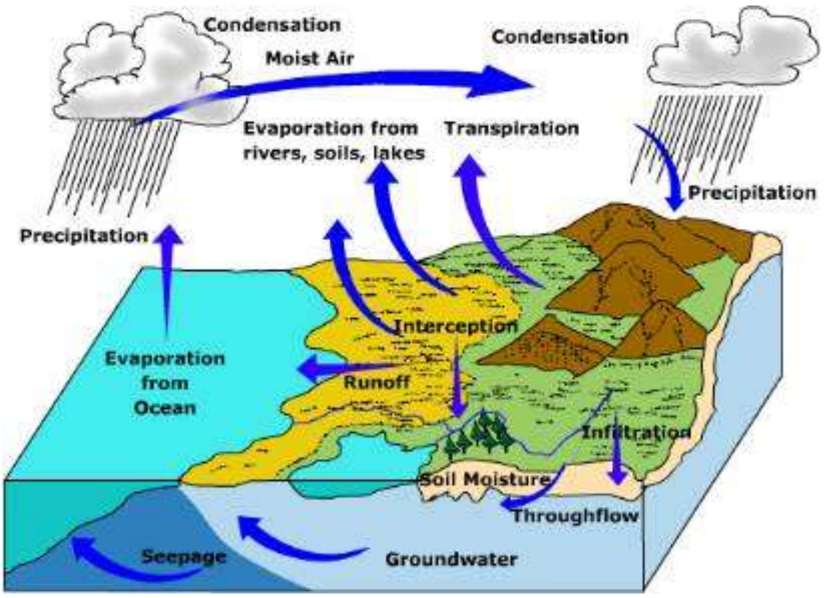
AGENDA AND AGENDA NOTES FOR THE 51st MEETING OF THE WORKING GROUP OF NIH

14 – 15 JUNE, 2021
AT 1000 HRS



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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 51st MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

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AGENDA ITEMS

ITEM NO. 51.1 Opening Remarks by the Chairman

ITEM NO. 51.2 Confirmation of the minutes of 50th meeting of the 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.** 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. 51.3 Action taken on the decisions/recommendations of the previous Working Group meeting

During the 50th 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. 51.4 Presentation and discussion on the status and progress of the work programme for the year 2020-21.

The approved Work Programme of the six Divisions of the Institute for the year 2020-21 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 2020-21					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	2	-	2	4	**8**	**1**
Ground Water Hydrology	1	2	2	9	**14**	**3**
Hydrologic Investigation	2	-	2	7	**11**	**-**
Surface Water Hydrology	2	-	6	2	**10**	**-**
Water Resources System	3	2	3	11	**19**	**-**
Research Management & Outreach	3	-	1	3	**7**	**-**
Total	**13**	**4**	**16**	**36**	**69**	**4**

During the present meeting, Division-wise progress and status of the work programme for the year 2020-21 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2020-21.

ITEM NO. 51.5 **Presentation and finalization of the work programme for the year 2021-22.**

The proposed 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**

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 2020-21 shall be presented.

ITEM NO. 51.6: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 50^{th} MEETING OF WORKING GROUP

APPROVED MINUTES OF THE
50TH MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING 20-21 AUGUST2020

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. 50.1: OPENING REMARKS BY THE CHAIRMAN

The Chairman, WG, welcomed the WG members and the Scientists of NIH. The Chairman 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. Vijay Kumar	▪ Suggested use of newly developed software to verify results of studies earlier conducted by NIH
2.	Dr. S P Aggarwal	▪ Provide a link for data availability
3.	Sh. Man Singh	▪ NIH scientists should think beyond RCPs
4.	Dr. Bhishm Kumar	▪ For Henval experimental station, suggested extensive characterization using hydromet, chemical and isotopic studies
5.	Prof. A P Dimri	▪ NIH should take up urban flooding studies ▪ NIH scientists should think beyond RCPs ▪ Create databank at NIH

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

ITEM No. 50.2: CONFIRMATION OF MINUTES OF 49th MEETING OF WORKING GROUP

The 49th meeting of the Working group was held during 2-3 May, 2019. The minutes of the meeting were circulated to all the members and invitees vide letter No. **RMOD/WG/NIH-10 dated 3 Dec., 2019**. The members confirmed the minutes of the 49thWorking Group meeting.

ITEM No. 50.3: 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 49th working group meeting.

ITEM Nos. 50.4& 50.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2019-20 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2020-21

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2019-20 and also to present the proposed studies for F.Y. 2020-21. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2020-21, 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, and technology transfer activities. 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.

Progress of Work Program for 2019-20 and Work Program for 2020-21

S. No.	Study	Recommendations/Comments
	Internal Studies	
1.	**Title:** Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows **Study Group:** Pradeep Kumar (PI), C. K. Jain Duration: 3 Years (04/16-05/19) Status: Completed	Dr. Pradeep Kumar presented the study which is completed and the report has been submitted.
2.	**Title:** Water quality assessment for Haridwar District **Study Group:** R.K. Nema (PI), Rajesh Singh, J. V. Tyagi & Pradeep Kumar **Duration:**1.5 years (05/19-12/20) **Status:** Ongoing	Dr. Rajesh Singh presented the progress of the study.The members appreciated and expressed that this type of studies are very useful and should be carried out sincerely. Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) indicated that the study is very important and the results would be useful for drinking water supply & water quality management in the district. He suggested that the time duration of the study should not be reduced. Dr. Pawan Labhasetwar (Scientist, NEERI) suggested to carry out the sanitary surveillance.
3.	**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	The members were informed about the progress of the study and the ongoing activities.
	Internal Studies (New Study)	
4.	**Title:** Identification of Causes for deterioration of 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)	Dr. M. K. Sharma presented the proposal. Dr. Man Singh suggested to fill the gaps in the studies conducted so far on river Hindon and to bring a holistic prespective for rejuvenating the river. Dr. Arun Kumar Saraf suggested that we should focus on small rivers for rejuvenation or Hindon section wise. Dr. Pawan Labhasetwar suggested that a thorough water quality investigation for pre- and post-monsoon duration should be carried out. An inventory of all the drains need to be prepared. Dr. Varun Joshi recommended to go through Ph.D. thesis of his students.

5.	**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)	Dr. Rajesh Singh presented the proposal. Dr. Pawan Labhasetwar (Scientist, NEERI) suggested analysis of river water quality in the breaded segment. Dr. Deshpande suggested modification in third objective i.e. Statistical Analysis as it is the part of methodology and cannot be a standalone object.

Training Programmes organized during 2019-20

SN	Topic	Duration	Place
1.	Hydrologic Modelling using SWAT (Coordinator: Dr. J. V. Tyagi)	Two weeks 20-31 May 2019	Roorkee
2.	Ground Water Quality Monitoring & Assessment under NHP-PDS (Coordinator: Dr. M. K. Sharma)	5 Days 3-7 June 2019	Roorkee
3.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days 17-21 June 2019	Roorkee

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-21

SN	Study	Study Team	Duration/Status
	Sponsored Projects (Ongoing)		
1.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	M. K. Sharma(PI) Manohar Arora Pradeep Kumar Rajesh Singh D. S. Malik (GKU)	5 Years (04/16-03/21) **Sponsored by**: DST (NMSHE) **Project Cost**: Rs. 2.25 Crore **Status:** In-progress
2.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur, CGWB, Raipur	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 25.4 Lakh **Status:** In-progress *Request Extension upto 03/21*
3.	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 (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** In-progress *Request Extension upto 03/21*
4.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi, M. K. Sharma, Nitesh Patidar **Partner:** CGWB (Delhi unit)	3 Years (11/19 – 10/22) **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress
	Internal Study (Ongoing)		
5.	Water quality assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh J. V. Tyagi Pradeep Kumar	3 years (05/19-12/20) **Project cost:** 17.10 lakh **Status:** In-progress
6.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma	4 years (11/19-10/23) **Project cost:**43.02 lakh **Status:** In-progress

		Rajesh Singh R. K. Nema	
Internal Study (New)			
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 Nitesh Patidar Surjeet Singh Rajesh Singh	3 Years (07/20-06/23) **Project cost:** Rs. 20.24 Lakh **Sponsored by**: Internal **Status:** New Project
8.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi R.K. Nema Pradeep Kumar M. K. Sharma	2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** New Project
Consultancy Projects (New Project)			
9.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	J. V. Tyagi (PI) Pradeep Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural, P. K. Singh, M. K. Sharma, Rajesh Singh, R. K. Nema	2 Years (03/20-02/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** New Project

Training Programmes

SN	Topic	Duration	Place
1.	Water Quality Management under NHP-PDS (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
2.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days	Roorkee
3.	Water Quality: Concepts and Analysis under NHP (Coordinator: Dr. Pradeep Kumar)	5 Days	Roorkee
4.	Contaminant Transport Modeling under NHP-PDS (Coordinator: Ms. Anjali)	5 Days	Roorkee

GROUND WATER HYDROLOGY DIVISION

Dr. Anupma Sharma, Scientist 'F' presented a brief overview, status of studies and activities carried out by the division since the 49th Working Group meeting held in November, 2019. She 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. Dr. Sharma informed that two in-house R&D studies and twelve sponsored studies were approved for the year 2019-20. 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 "*Integrated Hydrologic Model*" 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 guidance during the period were also reported. The progress of following studies was presented by respective Principal Investigators:

S. No.	Project	Project Team	Duration & Status	Funding Source
		Internal Studies		
1. NIH/GWH/ NIH/19-20	The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year (08/19 – 07/20) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
2. 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	3 months (07/20 – 09/20) *Status: New Study*	Referred by DoWR (MoJS)
3. NIH/GWH/ NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Nitesh Patidar (PI), Gopal Krishan, Suman Gurjar	2 years (08/20 – 07/22) *Status: New Study*	Internal Study
		Sponsored Projects		
4. NIH/GWH/ NIH/15-20	Peya Jal Suraksha - Development ofSix Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply	Surjeet Singh (Lead), B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal	4.5 years (11/15–03/20) *Status: Completed*	Sponsored by MoWR, RD & GR under Plan Fund
5. NIH/GWH/ CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Sponsored by Federal Ministry of Education and Research, Germany

The suggestions emerged during the presentation of progress of these studies are given below:

S. No.	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/Suggestions
	Internal Studies	
1	The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains (Ongoing) **Study Group:** Sumant Kumar, C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra **DOS:** Aug. 2019 **DOC:** Jul. 2020	Dr. Sumant Kumar (PI) presented the objectives, methodology, achievements and expected outcome of the study. The PI requested for the extension of the study for seven months and it was approved by members. PI also informed that a word 'farm-scale' has been replaced with 'agricultural' in the study title and it was approved by the members. Now, the study title shall be "The regional hydrological impact of agricultural water saving measures in the Gangetic plains".

2	Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi (New) **Study Group:** Gopal Krishan, B. Venkatesh, Nitesh Patidar **DOS:** Jul. 2020 **DOC:** Sep. 2020	Dr. Gopal Krishan (PI) presented the background, statement of the problem, objectives, methodology and future plans and also requested for extension of time period by two months, which was agreed during the meeting.
3	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System (New) **Study Group:** Nitesh Patidar (PI), Gopal Krishan, Suman Gurjar **DOS:** Aug. 2020 **DOC:** Jul. 2022	Dr. Nitesh Patidar (PI) presented about the background, objectives, methodology and future plan of the study. Dr. R.D. Deshpande suggested to measure evapotranspiration in the field, if feasible.
	Sponsored Projects	
4	Peya Jal Suraksha -Development ofSix Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply (Completed) **Study Group:** Surjeet Singh, B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal **DOS:** Nov. 2015 **DOC:** Mar. 2020	Dr. Surjeet Singh (PI) presented the study in detail on the RBF sites developed in various states. He described about the selection of sites, details on drilling of RBF well, construction of pump house, performance on water quality, safety from floods, etc. and future plan. Mr. S. M. Sharma, Working Group member requested to provide the draft final report. Director NIH advised to send the report to Mr. S. M. Sharma for review in addition to the approved list of reviewers.
5	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF (New) **Study Group:** Gopal Krishan **DOS:** Jul. 2020 **DOC:** Jun. 2023	Dr. Gopal Krishan (PI) presented the background, work packages and future plan of the study.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2020-21

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, C. P. Kumar, P. K. Singh	2 years (05/19 - 04/21) *Status: In progress*	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, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year 8 months (08/19 – 03/21) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)

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	5 months (07/20 – 11/20) *Status: New Study*	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, Suman Gurjar	2 years (08/20 – 07/22) *Status: New Study*	Internal Study
Sponsored Projects				
5. NIH/GWH /NMSHE/ 16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8
6. 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	3.5 years (12/17-06/21) *Status: In progress*	Sponsored byBGS, UK
7. NIH/GW H/PDS/1 7-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3.5 years (12/17-06/21) *Status: In progress*	Sponsored by NHP under PDS
8. NIH/GW H/PDS/1 7-21	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	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
9. NIH/GW H/PDS/1 7-21	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 (12/17-11/21) *Status: In progress*	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	3 years (01/18 - 12/20) *Status: In progress*	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)	3 years (01/18 - 12/20) *Status: In progress*	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 & Water Resources Dept. Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, New Delhi	4 years (04/18-03/22) *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 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)	5 years (03/19 - 02/24) *Status: In progress*	Sponsored by DST
14. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Sponsored by Federal Ministry of Education and Research, Germany
Consultancy Projects				

1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 17.70 lakh *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 1.18 crore *Status: In progress*	Punjab Government
3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	1.5 year (04/19-09/20) Cost: 11.80 lakh *Status: In progress*	Irrigation Deptt., Saharanpur

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr Sudhir Kumar, Scientist-G and Head of the H. I. Division presented the activities 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 including the new proposals, 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 November 2019 to August 2020.

Table 1: Status of studies carried out by HI Division during Nov'19 to Aug'20

Type of study/Project	Approved Studies	Completed Studies	New studies	Total
Internal Studies	2	1*	-	1
Sponsored Projects	9	2	-	7
Consultancy Projects	5	1	5	9
Total	16	4	5	17

*Dropped

Table 2: Details of training Courses/Workshops organised by HI Division during Nov'19 to Aug'20

SN	Title of Training Course/Workshop	Duration	Venue	Co-ordinator
1.	Tools and techniques of hydrological investigations	04 - 08 Nov 2019	NIH, Roorkee	S. M. Pingale

Table 3: Details of samples analysed by HI Division Labs during Apr'19 to Mar'20

SN	Parameter analysed	No. of samples
1	δ^2H on DI-IRMS	6,707
2	δ^{18}O on DI-IRMS & CF-IRMS	6,693
3	Tritium enrichment / measurements	378
4.	WQ samples on IC	1,075

Table 4: Details of Research Publications by HI Division during Nov'19 to Aug'20

	Published	Accepted	Communicated
Books/Book Chapter	-	-	-

International Journals	2	-	6
National Journals	1	-	-
International Conferences	5	3	-
National Conferences	2	-	-

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

<u>INTERNAL STUDIES:</u>

SN	Project	Study Team	Duration	Status	Comments/ Action(s) Suggested
1.	Hydrological investigations of selected springs in Tehri Garhwal District , Uttarakhand **<u>Earlier title:</u>** Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand	S M Pingale (PI), Sudhir Kumar Suhas Khobragade S. S. Rawat Rajeev Gupta	3 years (04/19 to 03/22)	Continuing Study	i) Dr. Bhishm Kumar suggested (i) only important springs, i.e., which are being used by local public should be studied, (ii) tritium dating of the spring water should be carried out to understand the recharge zones. ii) Dr. RD Deshpande suggested to reformulate the first three objectives of the study. iii) Dr. Sudhindra Mohan Sharma suggested (i) to also develop the correlation of spring characteristics with geomorphology, and (ii) to suggest the guidelines for spring studies.
2.	Isotope fingerprinting of precipitation over Indian Region	Nidhi Kalyani (PI), Sudhir Kumar MS Rao Scientists from RC's	3 years (04/19 to 03/22)	Continuing Study	To be dropped as no progress is made. May be considered in future.
3.	Groundwater recharge estimation in a part of Sabarmati basin	M. Someshwar Rao (PI) Sudhir Kumar Vipin Aggarwal	2 years (09/20 to 08/22)	New Study	Dr. Bhishm Kumar suggested that (i) tritium tagging technique may be used with high precaution, and (ii) stable isotopes should be used for determination of recharge.
4.	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 (7/20-6/23)	New study	Could not be presented due to shortage of time

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-2021

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)	Continuing Study
2	Groundwater Recharge estimation in a part of Sabarmati basin	**M. Someshwar Rao**(PI) Sudhir Kumar Vipin Aggarwal	2 years (9/20 – 8/22)	***New 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 (9/20-8/23)	***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 (04/16-03/21)	Continuing Study under NMSHE Project
2.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	**M. Someshwar Rao** (PI) Sudhir Kumar	3 Years (06/16 -05/19) **Ext. upto 03/21**	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 (1/18 – 6/21)	Continuing Study PDS under NHP
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 (1/18 – 6/21)	Continuing Study PDS under NHP
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)	Continuing Study PDS under NHP
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	1 year (04/19 – 03/20) Extended till 03/21	Continuing Study under NCESS, MoES
7.	Groundwater Rejuvenation As Climate changeE Resilience for marginalized and gender sensitive GangeS (GRACERS)	**Sudhir Kumar (PI)** M. Someshwar Rao SM Pingale	2 years (06/19 – 5/21)	IIT Bombay, Mumbai

Table 2: Training Courses/Workshops proposed by HI Division for the year 2020-2021

S. N.	Title of Training Course/Workshop	Duration	Venue	Co-ordinator
1.	Advanced tools and techniques for hydrological investigations	November 2020	NIH, Roorkee	S. M. Pingale
2.	Conservation and management of lakes, wetlands and springs	December 2020	NIH, Roorkee	S. D. Khobragade

SURFACE WATER HYDROLOGY DIVISION

Dr. Rakesh Kumar, Sc G & Head, Surface Water Hydrology Division presented the various activities of the division. 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:

S.N.	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/Suggestions
	SPONSORED STUDIES	
1.	Hydrological modeling in Alaknanda basin and assessment of climate change impact (NMSHE) **Study Group:** A.K. Lohani Sanjay K. Jain, Archana Sarkar, V.S. Jeyakanthan, L.N. Thakural **DOS:** April 2016; **DOC:**March 2021	VIC and WinSRM models have been setup for the study basin. Further, calibration of both VIC and WINSRM models with the available data has been carried out. The study also extended upto entire upper Ganga basin catchment up to Rishikesh and both the above mentioned models were calibrated and validated. Further climate change scenario have been downloaded and applied to generated future runoff series using the selected models. The study will be completed by December 2020.
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, WRD Rajasthan, Sanjay Agarwal, Shailendra Kumar **DOS:** Oct. 2019; **DOC:** Dec. 2020	Rainfall-runoff models e.g. SWAT and VIC have been setup for the study catchments. Request were made to WRD, Rajasthan for the G&D data for the selected basins. It was informed by the WRD, Rajasthan that the G&D data for the study are not available. Further, G&D data for the other sites available with CWC were provided by WRD, Rajasthan in the month of July 2020. Now with these data the hydrological models are being calibrated for the gauged sites. Further, using the calibrated parameters of the hydrological models runoff time series will be generated for the study basins. The progress of the study was presented in the R&D session of PDS held in Jan 2020 at New Delhi.
	INTERNAL STUDIES	
3.	Development of regional methods for design flood estimation in Uttarakhand **Study Group**: J.P. Patra Rakesh Kumar, Pankaj Mani, Sanjay Kumar	Mr. Jagadish Prasad Patra, presented the objectives, need for such study with brief methodology of the completed internal study entitled “Development of regional methods for design flood estimation in Uttarakhand”. The various objectives of study and work carried out were presented. The results of rainfall and flood frequency analysis using L-moments approach are presented with detail explanation. The relationships developed to estimate design flood for various return periods with catchment area are also presented. The

	DOS: April 2017; **DOC:** March 2020	Nonstationary Extreme Value Analysis considering the aspect of non-stationary in data series is presented in detail for annual maximum peak flood series and 1day annual maximum rainfall series. It is presented that an unjustified assumption of stationarity could lead to an underestimation of extreme floods. However, it is highlighted that effect on such nonstationary approach may not be always very critical in terms of water level in the river viz. water surface in a bridge, over topping of embankments etc. Further, effect of Tehri dam for moderation of flood peaks at Rishikesh is also discussed considering reservoir index as an additional co-variate. However, the results obtained until now are not very conclusive. The experts enquire about any specific recommendation regarding the effect of climate change in flood frequency analysis. It was explained that the considering various uncertainties associated with climate change, is difficult to exactly quantify the increase in design flood value. However, with example it is explained that non-stationary frequency analysis needs to be carried out to check the resilience of various infrastructures with respect to their design life.
4.	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	Dr. Sanjay Kumar presented the progress of the study, he mentioned that the study has five objectives and the work has been completed on three objectives. The work on other two objectives is under progress based on secondary data from various reports and manual as short interval recorded rainfall (hourly) data at CWC gauging sites has not been provided. He mentioned that based on the available secondary data and collection of the additional rainfall data of nearby sites from IMD, the study will be completed in time.
5.	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin **Study Group:** Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu **DOS:** Nov. 2018 **DOC:** March 2021	Dr Archana Sarkar presented the background and objectives of the study. She presented the methodology adopted and detailed results of the downscaled and bias corrected climate data (precipitation, maximum temperature, minimum temperature, mean temperature) for historic as well as future time period upto 2100 from 16 GCMs under two future emission scenarios (RCP4.5 & RCP8.5). She also presented the data availability for hydrological modeling in the Banas basin upto the Bisalpur reservoir and future plan of work. She informed the house that due to the present pandemic situation, field visits for some more data collection could not be taken up and the study requires one year extension upto October 2021. The Chairman asked the PI to complete the study by March 2021. Dr Deshpande from SAC, Ahmedabad enquired about the inflow and outflow from the Bisalpur reservoir. Another member from NEERI, Nagpur also enquired about water allocation priorities from the reservoir to which Dr Sarkar presented the Dam operation data given by WRD, Rajasthan. No other specific comments were received from the committee members present.

