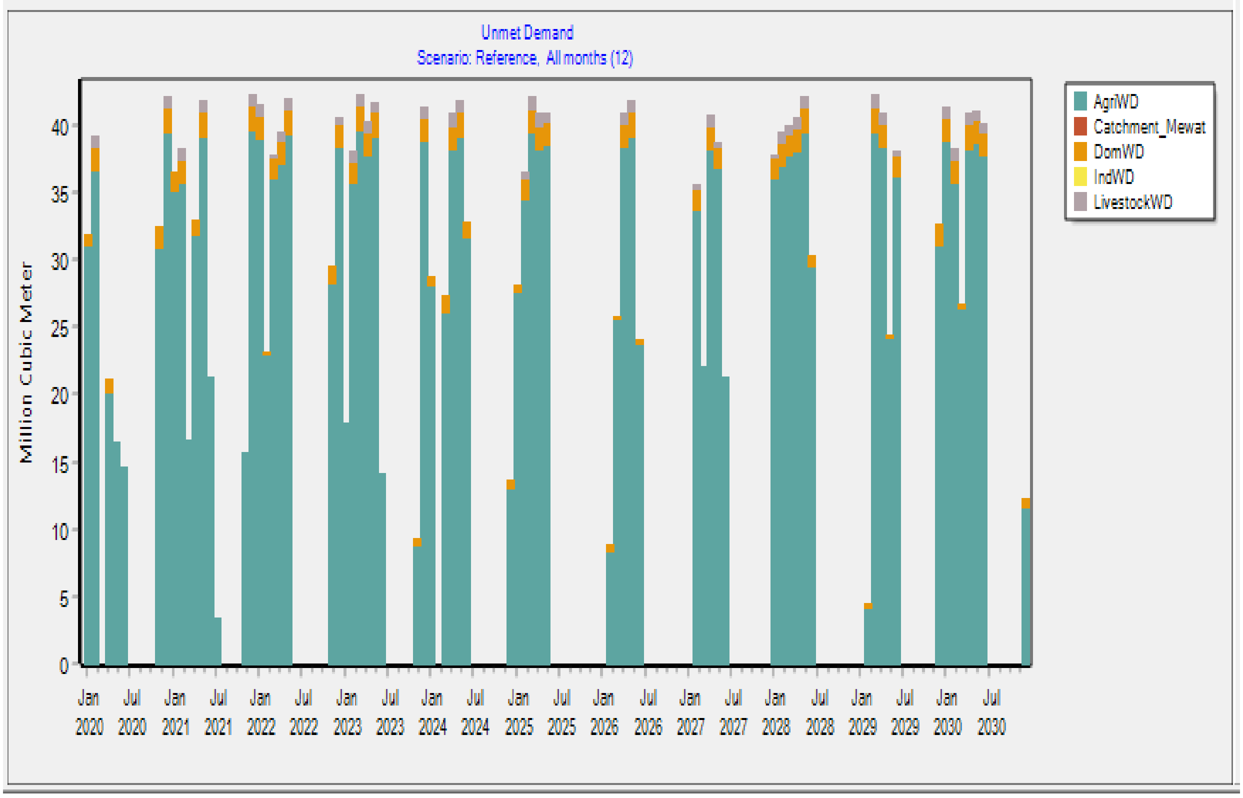


Fig 4. Monthly unmet demand from 2020 to 2030



The cost of cultivation for major Kharif and Rabi has been obtained from Directorate of Economics and Statistics, Ministry of Agriculture and Farmer Welfare for the year 2018-19 and implementation of Linear Optimization model with all the inputs is under progress.

10. Research outcome from the study

The following are outcome envisaged from the study

- Maximum net profit, minimum investment cost and minimum water usage for each scenario
- Optimal land allocation for different crops (considering staple food, nutrition value), Kharif season and rabi season for each scenario

11. Timeline

Sl. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Literature review, Collection of hydro meteorological data, preparation of base map of the catchment, population data, crop type data, water availability data, cost of cultivation								
2	Compilation and verification of hydro-meteorological data, baseline survey data, census data and crop type data, cost of cultivation								

3	Preparation of input data for WEAP model								
4	Estimation of demand and supply delivered for existing cropping pattern by WEAP								
5	Estimation of demand and supply gap for different scenarios using WEAP								
6	Optimization of income from agriculture sector using LINGO for inputs from the scenario analysis								
7	Report writing								

1. Title of the study:

Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun

2. Study Group:

NIH, Roorkee	Swami Rama Himalayan University (SRHU-HIHT), Dehradun
Omkar Singh, V.C. Goyal, Rajesh Singh, Jyoti Patil, Rohit Sambare, N.R. Allaka, Staff from WQ lab	Er H P Uniyal, Mr Nitesh Kaushik

3. Type of Study: Internal

4. Nature of Study: Development of R&D framework

5. Date of start: April, 2022

6. Expected date of completion: March, 2024

7. Duration of the study: 2 year

8. Weather externally funded or not: Internal; **NIH Budget:** 30 Lakhs

9. Objectives:

- The major objective is to develop a Water Security Plan for Healthcare Facilities in India, with the help of a case study in SRHU-HIHT hospital
- The sub-objectives to attain the major objective include assessment of water demand and water availability (both freshwater and wastewater); evaluation of the quality of water and wastewater for drinking, clinical and other purposes; assessment of rainwater harvesting potential for utilization/ augmentation of groundwater recharge/disaster risk preparedness; and conducting water audit for the hospital campus
- Wastewater monitoring & characterization to develop an appropriate design of CW-NTS technology for treatment & gainful recycling of hospital wastewater
- Outreach activities toward water security/water conservation awareness for medical professionals, hospital staff, and other stakeholders

10. Statement of the Problem

India is witnessing tremendous growth in healthcare infrastructure. The sector is growing at a rapid pace owing to the awareness and importance of good health and wellbeing. Hospitals and healthcare facilities (HCF) operate 24/7, with a continual stream of people working and visiting, and life-saving procedures being performed. Water plays an important role in HCF- from patient care and safety to daily operations, which causes them to use a significant amount of water. Consumption of large amount of water by the hospitals leads to the generation of large volumes of wastewater. Monitoring of water quality at HCFs is extremely important, as many functions and facilities require high-quality water. Also, since hospital wastewater (HWW) imposes a grave hazard to human health and the environment, its monitoring as well as treatment is desirable at HCF. Focusing on water efficiency and adopting better water management practices in these facilities is becoming increasingly urgent due to the volume of water they require. Another cause of concern at the HCF is extreme weather events such as storms, floods, drought, which create emergencies that damage infrastructure, compromising access to critical resources (e.g., food and water) and the safety of patients, visitors and staff. The vulnerability of HCF in disaster situations cannot be underestimated and, therefore, HCF are expected to prepare plans to deal with such emergencies. A Water Security Plan, which includes the components of water and wastewater in terms of both quantity and quality, is considered essential to effectively deal with the water-related situations and scenarios at HCF. This plan will not only address the challenges of water scarcity and water efficiency but also lead to cost saving for the hospital management.

11. Brief methodology:

- Review of relevant literature
- Identification of components of water security:
  Field investigation & collection of requisite data (hospital amenities/demography, etc.) for assessment of water demand, water supply and water audit (leakage & losses). In this study, the quantity of domestic water (m^3) per capita per month (DWR_m) will be estimated as follows (based on vision of Department of DW&S, MoJS, GoI): $DWR_m(m^3/month) = (P_{urban} \times 135)x10^{-3} \times 30$
  Components of water demand in the campus- BIS standard for hospital 450L/patient/day+ residential/domestic+ other colleges etc
- Water quality monitoring, analysis and assessment for drinking purposes in the hospital based on physio-chemical, trace and bacteriological water quality parameters (as per BIS 2012). The some of the water quality parameters includes pH, BOD, COD, suspended solids, pharmaceutically active compounds (PhACs), several microorganisms including antibiotic-resistant bacteria (ARB), antibiotic-resistant genes (ARG), persistent viruses, etc.
- Collection & analysis of household/hospital roof data from Jolly Grant Hospital:
  Estimation of roof top rainwater harvesting potential: The volume of rainwater that could be harvested per household per month will be estimated as per Eq. given by Ghisi et al., 2006, as below (Aladenola and Adeboye, 2010; Ishaku, et al., 2013):

$$VR = \frac{R.HRA.RC}{1000}$$

  Where, VR= monthly volume of rainwater per household (m^3), R= monthly rainfall depth (mm), HRA= household roof area (m^2), and RC= runoff coefficient (dimensionless).
- Collection & analysis of rainfall data for Dehradun from various sources.
- Volume of wastewater generated
- Wastewater quality monitoring, analysis and characterization of Jolly Grant Hospital
- Designing of CW-NTS technology for treatment & gainful recycling of hospital wastewater. The HIHT, Dehradun will provide funds for CW-NTS technology in the hospital premises.

Data Availability

Data regarding hospital amenities, demography, water supply, water demands will be taken from hospital authorities.