6.	Study of hydrological changes in selected watersheds in view of climate change in India **Study Group:** L.N. Thakural D.S. Rathore, Surjeet Singh, Sanjay K. Jain Sharad K. Jain **DOS:** April 2015; **DOC:** March 2020	Dr. Laxmi Narayan Thakural presented the objectives, methodology and the status of the above ongoing study. The GIS database created to meet out the objectives of the study using Digital Elevation Model (DEM) and satellite imagery for flow accumulation, stream network, watershed boundary, Land use/Land coverthematic maps in addition to soil map for the four watersheds was presented. Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches for the Ramganga, Bina, Dhadhar and Chaliyar river basins were also presented in the meeting. The outcomes/results of hydrological models calibrated and validated for the river basins i.e. Ramganga, Bina, Chaliyar and Dhadhar river basins were presented and the future simulations using future rainfall and temperature scenarios for the Dhadhar and Chaliyar basins were also presented. On the request of the PI, the study has been extended up to December 2020 to complete the future simulations under changing climate for the remaining two basins (which is under process).
7.	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:** March 2021	Dr. Ashwini Ranade, PI of the project presented the objectives, work plan and current status of the project. She has presented important results from global temperature trend analysis (1979-2018). Committee members well appreciated the work on the changes in 3-D global atmospheric thermal structure in recent years and its association with monthly rainfall of seven homogeneous zones of the country.
8.	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	PI of the study presented the objectives and the status of the study,with preliminary results of correlations analysis between low-frequency ocean-atmosphere oscillations and the streamflow at the selected gauging sites. Based on the suggestions from previous working group, an additional objective was added to the study objectives and the study will now be concentrated on 2 watersheds,Godavari and Narmada River Basins. No comments were made by the committee members. Dr. J V Tyagi, Director, NIH inquired if the study is going as per the schedule and suggested that the project be completed as scheduled, i.e. by the end of October 2021.
9.	Evaluation of water quality of Government schools in Roorkee block, District Haridwar **Study Group:** N.K. Bhatnagar M.K. Sharma, L.N. Thakural, Reena Rathore **DOS:** Oct. 2018; **DOC:** Sept. 2020	Head SWHD briefed the progress of the study on Evaluation of water quality of Government schools in Roorkee block, District Haridwar. Pre monsoon and post monsoon water sampling has been done and testing of water quality has been completed. Testing of metal ions for pre monsoon in water samples has been completed, post monsoon is under process. All GIS Maps has been completed. Report writing is under progress.The Chairman desired that the study should be completed and its report may be submitted by October,2020.
10.	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f **Study Group:**	It was informed by Head SWHD that in this study the methodology developed by the PI will be applied for carrying out flood frequency analysis generalized UEV (unified extreme-value) distribution for Lower Narmada & Tapi subzone-3b; and Lower Godavari subzone-3f. The efficacy of

	S.K. Singh **DOS:** April 2020; **DOC:** March 2021	the developed methodology will be demonstrated for flood frequency estimation.
11.	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:** July 2020; **DOC:** August 2022	Mr. Jagadish Prasad Patra, presented the current practice of dam break studies for preparation of EAP and the need for moving towards a Probabilistic dam break studies and importance of Exceedance Probability Inundation (EPI) Maps in future. The various objectives along with brief methodology was presented for the proposed study "Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan". It was explained that considering reduction in duration of the study, a truncated model approach will be used for modelling the breach outflow hydrograph rather than cloud computing or parallel processing approach. There was no specific comments on the study.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2020-21

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD /16-21	Hydrological modeling 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 March 2021)
2.NIH/SWHD /19-20	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	15 months (Oct. 2019 to Dec. 2020)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
4.NIH/SWHD/ 17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
5.NIH/SWHD/1 8-20	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2 years (Nov. 2018 to October 2020) Extended up to March 31, 2021)

6.NIH/SWHD/ 15-19	Study of Hydrological Changes in selected Watersheds in view of Climate Change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay K. Jain Sharad K. Jain	4 years (April 2015 to March 2019) Extended up to Dec., 2020
7.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)
8.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	3 years (Nov 2018 to October 2021)
9.NIH/SWHD/ 18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. thakural Reena Rathore	2 years (Oct 2018 to sept. 2020)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
10.NIH/SWHD /20-21	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f	S.K. Singh	One year (April 2020 to March 2021)
11.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 (Aug 2020 to Jul 2022

WATER RESOURCES SYSTEMS DIVISION

During the working group meeting, internal completed/ ongoing studies and proposed new studies were presented. None of the sponsored studies were presented during the WG. Accordingly, two completed studies, three ongoing studies and four new studies were presented by the respective PIs. Dr. Sanjay K Jain, Sc. G and Head, presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Thereafter, PIs of the studies as discussed above presented their studies. Following are the comments/suggestions received from working group on the presentations of the various studies.

PI: Dr. M. K. Nema (MKN), Scientist "D"

MKN presented one completed and one proposed study.

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

MKN presented the completed study covering the study background, objective, methodology, instrumentation set up and various results. He informed that all the objectives had been accomplished. It has been explained that the first phase of the Henval study mainly dealt with the establishment of field observatory in the catchment and also time-series analysis of various meteorological, hydrological and lithological variable. The results of the evapotranspiration (ET) estimated by the various methods and their inter-comparison were presented. It was also informed that a detailed project report has been prepared and sent for technical review to external and internal experts. The WG members made no significant comments during the presentation.

2. Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya (Project Henval Phase-II) (New Study)

MKN proposed a new internal research study on the Henval experimental watershed. He expressed that considerable instrumentation has been done in the Henval catchment and in continuation Henval Phase-II is being proposed. He briefed about the study objectives, methodology, budget, and project timeline to the working group members. The working group members appreciated the initiatives and made no specific suggestions or comments about the new proposed study.

PI: Deepa Chalisgaonkar, Scientist "G"

DC presented one completed study and one proposed study.

1. Development of window based software for Flood Estimation (Completed)

Mrs. Deepa presented the study. She informed WINDOWS based software named "NIH_FLWin: A Windows based Software for Flood Estimation" has been developed. The modules in the software are classified in nine different categories dealing with different aspects such as Processing and Analysis of Precipitation Data, Computation of Discharge and Rating Curve Analysis, Computation of Excess Rainfall and Direct Surface Runoff, Unit Hydrograph Derivation, Reproduction of Direct Surface Runoff and Estimation of Flood, Design Flood, Channel Routing, Reservoir Routing Using Modified Pul's Method and Flood Estimation for Large Catchments. These modules have been further sub-divided into various sub modules.

She further added that the software provides a user-friendly environment. It also includes on-line help to guide the user for each module. Sample data has been included in the package for easy preparation of input files. The results are in the form of tabular and graphical options facilitating efficient analysis and reporting and are subjected to the assumptions and limitations of the respective techniques on which the programmes are based. The package provides useful information regarding the flood estimation which is very much useful to the field engineers.

Dr S P Agrawal enquired about the validation of the software. Dr A K Lohani informed that the software has been tested with sample data and it is working fine.

2. Upgradation of NIH_ReSyP – A Reservoir Systems Package (New Study)

Mrs. Deepa presented the study. She informed that there are two objectives. (i) Upgradation of NIH_ReSyP to VB.Net Platform and (ii) To carry out a number of modifications in various modules of NIH_ReSyP software developed in the institute about a decade back. The modules of NIH_ReSyP software 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 will be upgraded from VB6 to VB.NET. It was suggested by Dr. Vijay Kumar, MoES that a number of reservoir system studies have been carried out at NIH. It would be worthwhile to demonstrate the applications of NIH_ReSyP software modules with such data. It was clarified that in the previous version of the software, sample input - out files for each module were provided with the software and the same will be provided in this version also. Dr M K Goel added that the development of a user-friendly software for integrated operation of reservoir systems in accordance with the Indian practices.

PI: Dr. P. K. Singh (PKS), Scientist "D"

PKS presented one ongoing study and one proposed study.

1. Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework (Ongoing)

PKS presented the work on the ongoing study "Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework". During presentation, one of the experts asked whether the deep aquifers are considered in this framework. PKS informed that WA+ framework does not consider deep aquifer mechanism in developing water accounts. By the end of December, 2020, the remaining work on overall aspects of water resources availability (Sheet 5 and Sheet 1) will be completed and the final report of this project will be submitted. PKS further informed that the work has been also presented in IGWC-2019 and one research paper is ready for submission to the Current Science Journal. The presentation was appreciated by the experts.

2. 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. (New Study)

PKS also presented a new NHP sponsored 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". This study was specifically requested by the implementing agency (IA) of National Hydrology Project (NHP), i.e., Water Resources Department (WRD) Meghalaya to NIH Roorkee.

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

MA presented one ongoing study.

1. Monitoring and Modeling of Gangotri Glacier melt runoff and simulation of stream flow under different climate scenarios (Ongoing study)

MA presented the progress of the study. He informed that the data could not be collected for the ablation period of 2020 because of Covid 19 outbreak. The analysis of meteorological parameters was presented. The capabilities of HBV light model were demonstrated with the help of one case study for a Himalayan catchment the difference between SNOWMOD and HBV was explained. The CORDEX outputs will be used for studying the climate response. Dr Bhishm Kumar asked about the isotope analysis in the study. It was informed that samples are collected for isotope analysis in another NMSHE study. Dr Man Singh wanted to know how the individual components of streamflow are characterized. MA explained how snowmelt and ice melt can be separated. Director, NIH was interested in knowing the beneficiaries of this study. MA informed that studies carried out were presented in PAMC of DST and project report was submitted to DST. The results of the study were also used for reply of parliament queries. Also the results are communicated to the hydropower companies, State climate departments and GSI etc.

PI: Dr. Vishal Singh (VS), Scientist "C"

VS presented one ongoing study and one proposed study.

1. Real time flood modelling using HEC-RTS modelling framework (Ongoing)

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. Dr. Dimri suggested a similar new study on urban flood modeling. Dr. Sanjay Jain informed that the study is different than urban flooding study and some studies have been carried out in the Institute on urban flooding also.
No specific comments were received from the members.

2. Impacts of glacier and climate change on runoff for selected basins of Himalayan region (New)

VS presented the proposed new study on 'Impacts of glacier and climate change on runoff for selected basins of Himalayan region'. He explained that the main purpose of the study is to know the impact of glacier change on runoff and also to see the impact of climate change on runoff. No specific comments were received from the members.

The work program of the division for the year 2020-21 is given below.

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-2021

SN	Title	Study Team	Duration	Funding (Rs. Lakh)
Ongoing 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)	
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Singh A. K. Lohani	2 years (12/18-12/20)	
3.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years (04/18-03/21)	
Ongoing Sponsored 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 (01/16-12/20)	DST (52.15)
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar, V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
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 (01/16-12/20)	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 (01/16-12/20)	DST 86.1 (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 (01/16-12/20)	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 (01/16-12/20)	DST (90.99)
7.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema; Renoj J. Thayyen; Sharad Jain (Retd.); Sanjay Jain; P. K. Mishra; AP Dimri	3 years (2016-19) Extended up to Dec. 2020	MOES (Rs. 98 Lakh)
8.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore; L. N. Thakural; Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan	3 years 2017-2020	PDS under NHP (50.23 Lakh)

9.	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; Suman Gurjar	3 years (11/19-11/22)	NMHS-MoEF (143 Lakh)
10.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Renoj J. Thayyen A. P. Dimri (JNU) Sanjay K. Jain	3 years (06/19-11/22)	NRDMS-DST (23.19 Lakh)
11.	Permafrost mapping and characterisation of Ladakh Region	Renoj J. Thayyen; A. P. Dimri (JNU); G. Jeelani (KU); V. Agnihotri (GBPNI)	3 years (11/19-11/22)	NMHS-MoEF (197.48 Lakh)
New Internal/ Sponsored Studies				
1.	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
2.	Henvel Experimental Watershed: Observations and modelling (Phase II)	M K Nema Renoj J. Thayyen P K Mishra	3 years (08/20-07/23)	NIH
3.	Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package	D. Chalisgaonkar M. K. Goel	1 year (08/20-07/21)	NIH
4.	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	2 years (08/20-07/22)	NHP (14.50 Lakh)
5.	Preparation of Guidelines for the "Management of Glacial Hazards and Risks especially GLOFs & LLOFs"	Sanjay K. Jain A K Lohani	1 year (12/19-12/20)	NDMA (14.36 Lakh)

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 2019-20. He also presented tables showing the studies and activities proposed for the F.Y. 2020-21. Next, he invited Dr Jyoti Patil, Er Rohit Sambare and Dr Senthil Kumar to present the newly proposed studies.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2020-21

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	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	On-going
2	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	Jul 2020-Dec 2022	New

3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020- Jun 2022	New
4	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.	Jul 2020- Jun 2022	New
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-Mar 2021	On-going
2	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS (through Scheme funds)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018-Dec. 2020	On-going
3	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/Workshops during 2020-21

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Training on 'Water security for resilience to deal with disasters and outbreaks', under aegis of INC-IHP (proposal approved by Director, NIH)	Nov. 2020	Virtual training	Youth and YPs associated with WR Assessment & Management	V C Goyal, Jyoti P Patil, Amrendra Bhushan, Victor Shinde (NIUA)
2	Hands-on training on 'Life Cycle Approach for rejuvenation of ponds and lakes using Nature Based Solutions', to be funded by SERB, DST, GoI (proposal approved by Director, NIH)	Dec. 2020	NIH Roorkee	PG and PhD students of Water resources management/ engineering	Jyoti P Patil, V C Goyal, Omkar Singh, T Thomas, Rajesh Singh, Rohit Sambhare
3	Three-day training program on "Hydrology of water bodies and their development under climatic uncertainty"	Jan 2021	NIH Roorkee	Engineers in Irrigation/PHE /SWC departments	A. R. Senthil kumar, Santosh M Pingale, Rohit Sambare, N R Alakka

4	Awareness program on Ecohydrology for Wetland Conservation	Feb./ Mar. 2021	NIH Roorkee	Research scholars, and PG students	Rohit Sambare, Suhas Khobragade
5	Awareness Program for School Children	Oct/Nov 2020	5 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
6	Awareness Programme on "Water quality and water budgeting in 5 sub Villages of Ibrahimpur Masahi", Dist. Haridwar	Feb/Mar, 2021 (5 days)	Vill. Ibrahimpur Masahi,	Progressive Farmers	Omkar Singh, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka

Proposed Outreach Activities during 2020-21

S.N.	Activity
1	Preparation of a guidebook on 'Role of hydrology in district level planning' (V C Goyal, Jyoti Patil)
2	Preparation of Short Videos (5-10 min) on i) CW & FW/Nature Based Solutions/ Pond Rejuvenation ii) Wetland Hydrology iii) Crop diversity, water productivity & farmer's income iv) On studies and projects of NIH Scientists
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 50^{th} WG meeting

1.	Dr. J V Tyagi, Director, NIH	Chairman
2.	Dr. B P Yadav, IMD, New Delhi	Member
3.	Er. Bhopal Singh, NWDA, New Delhi	Member
4.	Dr. Vijay Kumar, MoES, New Delhi	Member
5.	Dr. P R Ojasvi, ICAR-IISWC, Dehradun	Member
6.	Dr. Sushil Kumar, WIHG, Dehradun	Member
7.	Er. Kireet Kumar, GBPIHE&D, Almora	Member
8.	Dr. R D Deshpande, PRL, Ahmedabad	Member
9.	Dr. R K Goyal, CAZRI, Jodhpur	Member
10.	Dr. Pawan Labhasetwar, NEERI, Nagpur	Member
11.	Dr. S P Aggarwal, IIRS, Dehradun	Member
12.	Dr. Man Singh, WTC, ICAR-IARI, New Delhi	Member
13.	Dr. Varun Joshi, GGSIPU, New Delhi	Member
14.	Prof. K K Singh, Kurukshetra Univ., Kurukshetra	Member
15.	Prof. A K Saraf, IIT Roorkee	Member
16.	Dr. Bhishm Kumar, IAEA (Retd.), Roorkee	Member
17.	Prof. Ramakar Jha, NIT Patna	Member
18.	Prof. A P Dimri, JNU, New Delhi	Member
19.	Dr. Debashish Sen, PSI, Dehradun	Member
20.	Dr. Sadhana Malhotra, Mindspace, Dehradun	Member
21.	Sh. Sudhindra Mohan Sharma, Ex-Nodel Officer, MoDWS, Indore	Member
22.	Dr. Rakesh Kumar, Sc. G & Head SWH Division, NIH	Member
23.	Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH	Member
24.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
25.	Dr. R P Pandey, Sc.G & Head EH Division, NIH	Member
26.	Dr. V C Goyal, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from NIH

	EH Division		SWH Division
1	Dr. M.K. Sharma, Sc.E	19	Dr. A.K. Lohani, Sc.G
2	Dr. Rajesh Singh, Sc.D	20	Dr. Sanjay Kumar, Sc.E
3	Dr. Pradeep Kumar, Sc.D	21	Dr. Archana Sarkar, Sc.E
4	Sh. Rajesh K. Nema, Sc.B	22	Dr. L.N. Thakural, Sc.D
5	Ms. Anjali, Sc.B	23	Sh. J.P. Patra, Sc.D
	GWH Division	24	Dr. Ashwini A. Ranade, Sc.C
6	Dr. Anupama Sharma, Sc.F	25	Sh. Sunil Gurrapu, Sc.C
7	Dr. Surjeet Singh, Sc.F	26	Sri N K Bhatnagar, Sc.B
8	Er. Sumant Kumar, Sc.D		**WRS Division**
9	Dr. Gopal Krishan, Sc.C	27	Dr. M.K. Goel, Sc.G
10	Sh. Nitesh Patidar, Sc.B	28	Smt. Deepa Chalisgaonkar, Sc. G
	HI Division	29	Er. D.S. Rathore, Sc.F
11	Dr. M.S. Rao, Sc.F	30	Dr. Renoj J. Thayyen, Sc.E
12	Dr. Santosh M Pingale, Sc.C	31	Dr. Manohar Arora, Sc.E
13	Ms. Nidhi Kalyani, Sc.B	32	Dr. P K Singh, Sc.D
	RMO Division	33	Er. Manish Nema, Sc.D
14	Er. Omkar Singh, Sc.F	34	Dr. P K Mishra, Sc.C
15	Dr. A R Senthil Kumar, Sc.F	35	Dr. Vishal Singh, Sc.C
16	Dr. (Mrs.) Jyoti P. Patil, Sc.D	36	Sh. P K Agarwal, Sc.B
17	Sh. Digamber Singh, Sc.C		
18	Sh. Rohit S. Sambare, 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	Ms. Anjali	Scientist B
7	Sh. Shekhar Saini	SRA
8	Smt. Babita Sharma	RA
9	Smt. Bina Prasad	RA

ENVIRONMENTAL HYDROLOGY DIVISION
Work Programme for the Year 2020-21

SN	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	M. K. Sharma(PI) Manohar Arora Pradeep Kumar Rajesh Singh D. S. Malik (GKU)	5 Years (04/16-03/21) **Sponsored by**: DST (NMSHE) **Project Cost**: Rs. 2.25 Crore **Status:**Draft Report submitted
2.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur, CGWB, Raipur	3½ Years (09/17-03/21) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 25.4 Lakh **Status:** In-progress
3.	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 (09/17-03/21) Extension requested till 09/21 **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** In-progress
4.	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 **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress
5.	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
Internal Study (Ongoing)			
6.	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:** In-progress
7.	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
8.	Development of rejuvenation plan for Hindon river system	M. K. Sharma (PI) Sudhir Kumar R. P. Pandey Anupma Sharma Anjali Vishal Singh Pradeep Kumar Nitesh Patidar	3 Years (07/20-06/23) **Project cost:** Rs. 20.24 Lakh **Sponsored by**: Internal **Status:** In-progress

		Surjeet Singh Rajesh Singh	
9.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi 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
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) Pradeep Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural P. K. Singh Rajesh Singh	2 Years (03/20-02/22) **Project Cost**: Rs. 1.1033 Crore **Sponsored by:** ICFRE **Status:** In-progress
11.	Area Drainage Study for Khavda Hybrid Renewable Power Project in Kutchh Region	J.V. Tyagi R.P Pandey (PI) J. P. Patra Shekhar Saini	4 months (07/20-10/20) **Project Cost:** Rs. 35,99,000/- **Sponsored by:** Adani Green Energy Ltd., Ahmedabad. **Status:** Completed
12.	Hydrological Designing for Diversion of Nallah to Suswa river at SSB Reserve Bn Hqrs area near Markhamgrant Doiwala	J.V. Tyagi R.P Pandey (PI) Pradeep Kumar J. P. Patra	½ month (02/21-03/21) **Project Cost:** Rs.7,67,000/- **Sponsored by:** CPWD Dehradun **Status:** Completed
13.	Hydrological Study of New India Garden (NIG) Project at Village Indraprasth, New Delhi	J.V. Tyagi R. P. Pandey (PI) Pradeep Kumar J. P. Patra	1 month (03/21-04/21) **Project Cost:** Rs. 41,30,000/- **Sponsored by:** CPWD New Delhi **Status:** In progress
14.	Water Quality Assessment at Inlet and Outlet of STPs	Rajesh Singh (PI)	2 months (02/21-03/21) **Project Cost**: Rs. 1.39 Lakh **Sponsored by:** Uttarakhand Pay Jal Nigam, Hardwar **Status:** In-progress

Training Programmes/Workshop organized:

SN	Topic	Duration	Place
1.	Online Training Course titled "Data Processing for Water Quality" (Coordinator: Dr. M. K. Sharma and Anjali Bhagwat)	5 Days 5-9 October 2020	Roorkee
2.	Mandatory Level-II training for Senior Research Assistants (SRAs) of CWC (Coordinator: Dr. M. K. Sharma)	4 Days 19-22 October 2020	Roorkee
3.	Online Training Course titled "Data Processing for Water Quality" (Phase II) (Coordinator: Dr. M. K. Sharma and Anjali Bhagwat)	5 Days 2-6 November 2020	Roorkee

4.	Online Workshop on "Biodiversity and Ecosystem Health Assessment of Upper Ganga Basin" under NMSHE Project jointly organized by GKU, Haridwar and NIH(Organizing Secretaries: Dr. D. S. Malik and Dr. M. K. Sharma)	5 Days 22-26 February, 2021	GKU, Haridwar

Publications:

Int. Journal	Nat. Journal	Int. Conference	Nat. Conference	Book Chapter	Total
09	03	07	02	08	**29**

International Journal

1. Sharma, M. K., Thayyen, Renoj J. and Shyamlal (2021) Role of sediment in solute acquisition in the Himalayan Glacier meltwater stream - Gangotri Glacier, Uttarakhand, India, Hydrological Processes, 35, 1-16, DOI: 10.1002/hyp.14018.
2. Ali, S., Babali, Singh, S., Singh, R., Tyagi, M. and Pandey, R. P. (2021). Influence of multidrug resistance bacteria in river Ganges in the stretch of Rishikesh to Haridwar. Environmental Challenges, 3, 100068.
3. Krishan, G., Sejwal, P., Bhagwat, Anjali, Prasad, G., Yadav, B.K., Kumar, C.P., Kansal, M.L., Singh, S., Sudarsan, N., Bradley, A., Sharma, L.M. and Muste, M. (2021) Role of Ion Chemistry and Hydro-Geochemical Processes in Aquifer Salinization—A Case Study from a Semi-Arid Region of Haryana, India, Water , **13**, 617. Doi: 10.3390/w13050617 (IF: 2.92)
4. Goyal, V. C., Singh, O., Singh, R., Chhoden, K., Kumar, J., Singh, N., Shrivastava, N. G., and Carvalho, L. (2021). Ecological health and water quality of village ponds in the subtropics limiting their use for water supply and groundwater recharge. Journal of Environmental Management, 277, 111450 (IF: 5.647).
5. Kashyap, S., Singh, R. and Singh, U. P. (2020) Inorganic and organic anion sensing by azole family members. Coordination Chemistry Reviews, 417, 213369 (IF: 15.367).
6. Malik, Ashish and Bhagwat, Anjali. (2020). Modelling groundwater level fluctuations in urban areas using artificial neural network. Groundwater for sustainable Development. 12, 100484. Doi:10.1016/j.gsd.2020.100484 (IF: 4.30)
7. Birara, H., Pandey, R.P. and Mishra, S.K. (2020) Projections of future rainfall and temperature using statistical downscaling techniques in Tana Basin, Ethiopia. Sustain. Water Resour. Manag. 6, 77. https://doi.org/10.1007/s40899-020-00436-1.
8. Krishan, Gopal, Prasad, Gokul, Bhagwat,Anjali, Kumar, C.P., Patidar, Nitesh, Yadav, Brijesh, Kansal, M.L., Singh, Surjeet, Sharma,Lalit Mohan, Bradley, Allen, Verma,S.K. (2020). Identifying the seasonal variability in source of groundwater salinization using deuterium excess- a case study from Mewat, Haryana, India, Journal of Hydrology: Regional Studies. 31, 10074 Doi:10.1016/j.ejrh.2020.100724 (IF:3.92)
9. Tiwari, K. K., Krishan, Gopal, Bhagwat, Anjali, Prasad, Gokul and Mondal, N. C. (2020). Evaluating fluoride contamination in groundwater in a semi-arid region, Dausa District, Rajasthan, India. (2020). Groundwater for sustainable Development. 11, 10046.5 Doi: 10.1016/j.gsd.2020.100465 (IF: 4.30)

National Journal

10. Sharma, M. K., Singh,Surjeet, Kumar,Pradeep, Patre, A. K., Kumar,Mohit, Prasad Beena, Shukla, A. K. and Das, P. C. (2020) Hydrogeochemical Evaluation of Groundwater of Bemetara District, Chhattisgarh, e-Journal of Geohydrology, International Association of Hydrogeologists Indian National Chapter, Vol. 1, Issue 2, 82-92.
11. Malik, D. S., Sharma, M. K., Sharma, Arvind K. and Sharma, Amit K. (2021) Status of fish diversity and their habitat ecology in the Upper Ganga Basin, Uttarakhand, Eco. Env. & Cons., 27, 5205-5209.

12. S. Sundriyal, S., Bhan, U., Selvakumar, S., Singh, R. and Dobhal, D. P. (2021). Two decadal changes in the major ions chemistry of melt water draining from Dokriani Glacier, central Himalaya, India. Journal of the Geological Society of India, 97, 308-314 (IF: 0.899).

International Conference

13. Rawat, Monika, Veerabhadrappa, S. M., Pandey, R. P. and Sena, D. R. (2021). Urban Sprawl Over a Lotic Ecosystem of Doon Valley: Trend and Future Implications. Proceedings of Second International Conference on Smart Energy and Communication, Springer Publisher, pp 557-568; Print ISBN978-981-15-6706-3; DOI: https://doi.org/10.1007/978-981-15-6707-0_54.
14. Rawat S. S., Nikam B. R. and Kumar P. (2021). Modelling of Sediment Yield in Tawi River for Identification of Critical Sources of Sediments. In: Proceedings of RCRM 2021 1st International Conference on River Corridor Research and Management organized by IIT, Jammu during 25-27 Feb 2021.
15. Mishra, P.K., Singh H., Thayyen R.J., Das S., Nema M.K., and Kumar P. (2021). Block level Livelihood Vulnerability Index of a Himalayan district in Upper Ganga Basin. In: Proceedings of HYDRO 2020 - International Conference on Hydraulics, Water Resources, and Coastal Engineering at NIT, Rourkela during 26-28 Mar 2021.
16. Kumar, Rajat, Bhagwat, Anjali, Pant, Apourv and Prasad, Beena (2021) Landfill leachate: Source of groundwater pollution. A case study of Gazipur, Delhi, Poster in International Symposium on "Valuing Water: Groundwater Sustainability and Climate Change" organized on March 21-22, 2021
17. Pant, Apourv, Bhagwat, Anjali and Kumar, Rajat(2021) Microplastics in groundwater and its quantification, Poster in International Symposium on "Valuing Water: Groundwater Sustainability and Climate Change" organized on March 21-22, 2021
18. Sharma, M. K., Prajapati, Parul, Bhanot, Kunarika, Wadhwa, Udita and Tomar, Garima (2020) Hydro-geochemical investigations in Upper Ganga Basin, India, International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals, organized by Academy of Natural Resource Conservation and Management, Lucknow (UP), India during September 11-12, 2020.
19. Raghav, Nandani and Sharma, M. K. (2020) Proficiency of Water Purification System Against Bacterial Contamination In Water International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals, organized by Academy of Natural Resource Conservation and Management, Lucknow (UP), India during September 11-12, 2020.

National Conference

20. Sharma, M. K. (2021) Study of Subglacial system: The main source of solute acquisition, Online National seminar on "Resilience of Groundwater Resources for Accommodating Changing Climate Scenarios" organized by the Indian National Chapter of International Association of Hydrogeologists (INC-IAH) during February 27-28, 2021.
21. Kumar P. and Pandey, R.P. (2021) Development of River Rejuvenation Plan: Case Study of Rispana River System. IN: Proceedings of National Conference on "Water Resources Management in Hilly Regions under Changing Climate" at Graphic Era University during 19-20 Mar 2021.

Book Chapters

22. R. Singh, S. Kashyap, A. Pandey (2021). Water quality and human health. In Climate Impacts on Water Resources in India: Environment and Health (Eds. A. Pandey, S. K. Mishra, M. L. Kansal, R. D. Singh, V. P. Singh), Springer Nature, Switzerland (ISBN: 978-3-030-51427-3).
23. R. Singh, D. Kanbienna, A. Pandey (2021). Water quality status of upper ganga canal. In Climate Impacts on Water Resources in India: Environment and Health (Eds. A. Pandey, S.

K. Mishra, M. L. Kansal, R. D. Singh, V. P. Singh), Springer Nature, Switzerland (ISBN: 978-3-030-51427-3).

24. M. K. Sharma, R. Singh, O. Singh, D. G. Durbude (2021). Contamination in drinking water supply: A case study of Shimla city, Himachal Pradesh, India. In Climate Impacts on Water Resources in India: Environment and Health (Eds. A. Pandey, S. K. Mishra, M. L. Kansal, R. D. Singh, V. P. Singh), Springer Nature, Switzerland (ISBN: 978-3-030-51427-3).
25. Pradeep Kumar,Jai PrakashNayak, and Shobha Ram (2020) Hydro-Ecological Assessment of Environmental Flows for Satluj River. In:Pandey et al. eds. (2020) ‘Climate Impacts on Water Resources in India', Springer, pp. 157-166.
26. SudinMoktan, R. P. Pandey, S. K. Mishra, R. B. Pokharel (2020) Study of Drought Characteristics in Ken River Basin in Bundelkhand Region in India. Hydrological Extremes (eds: PandeyAshish, SK Mishra, ML Kansal, Rd Singh and VP singh), Book published by Springer, Publisher, Pages 87-109.
27. Amrit Kumar, R. P. Pandey, S. K. Mishra (2020) Meteorological Drought Characteristics in Eastern Region of India. Hydrological Extremes (eds: PandeyAshish, SK Mishra, ML Kansal, Rd Singh and VP singh), Book published by Springer Publisher, Pages 111-120
28. HailuBirara, S. K. Mishra, R. P. Pandey (2020) Comparison of Methods for Evapotranspiration Computation in the Tana Basin, Ethiopia. Hydrological Extremes (eds: PandeyAshish, SK Mishra, ML Kansal, Rd Singh and VP singh), Book published by Springer Publisher, Pages 405-422
29. S. K. Malyan, S. S. Kumar, L. Singh, R. Singh, D. A. Jadhav, V. Kumar (2020) Bioelectrochemical systems for removal and recovery of heavy metals (In. Bioremediation, Nutrients, and Other Valuable Product Recovery. Eds. Lakhveer Singh DurgaMadhabMahapatraSveta Thakur), ISBN- 9780128217290, Elsevier Science, Chapter 9, pp. 185-203.

ENVIRONMENTAL HYDROLOGY DIVISION
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 (09/17-03/21) Extension requested till 09/21 **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **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 **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 (12/17-12/20)** Extension requested till 03/22 **Project cost:** Rs. 75.0 Lakh **Status:** In-progress
Internal Study (Ongoing)			
4.	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:** In-progress
5.	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
6.	Development of rejuvenation plan for Hindon river system	M. K. Sharma (PI) Sudhir Kumar R. P. Pandey Anupma Sharma Anjali Vishal Singh Pradeep Kumar Nitesh Patidar Surjeet Singh Rajesh Singh	3 Years (07/20-06/23) **Project cost:** Rs. 20.24 Lakh **Sponsored by**: Internal **Status:**In-progress
7.	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
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) Pradeep Kumar (Co-	2 Years (03/20-02/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033

		PI) T. Thomas (Co-PI) L. N. Thakural P. K. Singh Rajesh Singh	Crore **Status:** In-progress
9.	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	1 month (03/21-04/21) **Project Cost:** Rs. 4,13,0000/- **Sponsored by:** CPWD New Delhi **Status:** In progress

Training Programmes

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

Study - 1 (Sponsored Project)

1. **Title of the Study:** Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin (Subproject-10).

2. **Study Group:**

Project Investigator/Co-Project Investigator Dr. M. K. Sharma, Sc. 'E' Dr. Manohar Arora,Sc. 'E'
Co-Investigator Dr. Pradeep Kumar, Sc. 'D' Dr. Rajesh Singh,Sc 'D'
Scientific/Technical Staff Smt. Babita Sharma, RA Smt. Beena Prasad, RA Sri. Rakesh Goyal, Tech. Gr. I
Collaborating Agency Prof. D. S. Malik, Professor, GKU, Haridwar

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

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

5. **Date of start:** April 2016

6. **Scheduled date of completion:** March 2021

7. **Duration of the Study:** 5 Years

8. **Study Objectives:**

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

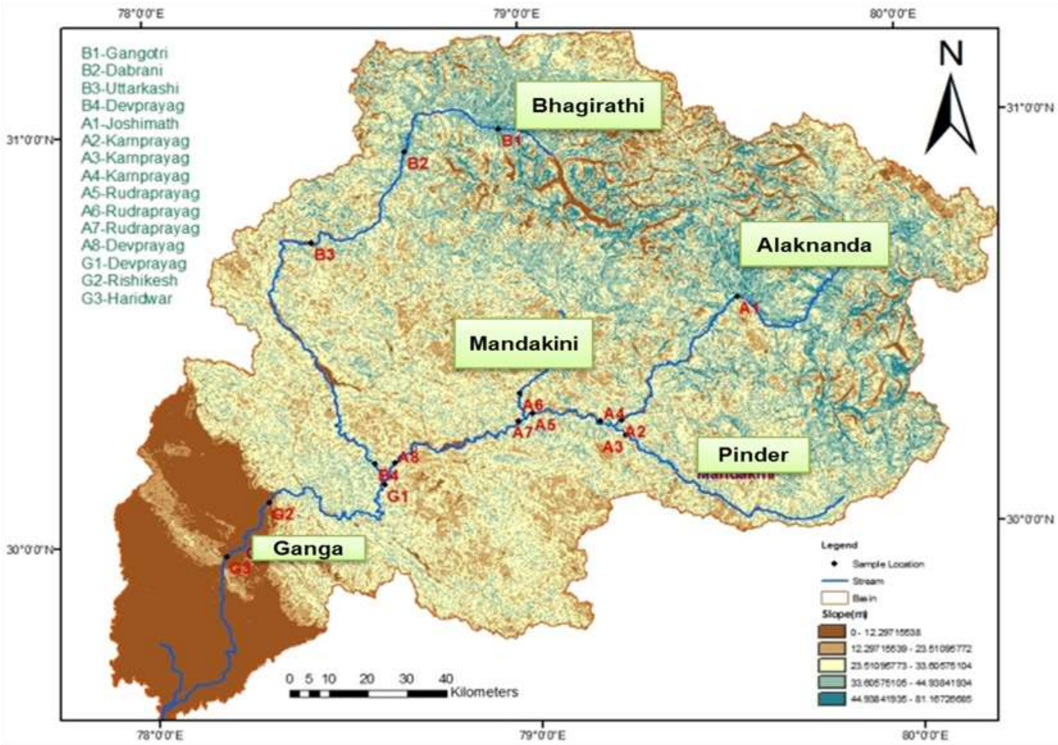
9. **Statement of the Problem:**

The States which share the Himalayas are also its principal sentinels. Adaptation toClimate Change must become an integral part of their development strategies. The special vulnerabilities of this ecologically fragile region need to be recognized, as much as its rich natural resources in terms of forests, water wealth, biodiversity and tourism potential. While a number of long-term measures are under consideration as part of the National Action Plan on Climate Change, several key and urgent interventions may be considered to prevent thefurther degradation of the Himalayan Ecology and to preserve their life-sustaining role for millions of our citizens. This not only includes those residing in this region, but also in the entire Indo-Gangetic Plain.

The cities in the Himalayan mountainous zones are increasing in size and in numbers. They are displaying the same degradation that plagues our cities in the plains – growing dumps of garbage and plastic, untreated sewerage, chronic water shortages, unplanned urban growth and heavy pollution from increasing vehicular traffic. This phenomenon will only exacerbate the impact from climate change.

Ecologically sensitive mountainous areas, like the Himalaya, are prone to adverse impacts of global climate changes on account of both natural causes and anthropogenic emissions in other parts of the world as well as those arising out of unplanned developmental activities in the region. Himalayan Ecosystem resources are critical on the face of natural disturbances, anthropogenic activities and climate change. It has important implications for formulation of management strategies and sustenance of dependent human societies. Some of the significant consequences arising out of the global warming on the Himalayan region could relate to a) variability in the volumetric flow of water in the rivers, b) loss in biodiversity, c) unsustainable changes in ecology, d) glacier recession, e) deforestation and degradation, f) conditions for impending natural disasters and g) dislocation of traditional societies dependent vulnerably on the Himalayan ecosystem.

Ganges, Brahmaputra, Yamuna, and other major river systems originate in the Himalayas. Any changes in the Himalayan glacier dynamics and melting are expected to severely affect about 1.3 billions of people. Water quality assessment and studies of in-stream reactions and sediment dynamics play an important role in this context. There are several reasons for this. Because of substantial efforts to reduce point pollution sources the relative effect of non-point pollution has increased. This has increased the need to identify major sources of nutrients and trace elements deposited within the river system.



Study area: Upper Ganga Basin

10. Approved Action Plan/Methodology:

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

11. Timeline:

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

12. Objectives and achievement:

Objectives	Achievements
Processing of Hydro-chemical data	• Spatial and temporal variation of hydro-chemical parameters completed. • NPS contribution for Alaknanda Stretch completed.
Adsorption characteristics	• Experiments of Adsorption of metal Pb, Cd and Nion bed sediment of Bhagirathi, Alaknanda and Ganga for different operating variables completed. • Adsorption data processed for thermodynamic parameters and adsorption kinetics.
Habitat characteristics	• Habitat characteristics data of 8 selected zones completed.
Aquatic biodiversity	• Relative abundant species of aquatic biodiversity completed. • Biodiversity indices (Shanon – Weiner Index, Simpson Index, Evenness Index) for 8 zones completed.
Environmental flow estimations	• Keystone species in the study area identified • Habitat suitability curves for the keystone species were developed. • Habitat Simulation Modellingusing SEFA software completed for maintaining environmental flow for sustenance of keystone aquatic species for Joshimath, Rudraprayag, Devprayag (After confluence), Uttarkashi, Devprayag, and Rishikesh sites.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
No comments	-

14. Analysis & Results:

i) All analysed water quality parameters are well within permissible limits of river water quality, except COD and TSS. COD is high at lower reaches of River Ganga (below 1200 m) which may be attributed to anthropogenic pollution. TSS is high at all the locations and decreases from higher elevation to lower elevation because sediments get deposited due to geomorphology of the river.

ii) Carbonate weathering is a major source of dissolved ions in the surface water of the study area and hydro-chemistry is also controlled by dissolution of rock forming minerals.

iii) Chemical mass balance approach accounts >30-50% contribution for almost all constituents from uncharacterised sources (NPS) in the stretch of River Alaknanda of Upper Ganga System during the months of November to February, which may be attributed to intense agricultural activities during the winter months particularly cereals and vegetables along with the runoff due to winter rains/ snowmelt coming from the landscape.

iv) Dissolved metal concentrations of Fe, Mn, Cu, Cr, Ni, Zn, Pb, and Cd in water samples of Upper Ganga Basin are well within acceptable limit of river water, except dissolved iron.

v) The sediments existing at the bottom of water column play a major role in pollution scheme of the river systems. Sediment concentrations provide a better evaluation of the degree and the extent of contamination in the aquatic environment. Higher ranges of iron followed by copper and manganese in the bed sediment of the study area are observed which might have principally originated from lithogenic sources and traces from anthropogenic sources.

vi) Enrichment Factor value was calculated for different metals and highest was observed for Mn, followed by Cu, Cr, Ni, Pb, Cd and Zn, which illustrates that all these elements vary from unpolluted to very smaller enrichmnent. The general trend for relative mobility is observed to be Fe>Mn>Cu>Cd>Pb>Cr>Ni>Zn.

vii) The adsorption of metal ions on sediments plays an important role in controlling metal pollution. The pH is the most important parameter in controlling metal ion adsorption. The adsorption of metal ions increases with increasing adsorbent doses and decreases with adsorbent particle size. The Kinetic data suggest that the adsorption of metal ions on bed sediments is an endothermic process, which is spontaneous at low temperature. Adsorption of lead is higher as compared to cadmium and nickel on the both size fractions of bed sediments of river Bhagirathi, Alaknanda and Ganga.

viii) Most common biotic species in the Upper Ganga Basin are phytoplanktons, zooplanktons, macro-benthos and fishes. Phytoplanktons are decreasing towards lower elevations while zooplanktons and macro-benthos are increasing at lower elevations.

ix) Drastic change observed in biotic community in all the observed three seasons. Winter and early summer seasons favour better growth of Biotic species.

x) Biodiversity Indices indicate that status of diversity varies from medium to maximum and river water is clean to slightly polluted.

xi) Aquatic habitat parameters were monitored at eight selected zones on quarterly basis for development of habitat suitability curves. Higher BOD observed during summer season in upper Ganga basin due to high temperature that favours microbial activity. Seasonal variation observed in abiotic parameters during the whole study.

xii) Physico-chemical parameters concentration of water showed that river water was under good quality condition i.e. good for aquatic biodiversity growth and survival.

xiii) The keystone species for upper (>1500m), middle (500-1500m) and lower (<500m) zones are Brown Trout, Snow Trout and Golden Mahseer respectively.

xiv) The habitat suitability curves for the keystone species were developed which may be used for the habitat simulation modelling with more detailed data.

xv) Habitat Simulation Modelling provides a number of optional scenarios for the maintenance of different levels of habitat sustenance whereas in case of hydrodynamic modelling, the flows optimum for maintaining a certain depth of water are recommended.

xvi) The final modelling output of the habitat simulation modelling is the Area Weighted Suitability (m^2/m of reach length) which indicates the suitability of a particular discharge for the habitat sustenance. Based on the variability of AWS for the historical flow variability, AWS duration analysis may be carried out in the SEFA software which may further be used for selecting a particular level of AWS for providing reasonable habitat for different seasons.

xvii) Assuming that the environmental flows may be kept for maintaining the median or higher values of AWS for sustenance of keystone aquatic species, e-flows are recommended for Joshimath, Rudraprayag, Devprayag (After confluence), Uttarkashi, Devprayag, and Rishikesh sites.

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

16. Deliverables: Technical report and research papers:

i. Draft Project Report submitted.
ii. Sharma, M.K., Kumar, Pradeep, Prajapati, Parul and Bhanot, Kunarika (2019)Hydro-chemical Characteristics of Upper Ganga Basin, India, Presented in Int. Conf. IGWC-2019 at IIT, Roorke during 21-25 Oct. 2019.
iii. Sharma, M.K., Malik, D. S., Tomar, Garima and Wadhwa, Udita (2019) Ecological and biodiversity studyof Upper Ganga Basin, India, Presented in Int. Conf. IGWC-2019 at IIT, Roorke during 21-25 Oct. 2019.
iv. Sharma, M. K., Prajapati, Parul, Bhanot, Kunarika, Wadhwa, Udita and Tomar, Garima (2020) Hydro-geochemical investigations in Upper Ganga Basin, India, International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals, organized by Academy of Natural Resource Conservation and Management, Lucknow (UP), India during September 11-12, 2020.
v. Malik, D. S., Sharma, M. K., Sharma, Arvind K. and Sharma, Amit K. (2021) Status of fish diversity and their habitat ecology in the Upper Ganga Basin, Uttarakhand, Eco. Env. & Cons., 27, 5205-5209.

17. Major items of equipment procured: Multi-Parameter Kit,

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

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

20. Study Benefits / Impacts:

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

21. Involvement of end users / beneficiaries:

22. Specific linkage with Institution and /or end users / beneficiaries: GKV, Haridwar

23. Shortcoming/Difficulties: No

24. Future Plan:

i. Organization of Stakeholder workshop
ii. Writing of Research Papers on findings of the project for International Journals.

Study - 2 (Sponsored Project)

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

2. **Study Group:**

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

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

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

5. **Date of start:**1 September, 2017

6. **Scheduled date of completion:** 31 March 2021

7. **Duration of the Study:** 3½ Years

8. **Study Objectives:**

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

9. **Statement of the Problem:**

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

In the District Bemetara, Chhattisgarh, the Precambrian sedimentary province includes Chhattisgarh Super group of rocks of upper proterozoic age of marine origin. It mainly consists of arenaceous-argillaceous-calcareous rocks and dominated by Limestone, dolomite and calcareous shale. The weathered, cavernous and fractured part of the formation constitutes the aquifers in the area. The groundwater of Bemetara district is affected by sulphate contamination reported by Public Health Engineering Department, Durg. Berla block of the district has also the possibility of such type of sulphate contamination in ground water. Therefore, Bemetara district is selected for purpose driven study for sulphate contamination in ground water. The high concentration of sulphate in ground water is due to the dissolution of gypsum veins present within maniyari shale formation. Higher concentration of sulphate in ground water causes gastrointestinal irritation. A cost effective, economic viable and environmental friendly measure will be suggested for remediation of groundwater with special reference to sulphate contamination considering hydrogeology of the area. After discussion with WRD, it was decided to focus on Maniyari shell formation region which will cover 9 blocks existing in five districts viz; Bemetara, Kawardha, Bilaspur, Mungeli and Baloda Bazar (Bhatapara).

10. Approved Action Plan/Methodology:

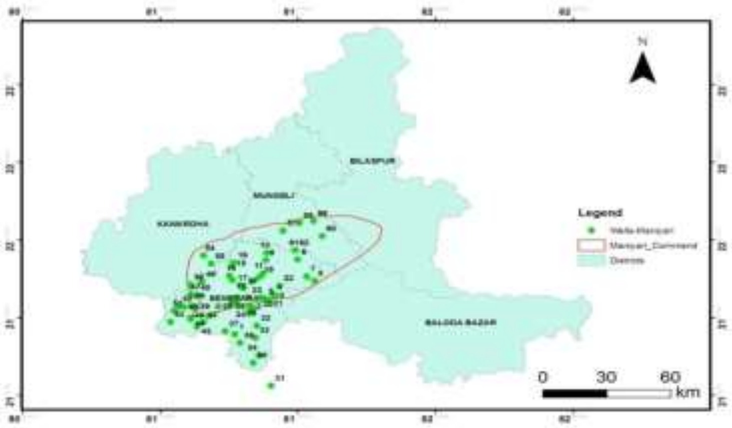
i) Literature survey on assessment of groundwater quality and issues in the region.

ii) Analysis of groundwater resources in the Bemetara district.

iii) Collection of existing meteorological and groundwater quality data of various locations of the Bemtara district and analysis.

iv) Collection of groundwater levels and lithological data from State Groundwater Department.

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



Study area: Maniyari Shale Formation

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

vii) Analysis on flow and movement of groundwater.

viii) Analysis for physico-chemical parameters: pH, EC, TDS, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4,) and Toxic (Heavy) Metals: As, Cd, Cr, Pb, Cu, Ni, Fe, Zn, Mn in the collected water samples.

ix) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose.

x) Ionic relationships will be developed and water types will be identified. Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards.

xi) Suitability of ground water for irrigation purpose will be assessed on the basis of total soluble salts, SAR and RSC. Classification of water will be made using Piper trilinear diagram, Chadha's diagram, U.S. Salinity Laboratory Classification.

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

xiii) MODFLOW & MT3D will used for modelling flow and transport of sulphate, the model will calibrated using data collected along space & time for a period of one year.

xiv) Suggesting ameliorative measures to control/ restore the groundwater quality for sustainable use by various users investigating site-specific measures considering contaminant transport, hydrogeology and system dynamics (flow-movement of groundwater, hydrogeology, managed aquifer recharge, withdrawal patterns, etc.).