12. Mile Stones

Sr. No.	Work Component	2022-23		2023-24	
		I	II	I	II
1.	Review of literature				
2.	Field investigation & collection of requisite data (rainfall, water demands and supply, wastewater discharge); data compilation, analysis and synthesis				
3.	Water and wastewater quality analysis for different uses and purposes				

4.	Estimation of roof rainwater harvesting potential and groundwater recharge potential				
5.	Suggesting wastewater reuse and construction of CW-NTS in the hospital premises				
6.	Preparation of water security plan				
7.	Outreach activities: appropriate water use, water conservation, wastewater treatment and recycling				
8.	Submission of Water Security Plan to hospital authorities				

13. Objective and achievement during last six months: New proposal.

14. Budget details

(Rs in Lakhs)

SN	Item	2022-23	2023-24	Total
1	Manpower at Roorkee 1 Nos Resource Person (Jr) @32,000/-	4.0	4.0	**8.0**
2	Travel ✓ Field data collection ✓ Meetings ✓ Stakeholders meetings	5.0	4.0	**9.0**
3.	Contingency ✓ Flyers ✓ Capacity building and outreach activities	4.0	5.0	**9.0**
4.	Consumables	2.0	2.0	**4.0**
	Total	**15.0**	**15.0**	**30.0**

15. Analysis & Results: New proposal.

16. End Users / Beneficiaries of the study: Hospital authorities, Public Health Centres, Public Health Engineering Department, Line departments (fire, irrigation, etc.)

17. Deliverables: Implementable Water Security Plan for hospitals and healthcare centers.

19. Major items of equipment procured:

20. Involvement of end users/beneficiaries: Facilities available at SRHU will be used

1. Title of the project:

Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)

2. Study Team:

V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare,
NIH Project Team: Dr. Sandeep Kumar Malyan, Dr. Shweta Yadav, Dr. Jhalesh Kumar
Partners: NIH-Roorkee, MNIT-Jaipur, IIT-Bombay, IRMA-Anand

3. Funding: DST (GoI), Cost: Rs. 5.1 Crore

4. **Duration:** Apr 2019-Mar 2024

5. Objectives of the study

The project **'Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)'** is funded by Department of Science & Technology (DST), Government of India. The National Institute of Hydrology (NIH) Roorkee is the leading institute for implementation of this project, in collaboration with the project partners from Indian Institute of Technology Bombay (IITB), Malaviya National Institute of Technology (MNIT), Jaipur and Institute of Rural Management Anand (IRMA), Ahmedabad. The objectives of the project are:

- Establishment of a state-of-art Centre for Eco-prudent Wastewater Solutions (IC-EcoWS) to harness the potential Natural Treatment Systems (NTS) and other eco-prudent resource recovery technologies for water security and sustainability in India,
- Development of a Decision Support Tool (DST) based on Life Cycle Assessment (LCA) and Multiple Criteria Decision Making (MCDM) approach for selection of appropriate "Technology Packages" for resource recovery oriented wastewater treatment infrastructure,
- Establishment of few pilot study sites ("Live Laboratories") for detailed assessment of selected NTS in urban, peri-urban and rural settings, for both secondary and tertiary treatment requirements as per new CPCB norms as well as for select emerging pollutants,
- To explore innovative ideas on the development (e.g. use of pre-fabricated structures, efficient structures for control of solid waste in sullage) and application (e.g. retrofitting of existing village ponds, drains, linkage to livelihood options) of NTS for wastewater treatment,
- To organize capacity building, awareness creation, documentation and dissemination activities, and preparation of a TOT Module on NTS applications and an Indian handbook for promotion and propagation of NTS for resource recovery and wastewater treatment in India.

6. Results achieved with progress/present status:

The progress of the project is given below:

Milestones achieved by NIH, Roorkee (March 2022)

Milestones	Activities	Target Month	NIH-Progress
Hiring of Project staff	Hiring of project staff	M6	Completed
Development of Centre Portal	Development of IC-EcoWS Centre Website and social media pages for information dissemination	M12	Completed
Organization of Users nteractions Workshop (annual)	IC-EcoWS Project Inception Cum Need Assessment Workshop (8-9 August, 2019)	M12	Completed
	Report on First Annual Workshop- IC-EcoWS Project Inception Cum Need Assessment Workshop		
Establishment of Live Laboratories	Procurement of several technical and scientific lab equipments for setting up the IC-EcoWS Innovative Centre at NIH Roorkee	M18	Completed
	Establishment of horizontal sub-surface -flow constructed wetland for domestic wastewater treatment (Peri-urban residential area in Roorkee)		
	Installation of Online Monitoring System for water quality monitoring		
	Assessment of NTS technology – NIH Colony		
Development and Application of Innovative ideas on NTS	Treatment of domestic wastewater by floating constructed wetland system using identified plant species at NIH Roorkee	M24	Completed
	In-situ treatment of domestic wastewater in urban drain using floating constructed wetland and Bio-Inoculum – Solanipuram Roorkee	M36	Ongoing
	Pilot-scale demonstration unit for wastewater treatment of residential building using Subsurface Constructed wetlands system at NIH Roorkee	M36	Ongoing
Documentation and dissemination	Capacity building, awareness creation, and dissemination activities (Factsheets)	M36	Ongoing