11. Timeline:

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

12. Objectives and achievements:

Objectives	**Achievements**
Field visit, Sampling and Data Collection	• Carried out Field visit and collected ground water samples during pre- and post-monsoon period of the year 2018 and 2019 from study area. • Collected ground water data, aquifer parameter data and Litholog data from State Ground Water Survey, Durg, WRD, Raipur and CGWB, Raipur. • Prepared drainage, geomorphology, lithology, landuse, soil and well location map of study area in GIS platform.
Analysis and Processing of the data	• Analysed the collected samples for Hydro-chemical parameters and metal analysis. • Processed ground water level data, litholog data of the study area and hydro-chemical data.
Modelling flow and transport of sulphate using MODFLOW & MT3D	• Prepared the input database for simulation of groundwater flow using MODFLOW & MT3D. • Groundwater Flow simulation has been completed using MODFLOW.
Organization of Training Workshops	Organized following two 5-day Training Course • Groundwater Quality Modelling during 12-16 February 2018 at NIH, Roorkee. • Groundwater Quality Monitoring and Assessment during 3-7 June 2019 at NIH, Roorkee.

13. Recommendation / Suggestion: No Comments

Recommendation / Suggestion	Action Taken

14. Analysis & Results:

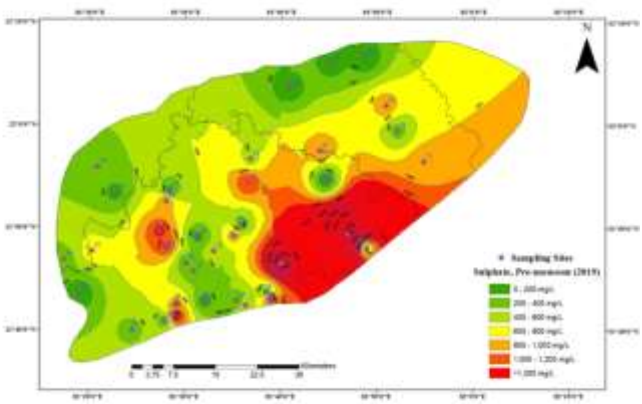
i) Prepared spatial distribution map of water quality parameters to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking water quality standards.

ii) Processed hydro-chemical data for calculating Water Quality Index.

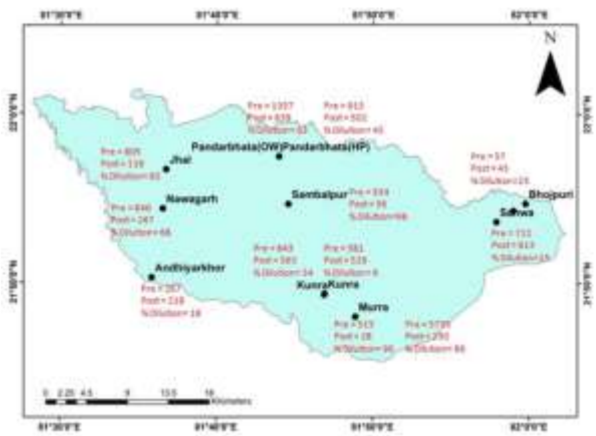
iii) Processed hydro-chemical data to understand the geochemical processes controlling the chemical composition of GW using Scatter Plots and Gibbs Plots.Prepared following database for simulation of groundwater flow using MODFLOW model:

- Contour maps for ground water level (2014-2018)
- River shape files in study area
- Shape file for Soil map, Geology, Villages, Blocks, District and landuse data
- River stage Data
- Data collection Blockwise of modelling area for Ground water recharge and draft

iv) Groundwater Flow simulation has been completed using MODFLOW and contaminant transport modeling and recharge estimation for getting sulphate concentrations within permissible limit for the sites having higher sulphate are in progress.



Sulphate distribution in Maniyari Shell formation



Probable Artificial Recharge sites for Sulphate Dilution in the modeling area

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

16. Deliverables: Technical report and research papers:
Research papers – 4 Nos.

i) Sharma, M.K., Kumar, Pradeep, Singh, Surjeet, Kumar, Mohit and Shukla, A. K. (2019) Source Identification of Sulphate Contamination using Hydrogeochemical Investigation: A Case Study of District Bemetara, Chhattisgarh, India, Submitted for Int. Conf. IGWC-2019 at IIT, Roorkee during 21-25 Oct. 2019.

ii) मुकेश कुमार शर्मा, प्रदीप कुमार, राकेश गोयल एवं मोहित कुमार (2019) "बेमेतरा जिले, छत्तीसगढ़ में भूजल गुणवत्ता का मूल्यांकन, राष्ट्रीय जल संगोष्ठी - 2019, प्रपत्र 8.6.

iii) Sharma, M. K., Singh, Surjeet, Kumar, Pradeep, Patre, A. K., Kumar, Mohit, Prasad Beena, Shukla, A. K. and Das, P. C. (2020) Hydrogeochemical Evaluation of Groundwater of Bemetara District, Chhattisgarh, e-Journal of Geohydrology, International Association of Hydrogeologists Indian National Chapter, Vol. 1, Issue 2, 82-92.

iv) Sharma, M.K. and Kumar, Mohit (2020) Sulphate contamination in groundwater and its remediation: An overview, Env. Monit. Assess., 192, 74, 1-10.

17. Major items of equipment procured:

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

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

20. Study Benefits / Impacts:

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

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

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

23. Shortcoming/Difficulties: No

24. Future Plan:

- Identification of Artificial Recharge sites and quantification of Artificial Recharge using MODFLOW & MT3D.

Study - 3 (Sponsored Project)

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

2. **Study Group:**

Lead Organization	**Project Investigator** Dr. Rajesh Singh, Sc. 'D'
	Co-Investigator Dr. Pradeep Kumar, Sc. 'D' Dr. Mukesh K. Sharma, Sc. 'E' Er. Sumant Kumar, Sc. 'D'
	Scientific/Technical Staff Sandeep Singh, RA Rakesh Goyal, Tech. Gr. I Meenakshi Rawat, JRF Prashant Kaushik, TA
Partner Organization	**Project Investigator** Er. Harminder Singh, Chief Engineer, Water Resources
	Co-Investigator Er. Narinder Kumar Jain, Director, WR&ED Dr. K. K. Kaushal, Sr. Hydrogeologist, WR&ED Mr. Sanjeev Bansal, Sr. Tech. Asst., WR&ED
Collaborators	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

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

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

5. **Date of start:** October 2017

6. **Scheduled date of completion:** September 2020 (Extension requested till September 2021)

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, and radon has been completed. • Processing of samples for pesticide and PAHs analysis has been completed and analysis will be done soon. • Onsite radon analysis for 1 district was not done due to Covid pandemic and will be carried out in April 2021.
4	Statistical analysis of data and Carcinogenicity test	• The health risk assessment for Bathinda district was done and the same is applied for other districts. • The scale for mutagenicity is being prepared and after that the carcinogenicity of drinking water sample from the study area will be carried out. This is taking time due to initial experiments of AMES test have low success rate. • The cancer wise data has been received for all the districts except, Faridkot.
5	Contaminant remediation	• The literature review related to contaminant remediation of contaminants in the drinking water is under progress.
6	Training & capacity building	• A training course for the government officials was organized during June 17-21, 2019. • Another training course and one stakeholders' workshop is proposed to be organized in May & July 2021 respectively.
7	Scientific publications	• 01 research paper in national journal, • 01 research paper in international journal, • 01 research paper in international conference, & • 03 manuscript are in writing stage
8	Final technical report	• The interim report has been prepared, which will be improved for final report.

13. Recommendation / Suggestion:

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

14. Analysis & Results:

Purchase of equipment & consumables:

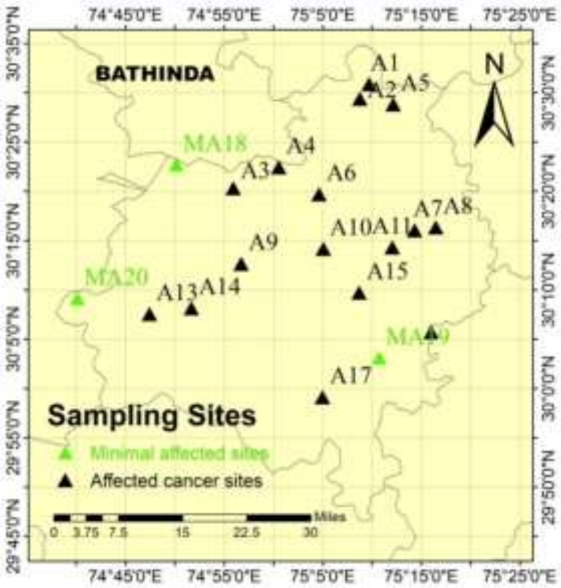
- Multiparameter Ion Analyzer with Electrodes: Purchased
- Laptop & Peripherals: Purchased.
- Syringe Pump along with accessories: Syringe pump purchase has been dropped due to escalation in the price.
- Software: GWB & AquaChem software has been purchased.
- Required planned glassware, plasticware, filter paper and chemical purchased for sample collection and analysis.

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 hand pump 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, and trace metals analysis has been completed and analysis of pesticides and polyaromatic hydrocarbons are being analyzed 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 from five districts. Radon analysis in groundwater of Fazilka is pending.

Carcinogenicity / Mutagenicity Test

- The experiments to develop the mutagenicity scale is under progress. The initial experiments of Ames test have low success rate.
- The experiments are expected to be completed by June 2021.

Contaminant Remediation

- The preparation for remediation strategy for the parameters exceeding the BIS/WHO limits are 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, 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) Analysis of pesticides and PAHs in the pre and post monsoon samples.
ii) Statistical analysis of data and carcinogenicity test.

Study - 4 (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. S.K. Juneja, Scientist D, 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			
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.	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:

- Field Survey was undertaken for selecting sites for Leachate sampling.

- For understanding the basic characteristics of leachate, preliminary samples were collected in order to find out the suitability of various experiments and to identify the procedures need to be followed in future.
- The physico-chemical, metal contents and isotopic parameters of Leachate were identified.
- The physico-chemical, metal contents and isotopic parameters of Groundwater in the study are identified.
- Presence of microplastics in leachate samples detected.

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

16. **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.

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

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

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

20. 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.

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
- Phyto-remediation measures.

Study – 5 (Sponsored Project)

1. **Title of the Study:** Water Efficient Irrigation by using SCADA system for medium 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: **December, 2020**
OBJECTIVES OF THE STUDY:

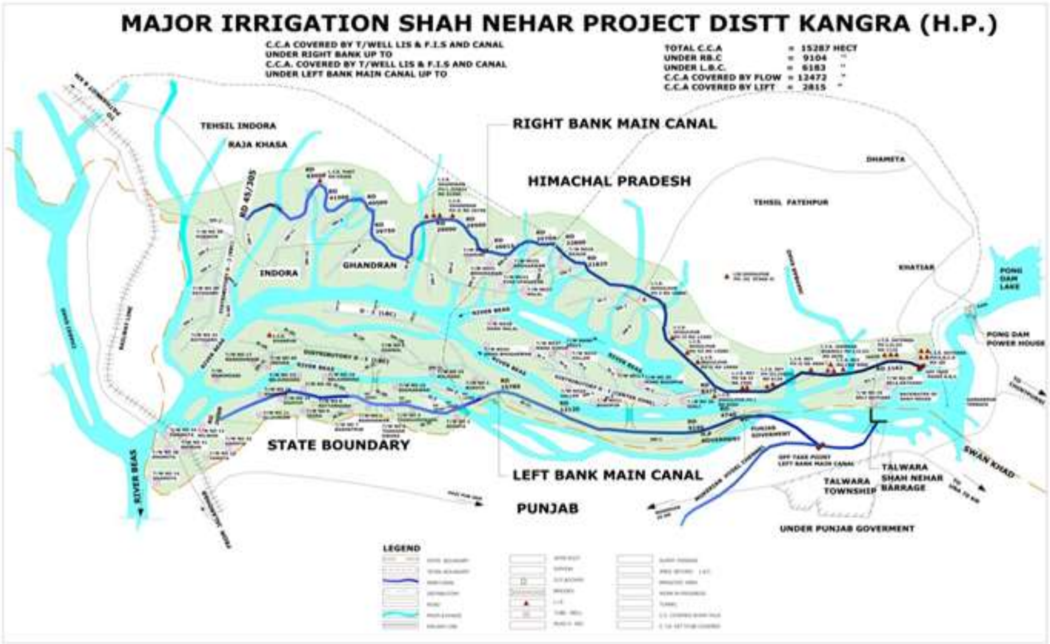
The primary objectives of this study is to **Devise a suitable approach to improve irrigation water use efficiency in Shah Nehar Project.** The specific objectives of the study are as follows:

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

Study Area : 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.

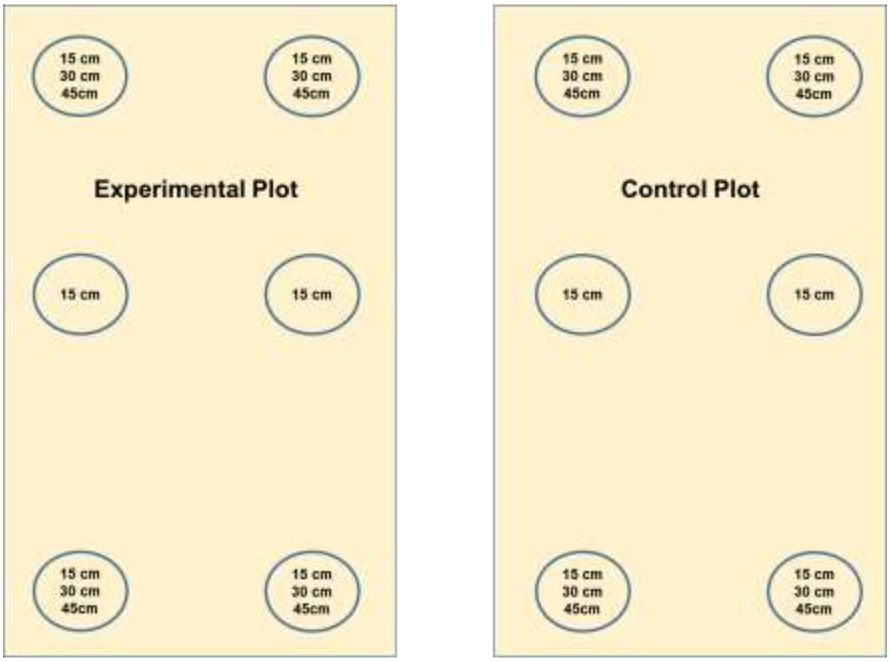
Progress of Work

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*

10. 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.
11. Installation of sensors and telemetry system for soil moisture monitoring and data transmission. (Work in progress).

12. 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 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 - 6 (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, and coliforms in the collected samples completed. • Analysis of trace metals in pre- & post-monsoon samples completed. • Samples processed for pesticides analysis and analysis will be completed in April 2021.
3.	Data Processing and Interpretation	• Data processing is under progress.
4.	Interim Report	• 1st interim report prepared and submitted.
5.	Final Report	• Preparation of final report is under progress.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) suggested that the study is very significant considering the deterioration in water quality of the district and it duration should not be reduced.	--
2.	Dr. Pawan Labhasetwar (Scientist, NEERI) suggested to carry out the sanitary surveillance.	Due to the covid pandemic the sanitary surveillance was not conducted.

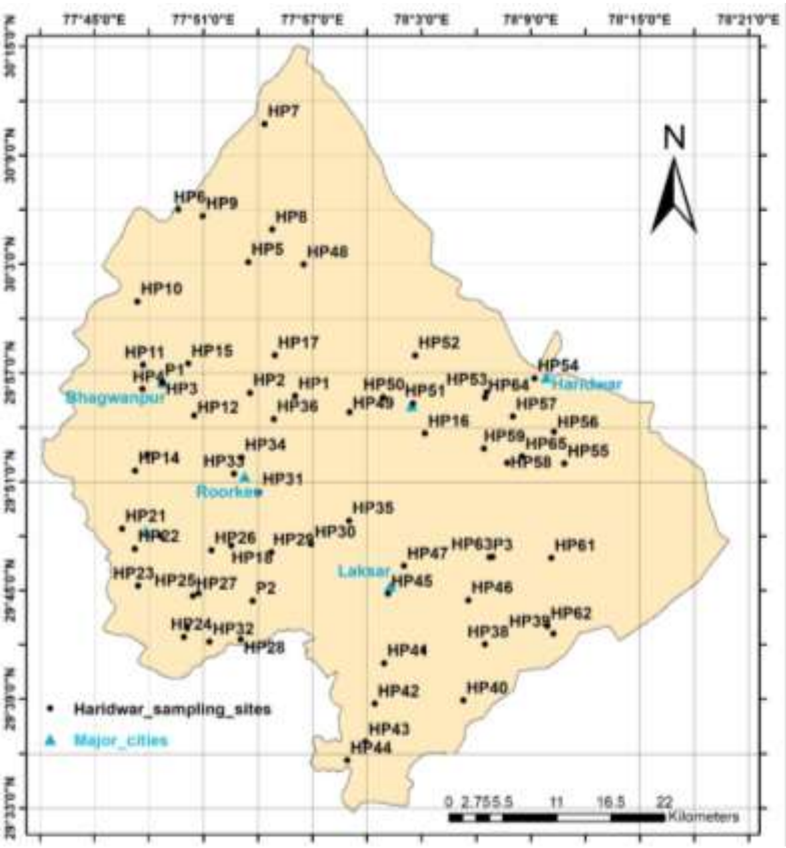
14. Analysis & Results:

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 hand pumps 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 ion, and bacteriological analysis completed for both pre- and post-monsoon samples. Trace metals analyzed for pre- and post-monsoon samples
- Processing samples for pesticide analysis have been completed and are being analyzed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).



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: The facility for analysis of pesticide was not available in the institute.

24. Future Plan:

- Analysis of pesticides in pre- & post-monsoon samples.
- Data processing & interpretation of results.
- Report and manuscript writing.

Study - 7 (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.RakeshGoyal, 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	--

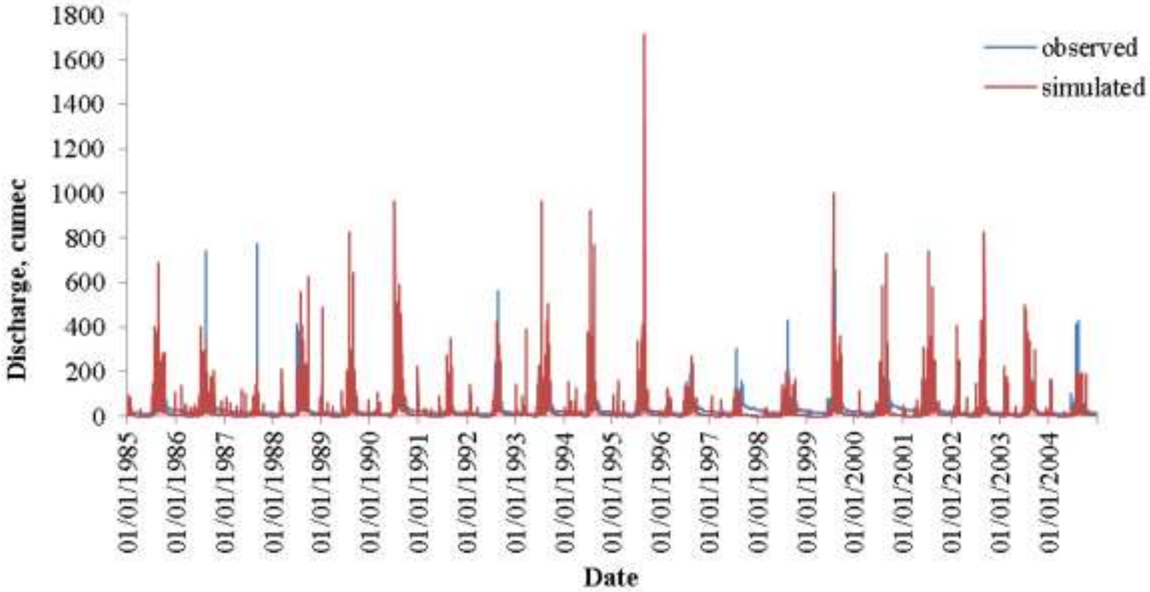
14. Analysis & Results:

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 2020, but, due to Corona pandemic, the same will be started from April 2021.

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 - 8 (Internal Study)

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

2. **Study Group:**

Study Team
Dr. M. K. Sharma, Sc. E– Principal Investigator Dr. Sudhir Kumar, Sc. 'G'- Project Coordinator Dr. R. P. Pandey, Sc. 'G' & Head Dr. Anupma Sharma, Sc. 'F' Ms. Anjali, Sc. 'B' Dr. Vishal Singh, Sc. 'C' Dr. Pradeep Kumar, Sc. 'D' Dr. Nitesh Patidar, Sc. 'B' Dr. Surjeet Singh, Sc. 'F' Dr. Rajesh Singh, Sc. 'D'
Supporting Staff
Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. **Type of Study:** Internal (Budget: Rs. 20.24 Lakh, NIH Funding)

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

5. **Date of Start:** July 2020

6. **Scheduled date of Completion:** June 2023

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

8. **Study Objectives**

i) Understanding the river basin system through historical data analysis of surface and groundwater sources
ii) To study the water balance of Hindon River basin
iii) Identification of major contaminant zones and sources of river pollution
iv) Identification of affluent and effluent sections of River Hindon
v) Prepare the river rejuvenation plan for River Hindon

9. **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

S. No.	**Major Activities**	**2020-21**				**2021-22**				**2022-23**				**2023-24**			
		Q 1	**Q 2**	**Q 3**	**Q 4**	**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	Reconnaissance visit and sampling plan																
2	Data collection																
3	Field surveys																
4	Inventory Plan																
5	Sample collection/Analysis/Experiment																
6	Preparation of database																
7	Identification of affluent and effluent sections																
8	MODFLOW Model: Calibration &Validation																
9	SWAT Model: Calibration, Validation & Simulation of river water and groundwater interaction																
10	Reach-wise Recharge augmentation plan																

11	Interim Report																
12	Final Report																

12. Objectives and achievement during last six months:

S. No.	Objectives	Achievements
(i)	Reconnaissance visit and sampling plan	Reconnaissance visit in River Hindon basin was made during November 11-12, 2020.
(ii)	Data collection	Groundwater level data and surface water data have been collected.
(iii)	Inventory Plan	An inventory of different point sources/tributaries/drains in the basin has been made.
(iv)	Preparation of database	Collected data is under processing.
(v)	Interim Report	Preparation of Interim Report is under progress.

13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	The study is appreciated.	--

14. Analysis & Results:

- Reconnaissance visit in River Hindon basin was made during November 11-12, 2020 and sites for discharge measurement were identified.
- Groundwater level data and surface water data have been collected and are being processed.
- An inventory of different point sources/tributaries/drains in the basin has been made.

15. End Users / Beneficiaries of the Study: Deptt. of Irrigation, UP, Ground Water Department, UP, and UPSPCB.

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:

a) Identification of major contaminant zones and Inventory of pollution sources contributing to the River
b) Identification of affluent and effluent sections
c) Reach-wise Recharge augmentation plan to rejuvenate the river
d) 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: None

24. Future Plan:

- Collection and analysis of samples from selected sites in the River Hindon Basin.
- Collection of groundwater level data, aquifer parameter data, litholog data for simulation of groundwater flow using MODFLOW.
- Secondary data procurement through various agencies required for SWAT model set-up.
- SWAT Model calibration and validation both for flows and for water quality.

Study - 9 (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:** March 2022
7. **Duration of the Study:** 1.75 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	• Preparation of 1st interim report is under progress.

13. Recommendation / Suggestion:

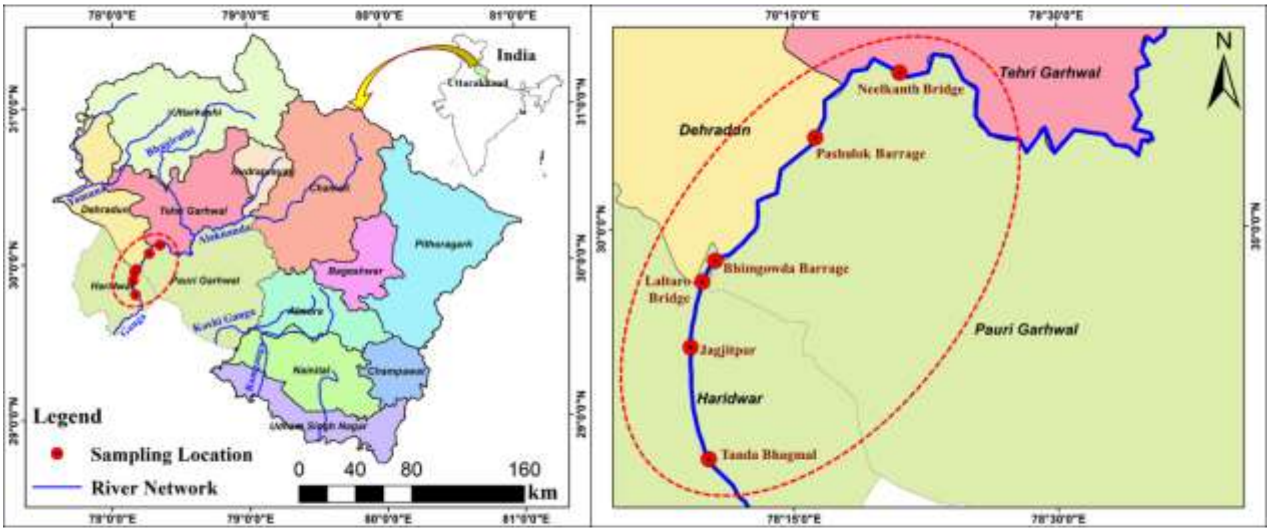
Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Pawan Labhasetwar (Scientist, NEERI) suggested analysis of river water quality in the braided segment.	Sample were collected from the braided channels of the river at Jagjitpur

2.	Dr. Deshpande suggested modification in third objective i.e. Statistical Analysis as it is the part of methodology and cannot be a standalone object.	The objective modified as suggested.

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:** One project staff of microbiology background is required to carry out the laboratory work.

24. **Future Plan:**

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

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	Mrs. Suman Gurjar	Scientist D
6	Dr. Gopal Krishan	Scientist D
7	Sh. Nitesh Patidar	Scientist B
8	Mrs. Anju Choudhary	PRA
9	Sri Sanjay Mittal	SRA
10	Sri S.L. Srivastava	SRA
11	Sri Ram Chandra	RA

APPROVED WORK PROGRAMME OF THE DIVISION FOR THE YEAR 2020-21

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, C. P. Kumar	2 years (05/19 - 04/21) *Status: In progress*	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, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year 8 months (08/19 – 03/21) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
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	5 months (07/20 – 11/20) *Status: New Study*	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, Suman Gurjar	2 years (08/20 – 07/22) *Status: New Study*	Internal Study
Sponsored Projects				
5. NIH/GWH/ NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8
6. 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	3.5 years (12/17-06/21) *Status: In progress*	Sponsored by 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 Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3.5 years (12/17-06/21) *Status: In progress*	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:*	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS

		Lalit Mohan Sharma		
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, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-11/21) *Status: In progress*	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	3 years (01/18 - 12/20) *Status: In progress*	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)	3 years (01/18 - 12/20) *Status: In progress*	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 & Water Resources Dept. Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, Delhi	4 years (04/18-03/22) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)
13. NIH/GWH/	Enhancing Food and Water Security in Arid Region	Anupma Sharma (Lead NIH),	5 years (03/19 - 02/24)	Sponsored by DST

DST/19-23	through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	C. P. Kumar, Suman Gurjar, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur)	*Status: In progress*	
14. NIH/GWH/ CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Sponsored by Federal Ministry of Education and Research, Germany
Consultancy Projects				
1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 17.70 lakh *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 1.18 crore *Status: In progress*	Punjab Government
3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	1.5 year (04/19-09/20) Cost: 11.80 lakh *Status: In progress*	Irrigation Deptt., Saharanpur

PROPOSED WORK PROGRAMME OF THE DIVISION 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: In progress*	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, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year 8 months (08/19 – 03/21) *Status: Completed*	Internal Study (in collaborab. with CSIRO, Australia)
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	11 months (07/20 – 05/21) *Status: In progress*	Referred by DoWR (MoJS) extended up to May, 2021
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	2 years (08/20 – 07/22) *Status: In progress*	Internal Study
Sponsored Projects				
5. NIH/GWH/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	5 years (01/16 - 03/21) *Status: In progress*	Sponsored by DST under NMSHE SP-1 likely to be extended up to Sept., 2021.
6. NIH/GWH/NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 03/21) *Status: In progress*	Sponsored by DST under NMSHE SP-8 likely to be extended up to Sept., 2021.
7. 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	3.5 years (12/17-06/21) *Status: In progress*	Sponsored by BGS, UK
8. 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 Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3.5 years (12/17-06/21) *Status: In progress*	Sponsored by NHP under PDS
9. NIH/GWH/PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar,	4 years (12/17-11/21)	Sponsored by NHP under PDS

	Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	*IIT-Roorkee:* M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	*Status: In progress*	
10. 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 (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
11. 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) (Extension by DST up to 12/21) *Status: In progress*	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
12. 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)	4 years (01/18 - 12/21) (Extension by DST up to 12/21) *Status: In progress*	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
13. 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:* Haryana Irrigation & Water Resources Dept., UP GW Deptt., Yamuna Basin Organization, CWC, Delhi	4 years (04/18-03/22) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)
14. 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), C. P. Kumar, Suman Gurjar, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner,	5 years (03/19 - 02/24) *Status: In progress*	Sponsored by DST

		NIAM Jaipur)		
15. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Federal Ministry of Education and Research, Germany
Consultancy Projects				
1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	2 years (03/19-05/21) *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	2 years (03/19-02/21) *Status: Completed*	Punjab Government
3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	2.5 years (04/19-09/21) *Status: In progress*	Irrigation Deptt., Saharanpur
4.	Hydro-geological Study of Area in the Vicinity of SEL Manufacturing Company Ltd. Nawanshahr District of Punjab	Surjeet Singh (PI)	6 months (02/21-08/21) *Status: In progress*	NIT, Jalandhar (Punjab)
5.	Geo Environmental study in and around OMC's located in Manglia, Indore	Sumant Kumar (PI)	6 months (11/20-5/21) *Status: In progress*	BPCL, Indore

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

Laboratory and Centre:

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

Trainings organized/ planned:

The division has organized four online trainings courses under NHP since previous working group meeting.

During the current financial year, 5-6 trainings/workshops shall be organized by the division related to ground water domain.

Outreach activities since previous WG meeting:

1. Scientists published/accepted **25** papers in international/national journals & conferences.
2. Scientists delivered **54** lectures in different training courses and workshops.
3. Scientists guided/guiding **12** M/Sc./M.Tech./Ph.D. students for their thesis work.

1. PROJECT REFERENCE CODE: NIH/GWH/NIH/19-21

Title of the Project: *Application of Satellite Data Products for Water Resources Assessment*

Project team

a.	Project Investigator	Ms. Suman Gurjar, Sc-C
b.	Co- Project Investigator	Dr. Vishal Singh, Sc-C
c.	Investigator(s)	Dr. Surjeet Singh, Sc-F

Type of study: Internal

Duration: May 2019 - April 2021

Objectives:

- Assess the applicability of using multi satellite data approach for water resource assessment.
- To analyze the accuracy of the satellite data product by calibrating it with the observed data and use the satellite data at places where there is scarcity of observed data.
- Explore the use of satellite data on scales smaller for water resources management.

Study area:

The study area is Ganga basin. The Ganga basin outspreads in India, Tibet (China), Nepal and Bangladesh over the total area of 10,86,000 Sq.km. The major part of the geographical area of the Ganga basin lies in India and it is the biggest river basin in the country draining an area of 8,61,452 Sq.km. The Ganges is the most populated river basin of the country and is home to half the population of India including two-thirds of the nation's poor people. The basin provides over one-third of the available surface water in India and is the focus of over half the national water use – 90 percent of this being in irrigation. Ganga basin is facing many challenges in terms of its flow regime due to water resources infrastructure, high level of water abstraction and ecological health of Ganga and its tributaries.

Methodology:

The methodology involves collection of available recent and historical hydrological and satellite data related to the basin area. This includes data on precipitation, evaporation, river flow, surface storage, soil moisture, groundwater levels etc. The various spatial and temporal data would be converted to uniform scale and duration by downscaling/upscaling. Water balance for the basin will be estimated. For assessment of surface water and groundwater, hydrological models such as SWAT-MODFLOW will be used. The results will be calibrated and validated using the observed data at certain locations of the basin, to verify the accuracy of the generated results.

Objectives & Achievements:

Objectives	Achievements
• Assess the applicability of using multi satellite data approach for water resource assessment. • To analyze the accuracy of the satellite data product by calibrating it with the observed data and use the satellite data at places where there is scarcity of observed data. • To explore the suitability of re-scaled satellite data for the purpose of water resources management.	• Preparation of raster maps of the entire study is completed. • Gridded data of hydro meteorological parameters is downloaded. • Data is processed for Yamuna basin. • For remaining sub-basins, data is being processed. • Objective 2 & 3 will be accomplished after the completion of objective 1.

Progress made so far:

The satellite data for meteorological parameters is being prepared sub basin wise due to huge size and processing time of data. Presently the data is prepared for the Yamuna basin. For the remaining sub basins, the data is downloaded but it is being processed for final input to the model. After the completion of the data preparation of all sub basins, the data will be used for water resource assessment of the complete basin using SWAT-MODFLOW.

2. PROJECT REFERENCE CODE: NIH/GWH/NIH/19-20

Title of the Project: *The regional hydrological impact of agricultural water saving measures in the Gangetic plains*

Project team

Project Investigator	Dr. Sumant Kumar, Sc-D & PI
Co- Project Investigator	Mr. C. P. Kumar, Ex-Sc-G & Head, GWHD
Investigator(s)	Dr. Archana Sarkar, Sc-E
	Dr. Surjeet Singh, Sc-F
	Dr. P. K. Mishra, Sc-C

Collaborator	:	CSIRO, Australia
Type of study	:	Internal (On-going)
Duration	:	August 2019 - March 2021
Budget	:	Rs. 5 Lakh

Objectives:

- A review of agriculture practices and agricultural water saving measures and their impact on groundwater resources.
- Trend analysis of groundwater level data to understand recharge and discharge processes.
- To study surface water and groundwater interaction based on available and monitored data.

Study area: Bhojpur district of Bihar

Statement of the problem:

Many farm-scale water saving measures have been in practice such as improved irrigation delivery technologies viz. drip irrigation; stopping seepage from water delivery canals; agronomic practices like alternative wetting and drying and other conservation practices (zero tillage, minimum tillage, etc.). Farm conservation practices affect the water accounting of watersheds. Water accounting is required to assess the relative contribution of components of water balance. For water accounting of large aquifers, we need to identify and quantify all the gains and losses from the aquifer. There are some research questions such as what is the likely impact of conservation agriculture and a plough pan/ puddled layer on recharge in the monsoon season? Can natural recharge to groundwater be enhanced by deep ploughing and breaking the plough pan in the monsoon season? What is the likely regional hydrological impact of farm-scale water saving measures? The proposed scoping study will be mainly based on available literature and hydrological data of water saving measures. The scoping study, therefore would provide a broad understanding of impact of the farm saving measures on groundwater resources in the selected watersheds of Bhojpur district of Bihar, lying in the Gangetic plains.

End Users/Beneficiaries:

Minor Water Resources Dept., Govt. of Bihar; Ministry of Agriculture and Farmers' Welfare, Govt. of India; Ministry of Jal Shakti, Govt. of India; NGOs; Local Community etc.

Objectives & Achievements:

Objectives	Achievements
A review of agriculture practices and agricultural water saving measures and their impact on groundwater resources.	Data on agricultural practices have been collected from Department of Agriculture, Govt. of Bihar and analysed. Literature review has been completed.

Trend analysis of groundwater level data to understand recharge and discharge processes.	The groundwater level data of 33 monitoring stations in the district have been collected from CGWB and trend analysis has been completed.
To study surface water and groundwater interaction based on the available and monitored data.	A coarse groundwater modelling has been completed to study the surface water and groundwater interaction.

Analysis and Results:

The geographical area of the Bhojpur district is 233729 Ha, out of which 188134 Ha is net cultivable area. The net irrigation area in Kharif season is 100407 Ha and in Ravi season it becomes 68781 Ha. The groundwater level data has been collected from the Central Ground Water Board (CGWB) and spatial behavior of water levels along with flow direction has been studied for the study area. The depth to water level in pre-monsoon season (year 2018) varies from 3.0 to 9.0 m bgl with minimum and maximum values observed in south western part and north eastern part (Fig. 1(a)). The hydraulic gradient indicated groundwater movement towards the river Ganga (Fig. 1(b)). The land use land cover (LULC) map of year 2018 at 30 m spatial resolution was developed using Landsat-8 satellite imagery downloaded from United States Geological Survey (USGS) website. The LULC classification showed that vegetation (46.13 %) followed by built-up area (21.64 %), fallow (16.52 %), barren land (7.37 %), sand bank (6.08 %), water (2.26 %) are the major types of land uses. Trend analysis was performed using Mann–Kendall test (at 5% significant level) for groundwater level. The results revealed that groundwater level is showing falling and rising trend, which are not significant except few locations. There are few locations viz. Kulharia, Jagdishpur, where groundwater level shows significant declining trend where as significant rising trend has been observed at Bihia. A temporal variation of GW level at Bakhorapur monitoring station has been shown in Fig. 2. The GW modelling was done to understand the SW-GW interaction and for water budgeting of the GW system. The data was taken from CGWB, Minor Water Resources Department, Govt. of Bihar, field investigation and assumption were made where data was not available. The head distribution for steady state modelling is shown in Fig. 3.

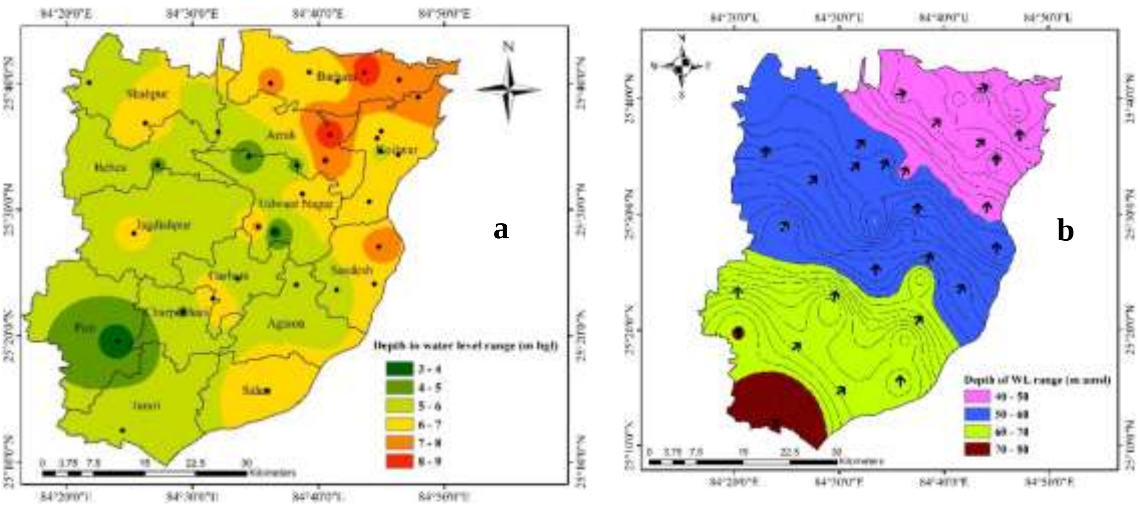


Fig. 1: (a) Depth to water level (m bgl) (b) Water table contours showing flow direction

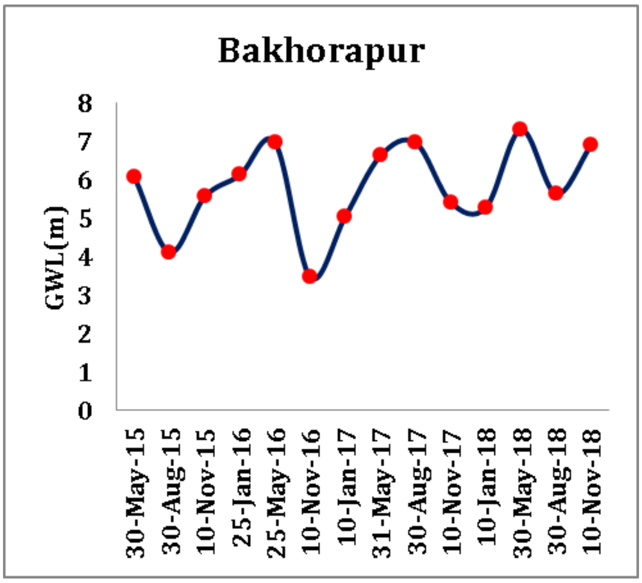


Fig. 2: GW hydrograph for a monitoring station

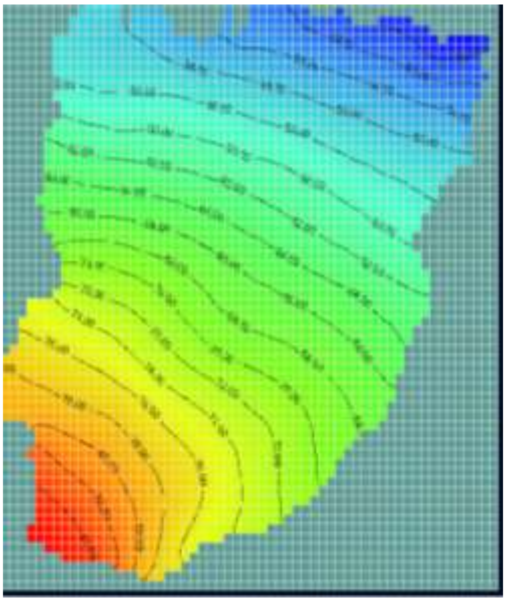


Fig. 3: Groundwater head distribution

3. PROJECT REFERENCE CODE: NIH/GWH/NIH/20-20

Title of the study: *Understanding in depth impact of salinity of river Mahadayi due to proposed dams on river Mahadayi*

Name of PI and members	:	Dr. M. K. Goel (Coordinator) Dr. Gopal Krishan (PI) Er. C.P. Kumar (co-PI) (Retired) Dr. B. Venkatesh (co-PI) Dr. Nitesh Patidar (co-PI)
Type of study	**:**	**Reference DoWR RD GR, MoJS**.
Date of start (DOS)	**:**	July 2020
Scheduled date of completion	**:**	May 2021
Location	**:**	Mahadayi river (Goa, Maharashtra, Karnataka)

Objectives & Achievements

Objectives	Achievements
To assess present status of salinity in the river Mahadayi	**80%** – Measurements are being done on daily basis at selected points
To assess extent of increase/decrease in the salinity of river Mahadayi during last 10 years and the main causes thereof	**50%-** Some data has been received for the years 2004, 2005, 2009, 2012, 2013, 2015, 2016, 2017, 2018 from NIO, Goa and analysis work is in progress
To determine the probable impact on the salinity of river Mahadayi on account of proposed diversion of water due to Kalasa and Bhandura dam on the river Mahadayi	**30**%- Discharge data will be provided by WRD, Goa. Sea salinity and river stage data has been collected from NIO, Goa Cross-section data has been provided by WRD, Goa

Statement of the problem:

The Mahadayi river is also known as Mandovi river originating from cluster of 30 springs at Bhimgad in western ghats in Belgavi district of Karnataka and has a length of 81 kms traversing in 3 states Karnataka (35 kms), Maharashtra 1 (km) and Goa (45 km) and an average depth of 5 m. Mandovi joins with the another river Zuari at a common creek at Cabo Aguada connected by a common Cumbarjua canal, forming the Mormugao harbour- Panaji, the state capital and Old Goa. The Mandovi and Zuari are exclusively used for the transportation of iron and manganese ores from the mining places located along their banks to the nearest Mormugao Port.

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

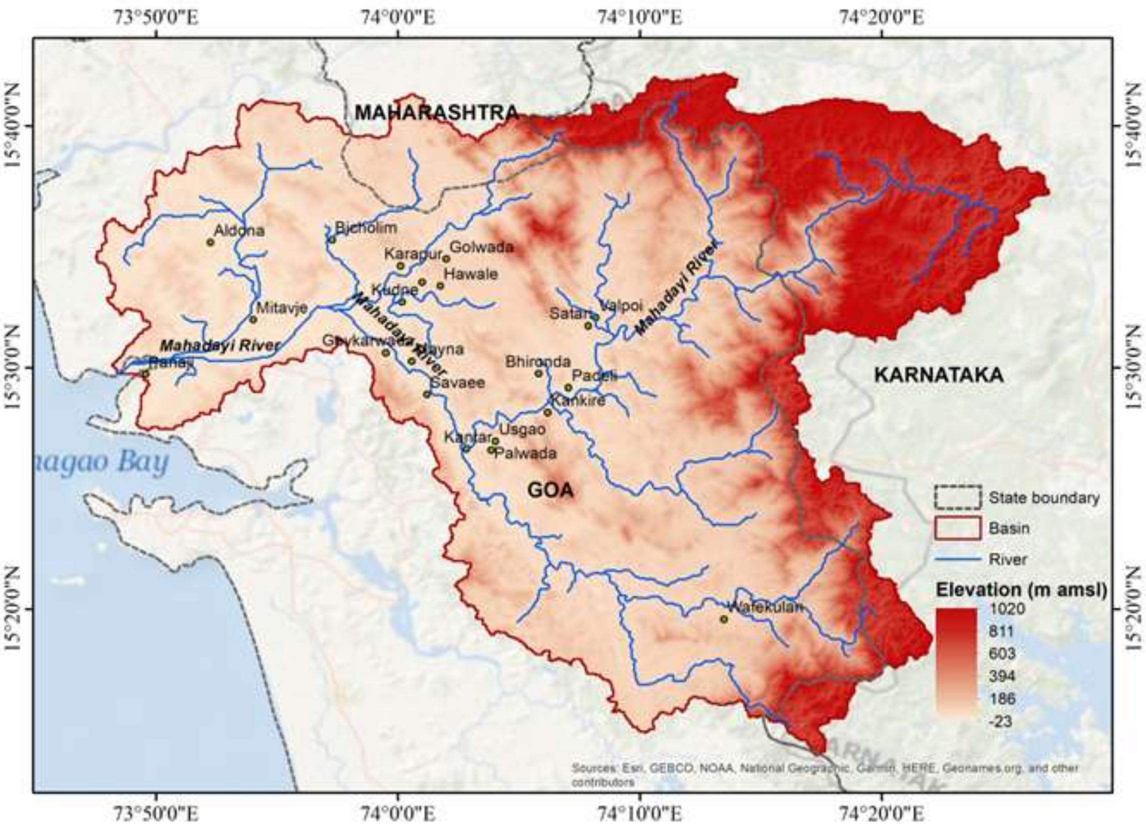


Fig. 1. Mahadayi River and its tributaries

Methodology:

Collection of data and maps:

River data:

Discharge data of Ganjem site provided by CWC is being examined. Fresh discharge data will be provided by WRD, Goa. Cross-section data has been provided by WRD, Goa

Salinity data: First time some points were measured in September, 2020 (fig. 2) and daily measurements are being taken in measurements will be recorded to study the longitudinal and the intra-seasonal variations of salinity.

Numerical models:

To model the salinity evolution along the river, a one-dimensional modelling approach will be employed. The HEC-RAS, a hydrodynamic model, will be used to predict salinity under different scenarios. The model will simulate hydrodynamic regime, sediment transport, and water quality along the river. Calibration and validation of the HEC-RAS model will be performed using in-situ observations of river discharge and salinity.

Two field visits were conducted during September, 2020 (Fig. 2) and February, 2021 to measure the salinity of river Mahadayi /Mandovi at selected locations (Panjim, Jetty (1), Jetty (2), Dewar ferry, Bhumika temple, Nakshtra Garden, confluence (Mahadayi - Kudne, vayanti, Bicholi), Ganjem, Amona, Kalasa, Kankurh, Nalah, Ghoteli bridge, Ghoteli police station) mainly on the points for which cross sections were available. The salinity levels were found low in September, 2020 at all points due to the rain water contribution but during February, 2021 high salinity levels were observed particularly at Dewar ferry, Confluence and Amona points (Fig. 3).

Fig. 2. Salinity measurements at selected sites

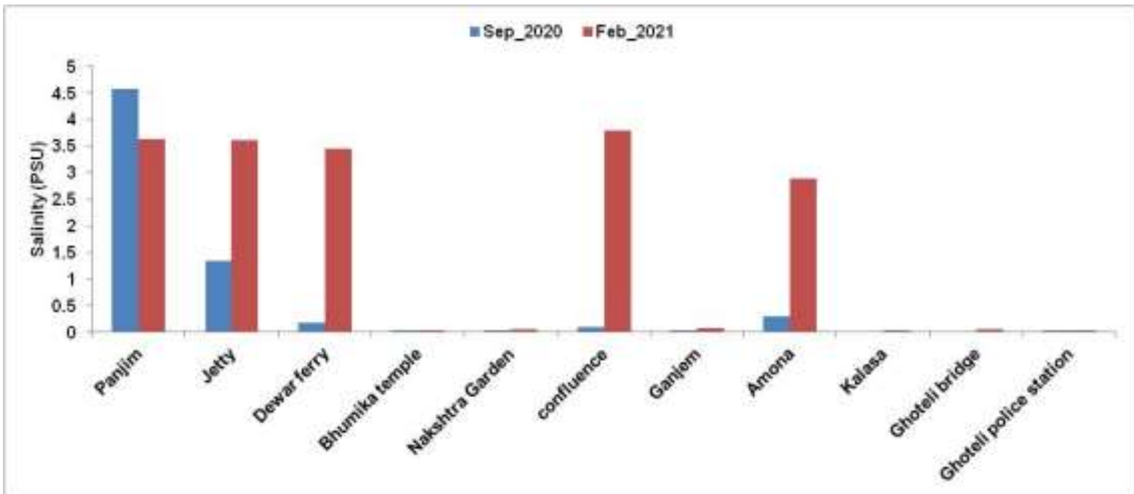


Fig. 3. Salinity levels during September, 2020 and February, 2021

This has been observed that Mahadayi being a monsoonal influenced river plentiful discharge during the monsoon (June–September) and negligible discharge during the dry period (October–May). Salinity values increases more than 3 mg/kg towards the estuary due to the sharp salinity gradient towards the sea side. Salinity was observed higher at Amona which is about 25 kms from the Panaji. All these make the estuary very turbid due to flocculation of clay.

Progress

- Salinity is being measured at selected points
- Cross section data has been collected from WRD, Goa
- Historical salinity data of sea has been collected from NIO, Goa
- Efforts are going on to collect discharge data from WRD, Goa

Action plan:

Period	**July 2020 to May., 2021** (Annexure 1)	Remark
July 2020 to May 2021	Collection of available data on Mahadayi river Data analysis and interpretation Prepare a status report and submit to DoWRRDGR, Ministry of Jal Shakti	Report preparation as per Annexure 1

Study Benefits /Impact:

Simulation of salinity distribution

- Longitudinal distribution of salinity for varying river discharges
- Long term (10 years) variations in salinity

Specific linkages with Institutions: Referred work of Ministry of Jal Shakti

Activity Schedule (Month-wise from Jul. 2020 To May, 2021)

Activity	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Collecting data	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Field survey/Data interpretation			♦					♦			♦
Report preparation			♦								♦

Future plan

- Execution of model
- Field visit to validate data
- Prepare report

4. 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-C
Mrs. Suman Gurjar, Scientist-C

Type of study: Internal (New)

Duration: Two years (August 2020 – July 2022)

Objectives

1. Development of the integrated GEE-MODFLOW model to estimate groundwater recharge and to disseminate model outputs.
2. Evaluation of the estimated recharge using in-situ observations.
3. Assessment of the impacts of various recharge/abstraction scenarios on groundwater system of Hindon river basin.

Statement of the problem

Groundwater resource had a significant contribution to meet societal needs and development objectives in India. In many parts of the country, groundwater is often the sole source of water and thus plays an important role in socio-economic development of the country. However, the excessive groundwater withdrawal led by growing water demands has imposed additional pressure on groundwater resources which has resulted in rapid and widespread groundwater declines. An assessment of country's groundwater by Central Groundwater Board (CGWB) reveals that out of the total 6881 blocks of the country, 17% are over-exploited, 5% are critical and 14% are semi-critical (CGWB 2017). Further, the declining groundwater levels due to over-exploitation has raised several queries about the changes in river water availability due to adverse impacts of aquifer depletion, vulnerability of groundwater contamination, and availability of surface water and subsurface water resources in the future. Therefore, to answer these queries and 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 (GRAS), 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 GRAS 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.

Methodology

The proposed GRAS will utilize various packages of MODFLOW (version 6) to assess groundwater recharge by simulating infiltration, evapotranspiration and unsaturated-saturated flows. A cloud-based data processing and visualization tool, named Google Earth Engine (GEE), will be utilized to extract information from remote sensing data at high spatio-temporal resolution for modelling and to disseminate model outputs. The GRAS will be developed into five modules, including (i) GEE-based data preparation module, (ii) infiltration and evapotranspiration module, (iii) MODFLOW-based unsaturated and saturated flow module, (iv) scenario analysis module, and (v) interactive output visualization module. It will be tested to assess groundwater recharge and investigate impacts of various hypothetical scenarios on groundwater regime in the Hindon river basin.

- *GEE-based data preparation module*. Google Earth Engine (GEE) is a free cloud-based platform that makes it easy to access high-performance computing resources for processing very large geospatial datasets. Moreover, it allows to access and analyze various remote sensing data available from various organizations throughout the world. In the data preparation module, GEE will be utilized to derive information that are important for groundwater recharge estimation, such as surface imperviousness, vegetation cover and phenology, soil moisture, precipitation and temperature.
- *Infiltration and evapotranspiration module*. A variety of infiltration and evapotranspiration approaches are available. Suitable methods will be selected based on their accuracy and compatibility with MODFLOW (version 6). Soil moisture data available from satellite remote sensing will be utilized to start the simulation of infiltration model.
- *MODFLOW-based unsaturated and saturated flow module*. MODFLOW is a U.S. Geological Survey modular finite-difference flow model which has widely been used to simulate groundwater flow. In the GRAS, MODFLOW will be used to simulate unsaturated and saturated flow through the subsurface. The impact of groundwater extraction through pumping will also be simulated using the MODFLOW.
- *Scenario analysis module.* This module will include various options to analyze 'what-if' scenarios. For example, prediction of future groundwater availability considering a groundwater pumping scenario, prediction of rise in groundwater table if some artificial recharge measures are adapted or a canal is constructed.
- *Interactive output visualization module.* This module will be designed to help researchers easily disseminate their results to other researchers, policy makers, NGOs, and even the general public. The Google Earth Engine will be utilized to develop this module which will allow to display and analyze the model outputs through an online web-based GEE application.

Deliverables

- Integrated GEE-MODFLOW model
- GEE-based web application for groundwater recharge assessment in Hindon river basin

- Model manual, research papers and reports

Objectives vis-à-vis Achievements

Objectives	Achievements
Development of the integrated GEE-MODFLOW model to estimate groundwater recharge and to disseminate model outputs	Development of the integrated model is in progress. Various modules to integrate GEE and MODFLOW have been developed in python. A Module to download and process GEE data, such as precipitation, potential evapotranspiration, land cover, etc., has been developed. Another module to create files for different MODFLOW packages (NPF, UZF, STO, WEL, IMS, etc.) has also been developed. These modules have been tested to run the MODFLOW-6 model in integration with GEE for estimating groundwater recharge. Development of GEE-based portal to disseminate model outputs is in progress.
Evaluation of the estimated recharge using in-situ observations	To evaluate the model performance, groundwater level data from Central Groundwater Board and Groundwater Department Uttar Pradesh has been collected. The estimation of groundwater recharge using water level fluctuation method is in progress.
Assessment of the impacts of various recharge/abstraction scenarios on groundwater system of Hindon river basin	Development of a module for the impact assessment is in progress.

Action plan and timeline (quarter-wise from Aug 2020 to Jul 2022)

Work element	Apr-Jun 21	Jul-Sep 21	Oct-Dec 21	Jan-Mar 22	Apr-Jun 22	Jul 2022
Development of GEE-MODFLOW model						
Measurement of soil moisture, infiltration, hydraulic conductivity and groundwater level.						
Development and testing of GEE-based data dissemination system						
Model calibration and validation						
Simulation runs for investigating various recharge/abstraction scenarios						
Preparation of research paper						
Preparation and submission of reports, model manuals and research papers						
Organization of training						

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

Title of the Project: *Development of a project website and hydrological database in Upper Ganga basin (SP-1)*

Study team

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

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.	In progress
Investigation and referencing of available spatial database from various sources.	In progress
Capacity building for use of hydrological data entry and processing software.	To be taken up
Development of interactive project web site with hydrological information system.	Has been developed and is being continuously updated.

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 referenced at a single platform for use in hydrological analysis for various purposes.

Data collected on hydrologic variables are generally raw which may not be used directly in most hydrologic analysis work. Processing of hydrological data has two major objectives: one to evaluate the data for its accuracy and the other to prepare the data in a form valuable to the users. The rapid advance in computer technology, in speed of operation and data storage capacity as well as the capability of hydrological software has greatly simplified the management of large quantities of hydrological data. All hydrological datasets can be maintained in well-defined computerized databases using standard database management system. Surface Water Data Entry System (SWDES), developed under Hydrology Project – I, and HYMOS software can be used for entry and processing of hydrological data in standardized format. This is essential for the long-term sustainability of the datasets in proper form and their dissemination to the end users. Both, raw and processed data sets are to be properly stored and archived to specified standards so that there is no loss of information. NIH has trained manpower on SWDES and HYMOS software which can be used entry and process the hydrological database for the Upper Ganga basin up to Rishikesh and to build capacity in other organizations dealing with hydrological data for their effective utilization.

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

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

Present Progress

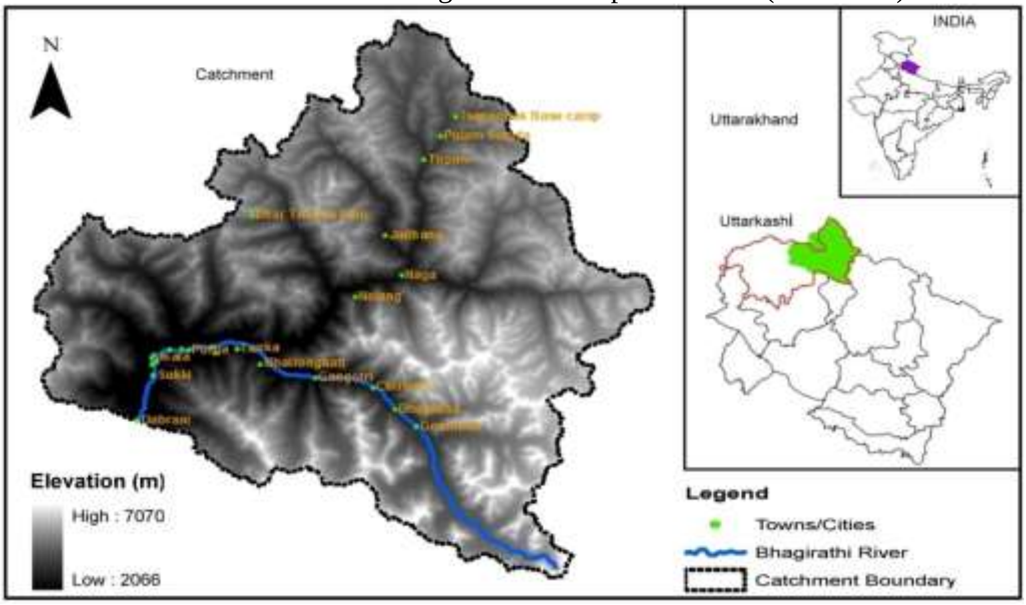
All the hydro-meteorological data (IMD and CWC) for various stations in/around the Upper Ganga basin has been imported in HYMOS data processing systems and processed using various techniques. Using the data of spatially correlated stations, the missing gaps have been gap-filled and consistency has been checked using double-mass analysis. For the corrected data, the trend analysis has been carried out for different stations. The temperature data of various IMD and CWC stations has been processed after a number of corrections (related to data entry error, interchange of columns of max. and min. temperature etc.) and trend analysis has been carried out. The plots of data for precipitation, no. of rainy days, max./min. temperature, and observed flows have been made at different time scales [Annual, seasonal (4), and monthly] and such plots have been linked to the project website. Z statistics and Sen's slope have also been estimated at various time scales and provided in the website. In addition, such analysis has also been carried out at more than 100 IMD stations in the pan-Himalayan region (in states of J&K, HP, UK, Arunachal Pradesh, and Assam). A view of such plots is presented below in Figure – 1 for illustration. The project website is being grossly updated to link the abstract outcome of various sub-projects for online demonstration.

Fig. 1: Plot of precipitation at Deoprayag at different time scales

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

Title of the study: *Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani*

Type of study	:	Sponsored by DST under NMSHE SP-8
Date of start (DOS)	:	January 2016
Scheduled date of completion	:	March 2021
Study Area	:	Bhagirathi Basin up to Dabrani (Uttarkashi)



Study objectives:

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

Action Plan:

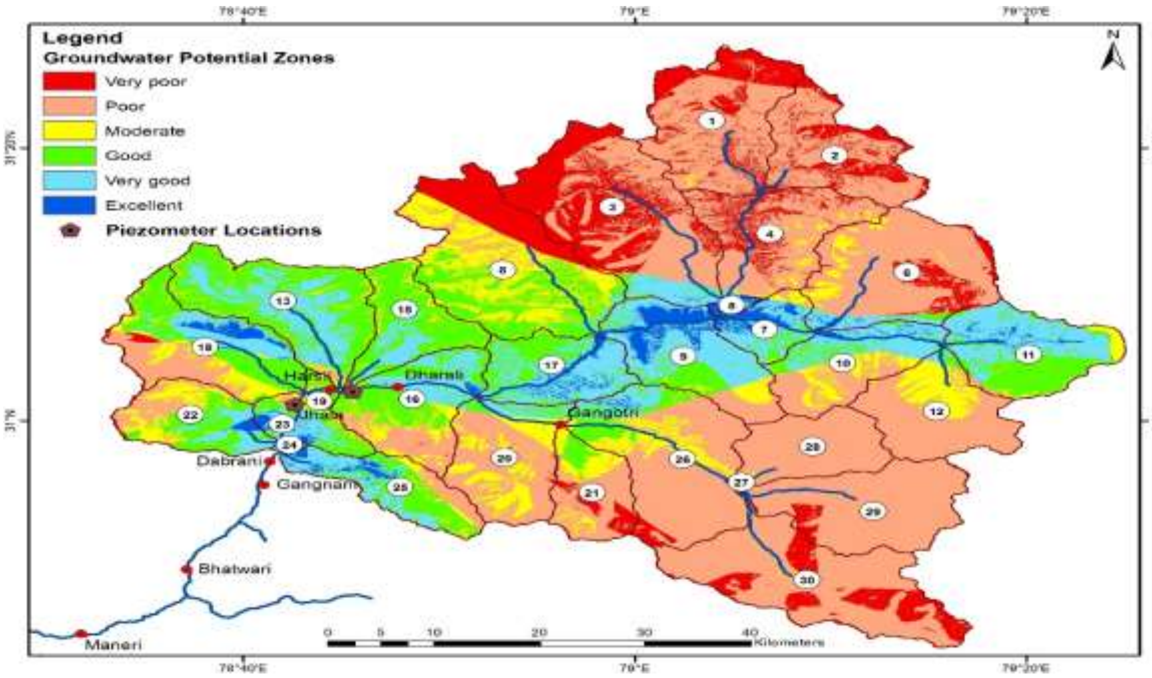
- Collection/procurement of available long-term hydro-meteorological and hydro-geological data for the study area.
- Preparation of various thematic layers (sub-basins, geology, soils, wells, snow cover, drainage, monitoring network, water use, etc.).
- Selection of suitable sites for piezometer development.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

Objectives vis-à-vis Achievements:

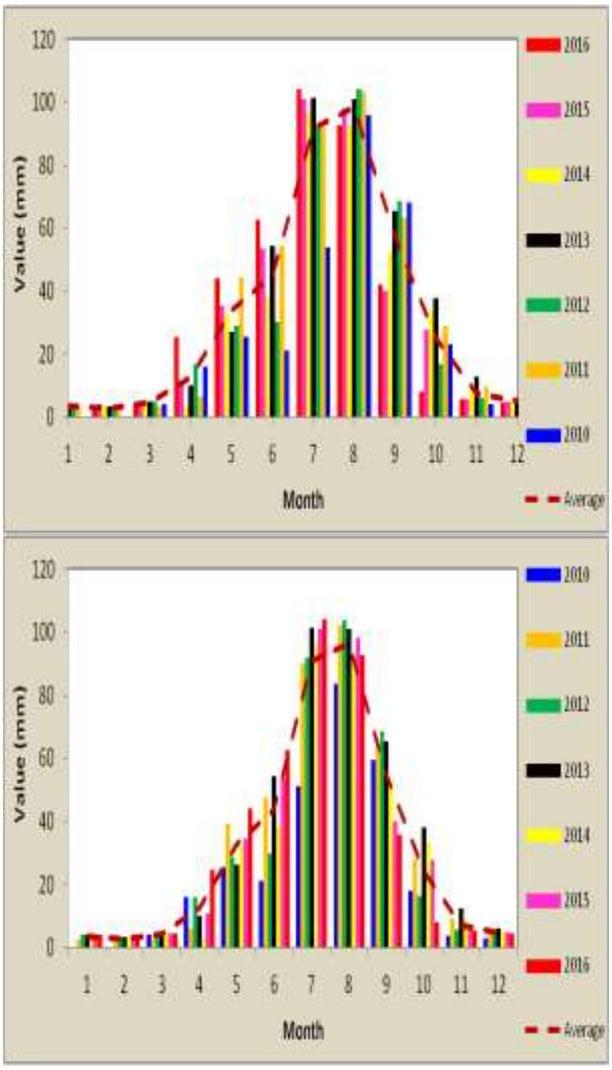
Objectives	Achievements
Understanding of river-aquifer interaction and dynamic processes in Himalayan environment	Completed
Groundwater potential assessment and availability prospects resulting from snow and glacier melt recharge	Completed

Analysis of Results:

The study is envisaged on the stream/river and groundwater flow interactions and dynamics including potential assessment emerging from snow and glacier melt recharge to answer the question of groundwater development prospects in the hilly areas as well as base flow regimes of the mountainous streams. In order to carry out the study, the existing basin information, geological and geo-hydrological investigations and development of piezometers for groundwater data acquisition are necessary. The study area, lying in the Uttarkashi district of Uttarakhand state, comprises an area of 3,487.06 sq.km. The Bhagirathi is the main river of the study area. The elevation of the basin varies from 2,066 to 7,070 m above mean sea level. Under the study, various thematic maps viz., digital elevation model, demarcation of basin boundary up to Dabrani, study area map, elevation zone map, 3D map, geological map, drainage map and stream ordering, sub-basin map, slope map, aspect map, digitization of ground surface contours at 10 m interval (SOI at 1:50,000), sampling location map, piezometer sites map, soil map, landuse, etc. have been prepared. Geological traversing from Dabrani to Gangotri was also done. Borelog data of five locations were collected and analyzed. The soil map of the area was also prepared. Two piezometers were developed through the UJS, Uttarkashi; one at Jhala and one at Harsil. Groundwater levels were continuously monitored in both these piezometers which were found to vary between 3.76 to 5.44 m-bgl at Jhala, and between 0.92 to 2.70 m-bgl at Harsil. The water sampling was also done for the isotopic and major ion chemistry analysis. It is observed that water type is $Mg\text{-}HCO_3$, or, $Mg\text{-}Ca\text{-}HCO_3$ for most of the sampling sites except for Jhala hand pump where the groundwater is $Na\text{-}HCO_3$ type. Durov's diagram indicates shallow fresh groundwater in aquifers composed of dolomite. However, the Jhala hand pump indicated that shallow portions of regional confined aquifers have ion-exchanged waters where Na^+ is dominant. Groundwater availability is estimated based on the annual groundwater recharge taking place in the area and water balance analysis based on the SWAT outputs. The groundwater potential zones have been identified using the index weighing scheme and the potential zones are classified into the excellent, very good, good, moderate, poor and very poor categories. Stakeholders interaction workshops shall be organized.



Groundwater potential zones map of the study area



Monthly infiltration in sub-basins 16 and 21 of Bhagirathi basin

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

Lab Facility used during the Study:

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

Data Procured/ Generated during the Study:

- Geological map; Water quality data; Isotopic data; Surface contours; Land use; Soils; Bore logs, Groundwater levels.

Study Benefits /Impact:

Process understanding of groundwater recharge due to glacier / snow melt recharge.

Specific linkages with Institutions: DST, UJS

Future Plan:

- Organization of stakeholders interaction workshops.

7. PROJECT REFERENCE CODE: NIH/GWH/BGS/17-20

Title of the study: *Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements*

Name of PI and members	:	Dr. Gopal Krishan (PI) Dr. Surjeet Singh (co-PI) Er. C.P. Kumar (co-PI) Dr. M.S. Rao (co-PI) **BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator)
Type of study	**:**	Sponsored**,** BGS, UK.
Date of start (DOS)	**:**	December 2017
Scheduled date of completion	**:**	June 2021
Location	**:**	Bist- Doab Punjab

Objectives & Achievements:

Objectives	Achievements
To characterize multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers	There is certainly a trend of groundwater depletion mainly due to the onset of pumping for irrigation during the Kharif season a part of which is in the monsoon season also. So the contribution of pumping could easily far exceed the 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 groundwater 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 main source of groundwater depletion in Jalandhar, Kapurthala and part of Nawanshahr districts
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	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. 80% of objective achieved. Satluj water and canal originating have highly depleted values as compared to Bes river values Reservoir samples are highly enriched.
To prepare a status report on groundwater issues in Punjab	Interim report is under preparation

Statement of 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.

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)

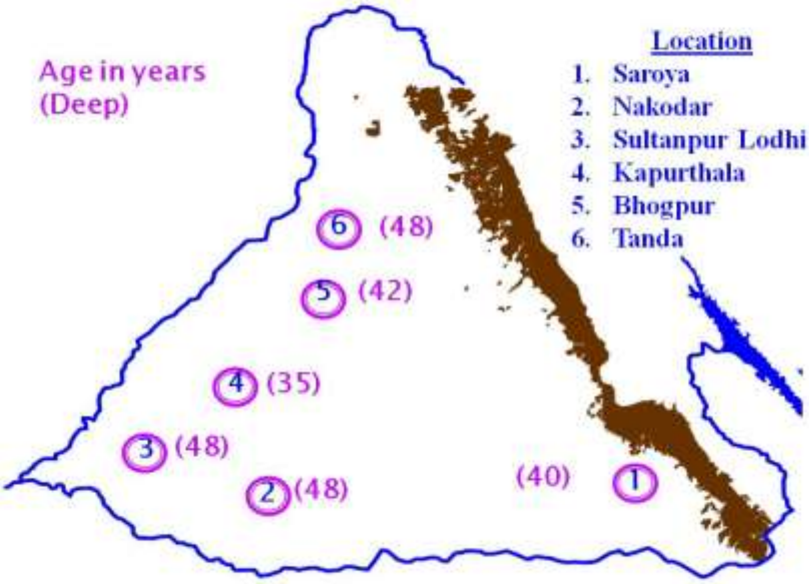


Fig. 1. Study area, Bist Doab, Punjab

The conductivity loggers are installed considering the physiography, geomorphology and hydro-geological conditions of the area.

(i) Saroya: Saroya is in Siwalik area where sandstones constitute good water bearing zones. These areas require special attention to mitigate the water needs of the people. Groundwater draft is 80%. In a Kandi tract of the State low height dams across choes are constructed for water harvesting.

(ii) Bhogpur – where farmers have adopted paddy cultivation due to profitability and incentives from the Government leading to extensive development of groundwater. There is an urgent need to change the cropping pattern in these areas and to adopt cultivation of those crops which require less irrigation. Groundwater draft is 80-90%.

(iii) Kapurthala- which is in the city area and stress on pumping of groundwater is increasing to meet the ever-increasing demand of water for domestic and industrial uses. This has resulted decline of water levels at faster rates as compared to adjoining rural areas. This over exploitation of groundwater has caused formation of groundwater troughs in the central part of the cities resulting in increased energy consumption. In order to arrest the water table decline, either canal water should be supplied to the thickly populated areas or well fields may be developed in the outskirts of the cities and water be supplied through pipeline. Groundwater draft is 90%.

(iv) Sultanpur Lodhi- low lying area and might experience rise in water levels. This area is near to Harike wetlands. Groundwater draft 60-70%.

As per study findings, 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 this 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?
- 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?
- Whether interpreting groundwater level changes, if we use water table fluctuation methods, potentially mis-interprets recharge process?

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 (Quarter-wise from Dec. 2017 To June 2021)

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)	♦	♦		♦			♦				♦		♦	

Activity	1st to 4th	5th To 8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
First Draft (NIH-BGS)	♦										♦			
Second Draft Report/ Technical publication (NIH-BGS)	♦	♦										♦	♦	
Final Report/ Publication(NIH-BGS)													♦	♦

Progress

- The study duration has been extended upto November 2022
- The water samples will be collected from piezometers in April-May, 2021

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

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

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

Type of study	**:** Sponsored (NHP)
Date of Start	**:** December 2017
Scheduled Date of Completion	**:** June 2021 (3.5 years)
Budget	**:** Rs.70 lakh
Location	**:** Bhojpur District, Bihar (Figure 1)

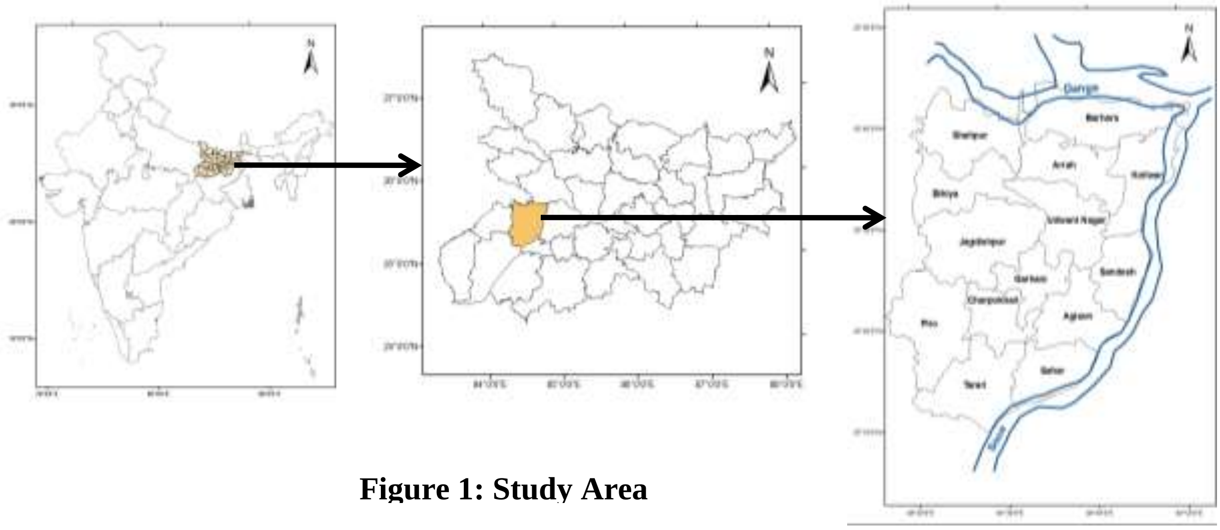


Figure 1: Study Area

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 regions of India. In recent decades, the increasing demand of groundwater for domestic, irrigation (round the year for food production) and industrial with the growing population rate led to extensive exploitation of fresh and potable groundwater.

In last decades, few investigators reported the elevated arsenic concentration and the process of the contamination in central Gangetic basin, but none seems to study 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 modellng. Column experiments 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:

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 contaminated aquifer	Near to completion. Eight piezometers have been constructed in the study area. Monitoring of water quality is under progress. Sediment samples have been analyzed in respect of its mineralogy. Sediment analysis using XRD and XRF methods have been completed.
Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.	Column experimental set-up is designed, fabricated and established in the lab. Batch experiment has been started.

Analysis and Results:

Based on the water sampling and analysis, the chemical results revealed that high arsenic concentration is found in the Holocene newer alluvium (northern part of district) and it is more concentrated in the depth range of 15-40 meter below ground surface. The relationship of As with other water quality parameters were studied and it was observed that strong positive correlation between arsenic and iron exist which indicate that reduction of iron oxide adsorbed with arsenic is responsible for arsenic mobilization in the ground water. The geochemical analyses suggest that rock-water interaction is controlling the geochemistry and chemical constituent of the groundwater is mainly controlled by carbonate weathering with limited contribution from silicate weathering. The isotopic signatures revealed that the Son river is recharging groundwater while the groundwater is contributing towards Ganga river. To study the impact of urbanization on arsenic mobilization, the land use land cover (LULC) map of year 2018 at 30 m spatial resolution was developed using Landsat-8 satellite imagery downloaded from United States Geological Survey (USGS) website. It is observed that arsenic is more concentrated in the built-up area in comparison to other land uses (Fig. 1). The plot of sediment water quality parameters viz. arsenic, iron and organic matter with soil depth were prepared to study vertical variation. It was interesting to note that arsenic has very good correlation with iron and organic matter. Arsenic is positively correlated with iron and inversely correlated with organic matter which justify our hypothesis of arsenic release in reducing conditions. For sediment characterization, XRD and RRF methods were used. The relative abundance of mineral phase was classified as Quartz>Illite>Kiolinite>Plasioclase feldspar>calcium carbonate. The XRD analyses does not show the presence of crystallized arsenic minerals phase in the study area.

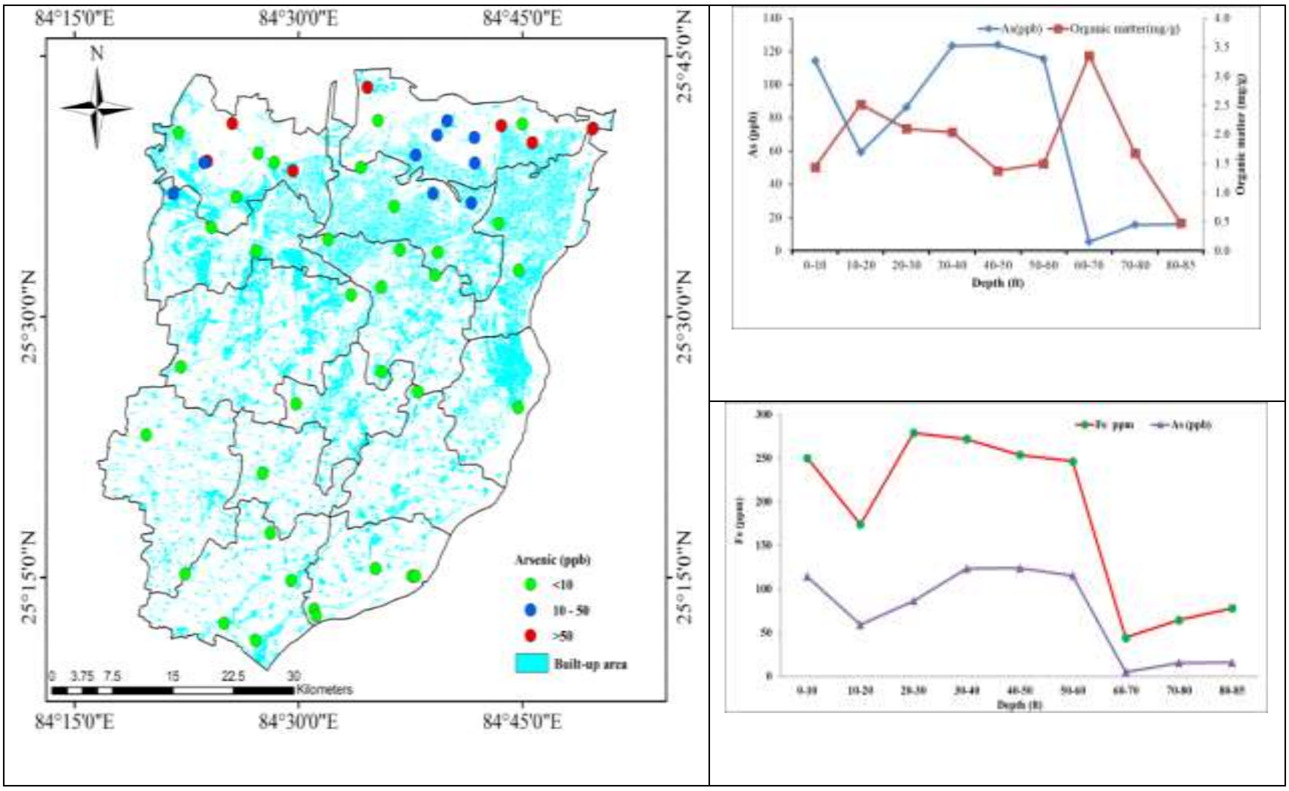


Fig. 1: Spatial variation of urban area with distribution of arsenic; Variation of arsenic, iron and organic matter with vertical depth of sediment.

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

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: Dr. Gopal Krishan (PI)
Mr. C. P. Kumar (co-PI)
Dr. Surjeet Singh (co-PI)
Mr. S. K. Verma (co-PI)
Haryana Irrigation Department
EE**,** Mewat
Consultants: IIT-Roorkee
Prof. M. L. Kansal
Dr. Brijesh Yadav
Sehgal Foundation, Gurgaon
Mr. Lalit Mohan Sharma

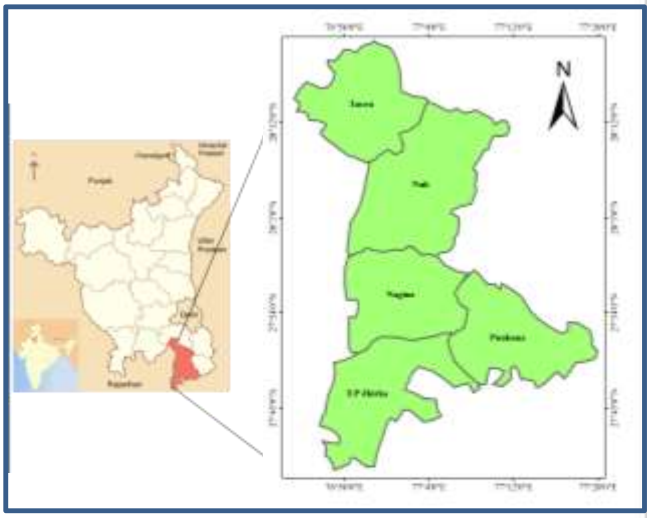
Type of study : Applied Research
Date of start (DOS) : December 2017 (NHP-PDS)
Scheduled date of completion : November 2021
Location : Mewat district, Haryana

Objectives	Achievements
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
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
To monitor influx of saline groundwater into fresh water zone	**Achieved (60%)-** Piezometers constructed and loggers installed
To assess the impact of groundwater salinity on socio-economic aspects	**Achieved-**Work is completed
To develop and demonstrate management and resilience building measures	**Achieved (60%) -**Experimental model developed and tested for development of fresh water bubble and recovery efficiency under controlled conditions. Work has been initiated for testing under 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 study deals with undertaking 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 Haryana 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 will also be undertaken. Development of a model to predict changes in groundwater salinity as a result of aquifer recharge and extraction is another focus of the study.



Map of Mewat District

Methodology:

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

In *Phase 1*, socio-economic based survey has been 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 has employed both qualitative and quantitative methods. Under the quantitative method, a well-structured coded interview schedule was used. Focus Group Discussions (FGD), as a qualitative method, were administered to collect information on the above socio-economic characteristics of the farmers.

Phase 2 of the study deals with developing 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 includes 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 waste water 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.

Objectives and Achievements:

Objectives	Achievements
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 are decreasing while no such observations are for salinity affected areas in Nagina block.

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.
To monitor influx of saline groundwater into fresh water zone.	Work is in progress, piezometers have been constructed to monitor influx.
To assess the impact of groundwater salinity on socio-economic aspects.	Achieved - Work is completed.
To develop and demonstrate management and resilience building measures	Achieved (50%) - Work is in progress, experimental model developed and tested for development of fresh water bubble and recovery efficiency. The same will be tested under field conditions.

Progress:

Understanding of the salinity mechanisms in different seasons (pre-monsoon, monsoon and post monsoon), ions and isotope were used. Sodium and calcium among cations and chloride among the anions had the highest degree of affinity and strong significance for all of the 3 seasons. Calcium-chloride water type dominated for all the three seasons (fig. 1) and Gibbs plot depicted that most of the Na^+ /Na^+ + Ca^{2+} and Cl^-/ Cl^- + HCO_3^- ratios shows the weathering of rocks to form minerals as the major reason behind the ionic chemistry of the groundwater (Fig. 2). The highest level of dissolution is encountered in case of NaCl, followed by $CaSO_4$, whereas $CaCO_3$ depicts precipitation. From geochemical aspects of weathering, evaporation and ion exchange are the major processes responsible for high salinity, and anthropogenic activities are leading to its expansion. The findings from this study will be useful in management and remediation of groundwater salinity of the region.

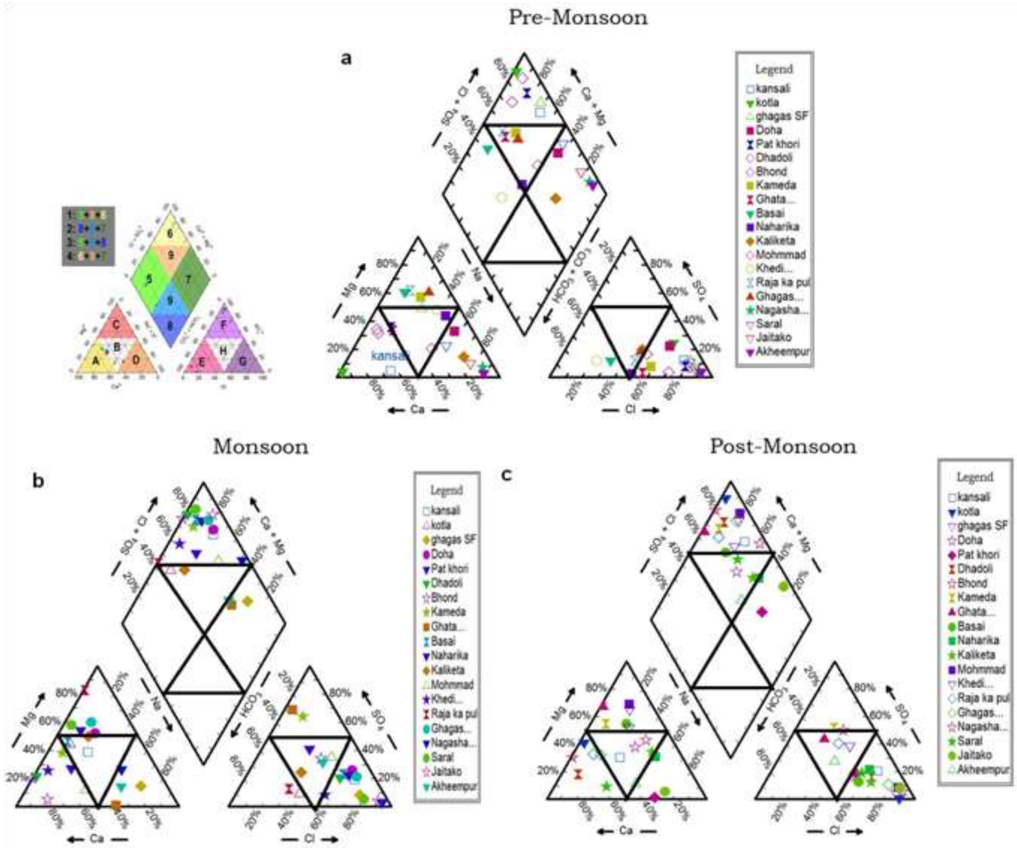


Fig. 1. Piper trilinear diagram of the groundwater water samples for (a) pre-monsoon (b) monsoon (c) post monsoon

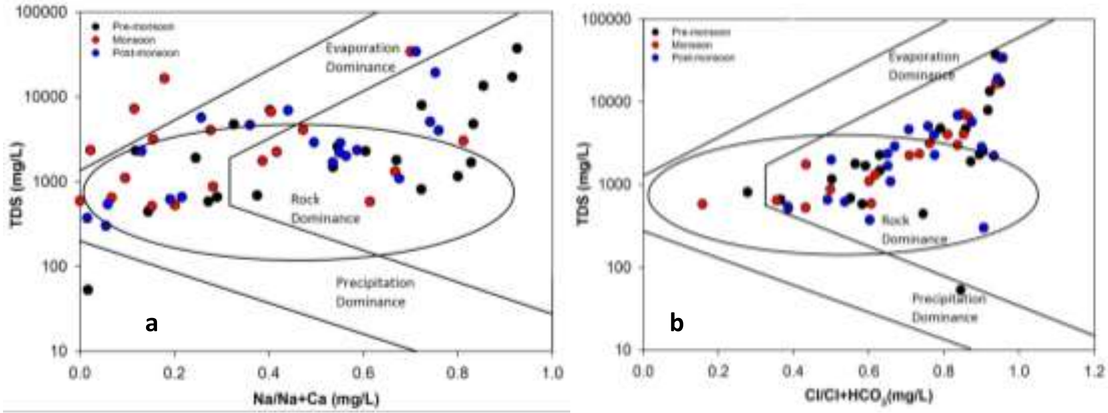


Fig. 2 Gibbs plots (a) TDS v/s Na^{+}+/ Na^{+}+ Ca^{2+} and (b) TDS v/s Cl^{-} / Cl^{-} + HCO_3^{-}

Similar findings were found using the isotopes, where it has been found that mineral dissolution was responsible for overall groundwater salinization with contribution of 97% (fig. 3),. In post monsoon season, contributions from initial salinity and evapo-concentration towards salinization increased by 8% and 3%, respectively.

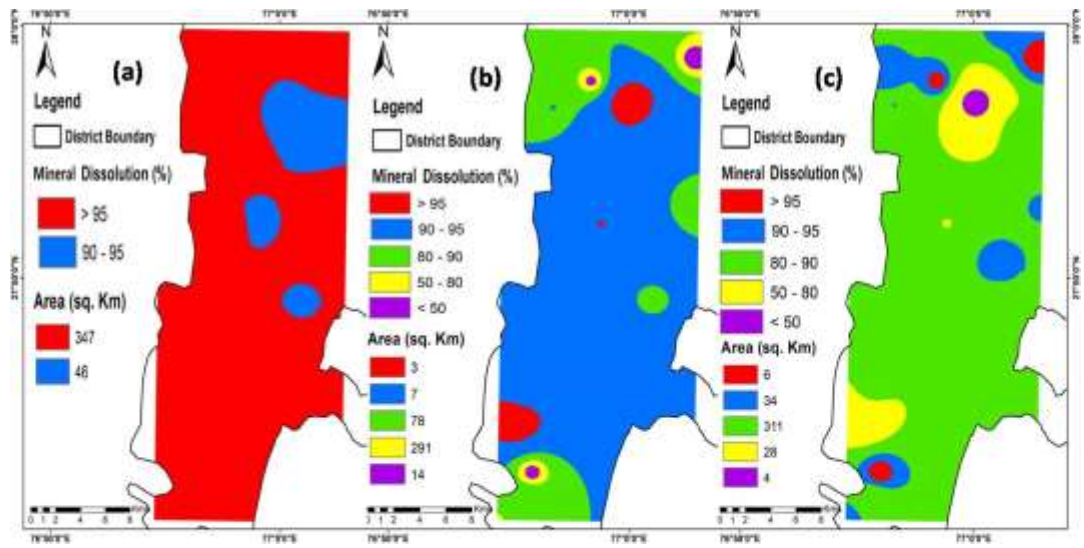


Fig. 3. Seasonal (a-pre-monsoon; b-monsoon; c- post-monsoon) variation in percent contribution of mineral dissolution in groundwater salinity in Mewat

Action plan:

Year	Jan 2018 to Jul 2022	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 and suggesting the suitable remedial measures

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

Activity Schedule for the Baseline Data Collection and Analysis in Mewat, Haryana (Quarter-wise from Jan. 2018 to Jul. 2022)

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

Data requirement & Expected source:
Hydro-meteorological data will be collected from the state departments.

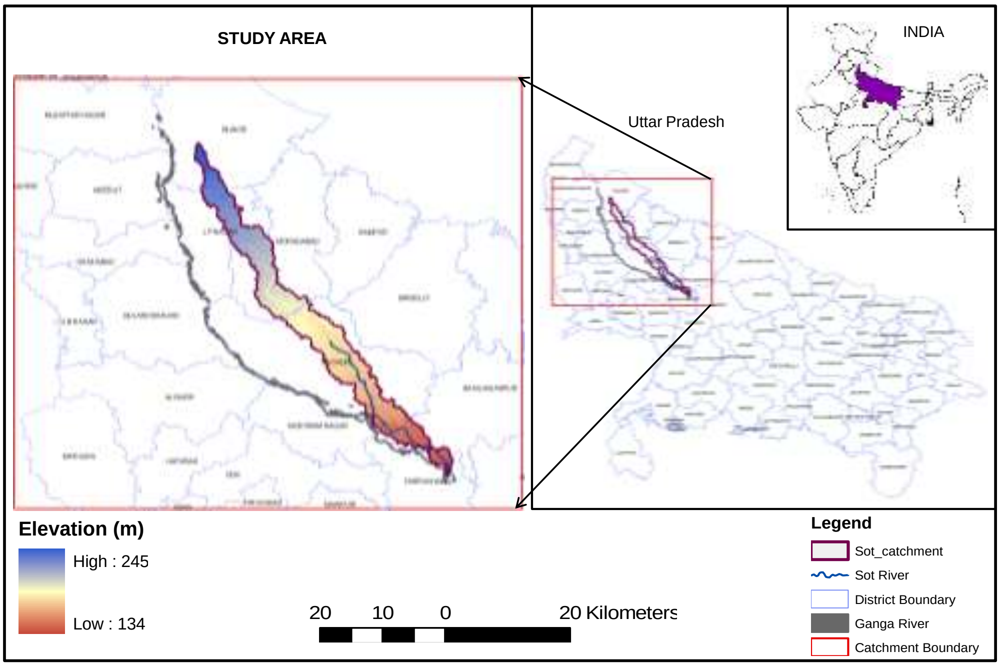
IPR potential and issues : Work is in progress

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

10. 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 : November 2021 (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, 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 of river and suggest measures for rejuvenation.

Methodology:

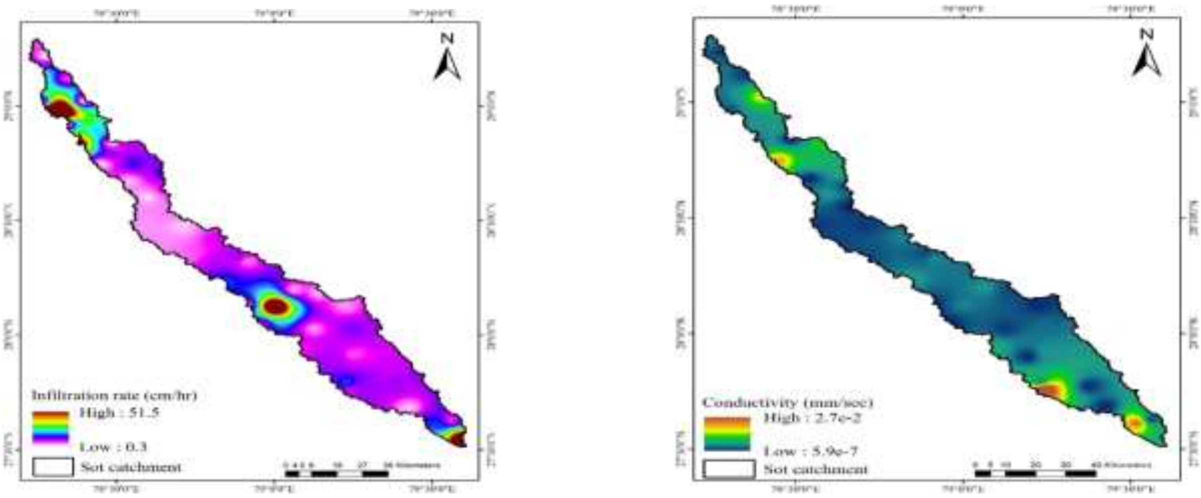
- Delineation of aquifers using litholog/ borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks software.
- Time series analysis by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river 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 Pettitt 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 a management plan for the enhancement of water resources both surface and underground.

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.	In progress
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.



Variation of infiltration rate and hydraulic conductivity in the Sot catchment

MODFLOW setup is in progress for the groundwater flow modelling. Litholog data is processed and hydro-stratigraphy is finalized. Model layers are being imported in the model.

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
- Economic benefits through livelihood upliftment
- Climate resilience

11. 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 (01/2018-12/2021)
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.	In-progress
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.	In-progress

Progress

[1] Progress made in geostatistical groundwater modelling for the spatial distribution of arsenic in India. Arsenic vulnerability mapping attempted by IITR employing Multi-Criteria Decision Making (MCDM) methods for twelve arsenic affected districts of Bihar, based on the secondary arsenic data of 2015 yielded satisfactory result while comparing with arsenic concentration maps of the respective districts. For gathering current arsenic scenario in the state, 93 water samples from hand pumps of Saran, Samastipur and Vaishali districts were collected in December 2019 and analyzed. Groundwater arsenic mapping across Ballia and across all 38 districts of Bihar was completed.

[2] Review of various arsenic remediation technologies. The technical and socio-economic analysis of Arsenic removal technologies were based on reliability, operational ease/simplicity, plant

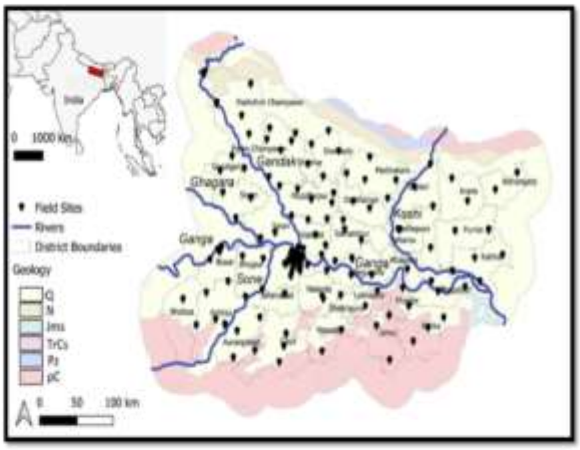
performance, affordability and social acceptability. Further, Life Cycle Analysis (LCA) was also conducted for assessment of environmental impacts associated with these arsenic treatment plants.

For arsenic remediation, nano material for injection is being 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 have been 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 have been developed by IITR for PRB.

[3] Completion of stage 2 sampling across Patna and Ballia districts (November 2019) to study the urban and rural organics responsible for mobilization of arsenic in groundwater. Higher-resolution sampling was undertaken in Patna district (n = 62) due to ongoing research in this area by the UoM and MCS. The total number of samples (n = 273) were spread over 38 districts of Bihar with an average of two depths collected in and around a particular location. Progress made in the installation of field monitoring (river/groundwater) stations along the length of the Ganga by IITKgp. Field samples in the upper, middle and lower Ganga particularly focused on organic, including emerging organic contaminants (November-December 2019).

FAR- Ganga team discussing the problems with Villagers during September 2019



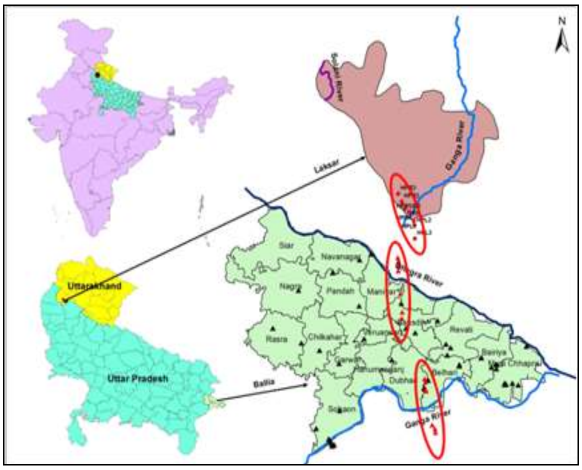
Groundwater Sampling Sites in Bihar

[4] Initially, seventy-two (72) water samples were collected from Ballia and Bahraich district of Uttar Pradesh by NIH team and analysed to study the variation of arsenic in the districts. Based on the water quality results, clusters of arsenic contaminated areas were identified. Sampling was made in Murli Chhapra block of Ballia where elevated concentration of arsenic (641 ppb) was found, to select the MAR site to study positive/negative impacts of MAR. Continuous quarterly groundwater samples monitoring at 32 locations in Murli Chhapra block of Ballia for chemical/isotopic analysis is being done. Surface water quality also is being monitored. Ten out of 32 samples (31%) were found above the acceptable limit of As. Installation of four piezometers in and around the MAR site is yet to be done.

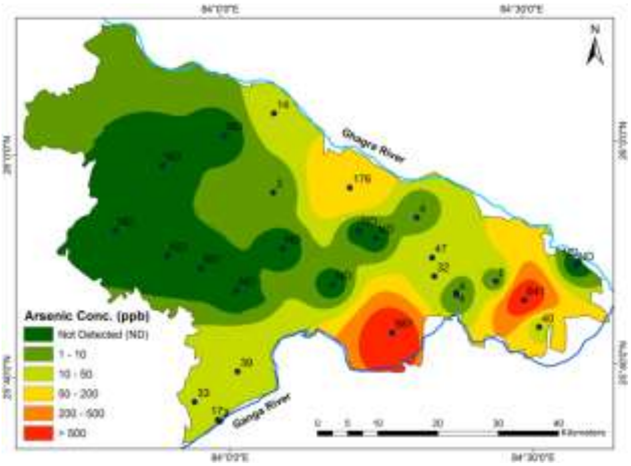
[5] For potential natural Hyporheic zone experimental sites, NIH carried-out GW & SW sampling in Bijnor and Moradabad area. Groundwater of both Bijnor and Moradabad area indicated arsenic concentration below permissible limit except few locations. Laksar (Uttarakhand) and Ballia (UP) were therefore identified 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). Water Quality profiling for total As, trace and toxic elements (Fe, Mn, Co, Pb, Cd, Cr, Zn, Ni, Hg, Cu), cations and anions (Na, Ca, K, Mg, NH_4, Cl, SO_4, NO_2^-, NO_3,

PO_4) and organics (DOC, TOC, etc.) and Isotopic (^{18}O & δD) sampling done quarterly during Jan, May, July, Sep, Nov 2019 and Jan 2020. EC, pH, DO and ORP measured *in-situ*. 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 (in progress WP6).



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 & Bahraich districts of UP mapped, clusters of arsenic contaminated areas 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 ground water samples monitoring at 32 locations in Murli Chhapra block of Ballia for chemical/isotopic analysis is being done. Surface water quality also is being monitored. 10 out of 32 samples (31%) were found above the acceptable limit of As. Arsenic is occurring along 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 & Mn.

[6] IITKgp has done detailed sampling of surface water and groundwater, and sediment sampling has been done across West Bengal. For arsenic mapping, extending from the ongoing work, arsenic concentration information is being integrated to develop hydro-geochemical maps of the study area and whole of India (>1.7 Million data points). Final data integration, culling, statistics have been achieved and various thematic layers have been prepared (Geology, Geomorphology, Hydroclimatic, Hydrology etc.).

For studying urban organics by IITkgp, as a part of an ongoing work, also overlapping with FAR-GANGA, detailed sampling of surface water and groundwater, and sediment sampling has been done across West Bengal. Outcome of these studies have recently been come out in the form of three publications in the International journal.

For contaminant transport, installation of piezometer nests is completed for 6 sites at Varanasi, Patna, Bhagalpur, Behrampur, Nadia, South 24 Parganas (headwater of Sunderbans) to study contaminant transport and river-groundwater interactions. Each nest contains two sampling wells and two observation wells. Real-time piezometric loggers are being deployed.

Field laboratory for detailed hydrogeochemical studies and reactive transport modelling has been installed in Nadia. Single and multiple tracer injection experiments have been performed in the site for tracking, multi-depth, conservative and reactive flow. Real-time and passive geophysics (ERT, EM and borehole geophysics) have been conducted to image the transport phenomenon. High-resolution (hourly to daily) sampling and in-situ analyses of tracers were done continuously for 10 months. Laboratory analyses of the tracers and water quality parameters including arsenic are being done.

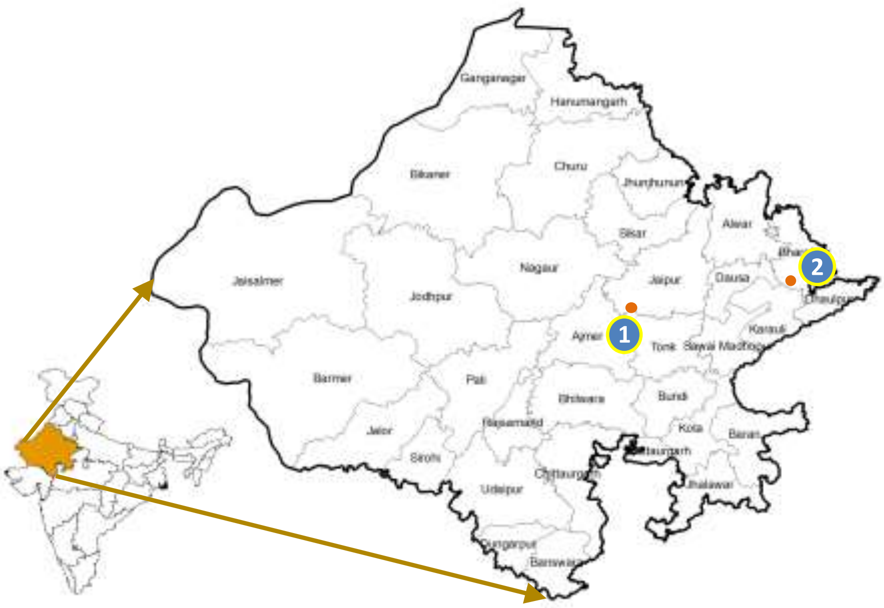
[7] Successful running of a series of stakeholder events in Roorkee, Varanasi and Patna. MCS organized stakeholder meetings, attended by multiple India/UK partners, at the Bihar State Pollution Control Board. The input of stakeholders at these and other meetings has been invaluable in guiding the FAR-GANGA project. Outreach activities have been undertaken in high schools/colleges in and around Patna, including citizen science projects.

[8] Publication of papers in the International Journal, National Journal and International and National Conferences. Project Management Board Meetings (PMB) were successfully organized in India and UK through online platform.

12. PROJECT REFERENCE CODE: NIH/GWH/DST/18-20

Title of the study: *Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants*

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 12/2021
India Project Partners: NIH Roorkee (India Lead); IIT Ropar; IIT Jodhpur
UK Project Partner: Cranfield University
Location Map



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.	Water levels and water quality being monitored at regular intervals. Chemical analyses of water samples and data processing.
Assess the proportion of recharged groundwater attributable to MAR systems at selected sites.	Groundwater recharge assessment for chauka system in Laporiya. Field and lab experiments conducted for saturated hydraulic conductivity, infiltration, grain size analysis, ICW and soil moisture retention curves. Soil parameters analyzed, and other meteorological and soil moisture data being monitored.
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.	Topographic and geophysical surveys conducted in Laporiya. Column experiments in progress to understand the transport of pollutants. Piezometers constructed at two sites in Laporiya and at one site in Bayana and data collected using DWLR. Geological samples collected and pumping tests conducted. Dissolution and Lysimeter experiments in progress. Collection and chemical analysis of groundwater and surface water samples from two sites located in Punjab and HP.
Develop analytical protocols to facilitate detection of micro-pollutants in water bodies	In progress
Understand the interactions of local users with the MAR structure and also their role in water management.	Socio-economic survey conducted at Laporiya field site. Project website developed
Interaction with project partners	Webex Meetings held on Apr. 2019; June 2019; Aug 2019; March 2020; Brain storming Session Dec. 2019; Joint Review Meeting July 9-10, 2019; Indo-UK Consortium Workshop Oct 8-11, 2019 at Cranfield Uni.; Online workshop May 14-15, 2020; Online Indian consortium meets

Laboratory Facility used during the Study:

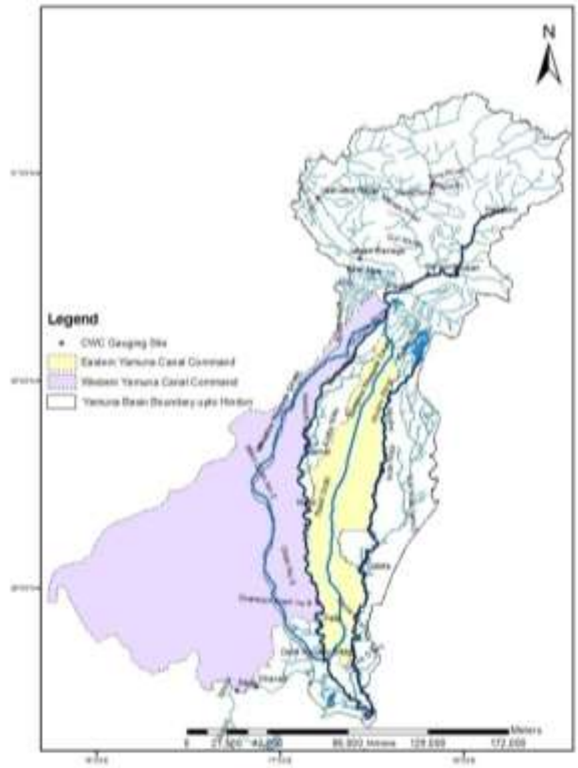
- Centre of Excellence for Advanced Groundwater Research
- Soil Water Laboratory
- Water Quality Laboratory

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

13. PROJECT REFERENCE CODE: NIH/GWH/CEHM/18-22

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

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



Study Area showing the Upper Yamuna Basin and the 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	Application of hydrological models completed for SWAT, HEC-RAS, VIC, QUAL2K. Application

simulation of the surface water, groundwater, and water quality	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 the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons river	Data processing and work on snowmelt runoff model WinSRM and SWAT in progress.
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 alternate scenarios of climate change	Extracted data for study area, processing of downscaled meteorological data for climate projections - statistical analysis between IMD data and NEX-GDDP data, bias correction, preparation of monthly time series
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 MIKE HYDRO and MODFLOW. Database buildup for WA+ tool to process spatial information on water depletion and net withdrawal using satellite measurements. Groundwater related data collected for Eastern Yamuna Canal Command. Processing of lithologs and groundwater levels.
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 groundwater resources	Modeling in progress using GIS based WetSpass distributed model. Initial results obtained. Field and lab experiments for soil parameters for selected sites in progress. Soil moisture monitoring to be taken up.
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) Assessment of changes in baseflow contribution to river Yamuna and strategies to enhance the contribution;
4) Evaluation of impact of climate variability on renewable groundwater resources;
5) Training Workshops for State Department officials of UP and Haryana.

14. 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: 03/2019 to 02/2024

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 visits to two sites in Barmer district for survey and characterization of sites for water resources intervention in Barmer District. Field visit to Bikaner district to carry out study on selected distributaries of Indira Gandhi Nahar Project (IGNP). Buildup of database in progress for development of model for better management of water in selected distributaries of IGNP in Bikaner district. Field experiments undertaken. Processing of meteorological data and groundwater levels. In addition, equipment purchase in process under project.
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 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.

15. PROJECT REFERENCE CODE: NIH/GWH/BMBF/2020-23

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) **HTWD, Germany** Prof. T. Grischek (Project Leader) Dr. C Sandhu (Project Coordinator)
Date of start (DOS)	**:**	July 2020 (Approval awaited from MoJS)
Scheduled date of completion	**:**	June 2023
Location	**:**	Agra, Uttar Pradesh

Objectives & Achievements

Objectives	Achievements
Determination of the upper limit for removal of "emerging pollutants" by RBF	**10%** – Past data has been collected and plotted
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
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:

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 impartially 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 in the 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 processes occurring during aquifer passage. Field investigations at various locations across India including in 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).

Agra is located in the state of Uttar Pradesh in the northern part of India at a distance of 200 km from the capital city New Delhi. The region features a semiarid climate that borders on a humid subtropical climate with mild winters, hot and dry summers and a monsoon season. However the monsoons, though substantial, are not quite as heavy as the monsoon in other parts of India. This is the primary factor in the Agra region that characterises it as a semiarid climate as opposed to a humid subtropical climate.

Main advantages of RBF in Agra are found with effective pre-treatment of drinking water by RBF and 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), RBF can serve as an important pre-treatment step and provide cost-savings for post-treatment.

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

Methodology:

NIH has already established a site at Agra. Samples will be collected from river, adjoining drainages and groundwater to assess the emerging pollutants. So the main focus of this project will be:

- 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

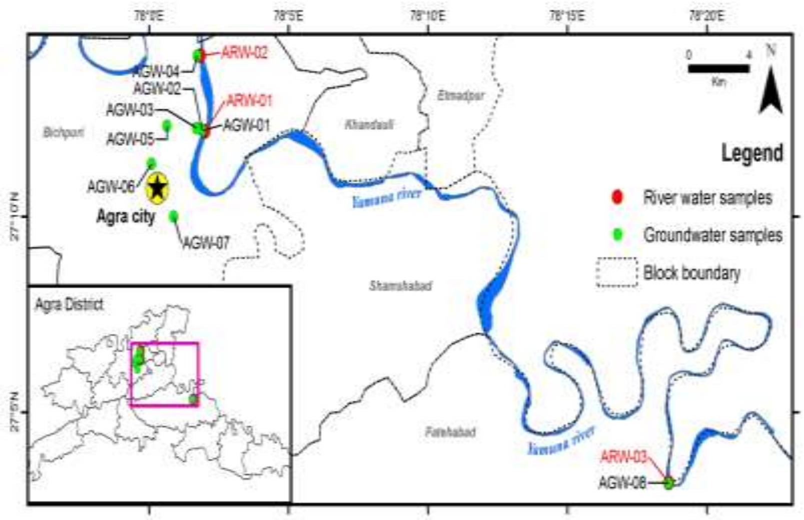


Fig. 1. Study site

Progress

Two agenda meeting were conducted on July 21, 2020 and February 03, 2021. In first meeting, on 21 July 2020 according to the agenda all Indian and German partners were able to participate online. The consortium coordinator Prof. Grischek welcomed the partners and introduced the project. The project background and aims, work packages, an overview of the overall budget and the immediate next steps to be taken by all partners, were presented. Subsequently all partners introduced themselves. Lastly, the cooperation agreement that all Indian and German partners have to sign and the transfer contract that only the Indian partners have to sign were discussed by the HTWD.

In second meeting convened on 03 February 2021 with 18 participants from 13 project partners), HTWD presented the status of project activities in the first 6 months of the project in 2020 and presented the overall work plan for 2021. Subsequently the partners presented their specific objectives, demonstration/case study sites, and work plans for 2021. Discussions/Questions on the demonstration/case study sites were done after the administrative and organisational aspects were discussed. Certain aspects for some sites were clarified during the meeting.

Action plan:

Period	July 2020 to June, 2023	Remark
July 2020 to June 2023	Monitoring of the site regularly Establishing the site with more infrastructure Prepare a status report	Report preparation as per Annexure 1

Study Benefits /Impact:

- The result will be the creation of a road map consisting of these implementation phases:
- informing and collating experience/knowledge;
- evaluating existing work bases and sharing or making them known within the network

Specific linkages with Institutions:

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

Activity Schedule (Quarter-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

Future plan

Use of synergies from the competence-pool of RBF/CW/MAR through training and thematic cooperation between part

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

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

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुव

APPROVED WORK PROGRAMME FOR THE YEAR 2020-2021

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)	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	2 years (4/20 – 3/22)	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 (7/20-6/23)	Continuing 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 (04/16-03/21)	Continuing Study under NMSHE Project
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 (1/18 – 6/21)	Continuing Study PDS under NHP
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 (1/18 – 6/21)	Continuing Study PDS under NHP
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 – 06/21)	Continuing Study PDS under NHP
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	1 year (04/19 – 03/21) ***Likely to be extended by 6 months***	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	2 years (06/19 – 5/21)	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 – 03/22	Continuing Study (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	3 Years (1/19 – 12/21)	Continuing Study (NMHS)

PROPOSED 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)	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	2 years (4/20 – 3/22)	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 (7/20-6/23)	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 (04/16-03/21) *Likely to be extended by 06 months*	NMSHE Project
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

S. N.	Project Title	Study Team	Duration	Status
3.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal	3 ½ year (1/18 – 6/21)	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 (1/18 – 6/21)	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)	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 M. Someshwar Rao BK Purandara YRS Rao	1 year (04/19 – 03/21) *Likely to be extended by 6 months*	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	2 years (06/19 – 5/21)	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 – 03/22)	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 – 12/21)	Continuing Study (NMHS)

ITEM NO. 51.2 ACTIONS TAKEN ON THE ADVICE / DECISIONS OF THE 50th MEETING

The specific action taken on the advice/decision of the 50th Working Group of NIH are as follows:

S. N.	Project	Comments/ Action(s) Suggested	Action Taken
1.	Hydrological investigations of selected springs in Tehri Garhwal District, Uttarakhand	iv) Only important springs, i.e., which are being used by local public should be studied	Springs used by the public have been selected for further analysis
		v) Tritium dating of the spring water should be carried out to understand the recharge zones.	Samples for tritium sampling have been collected. Samples for rainwater are to be collected.
		vi) To reformulate the first three objectives of the study.	The objectives have been reformulated

		vii) To also develop the correlation of spring characteristics with geomorphology, and	The correlation between geomorphologic parameters with spring location and discharge shall be developed
		viii) To suggest the guidelines for spring studies.	Guidelines shall be suggested, once the study is completed
2.	Isotope fingerprinting of precipitation over Indian Region	To be dropped as no progress is made. May be considered in future.	Study has been dropped
3.	Groundwater recharge estimation in a part of Sabarmati basin	i) Tritium tagging technique may be used with high precaution, and	Tritium tagging will be used at few points with very diluted tritiated water.
		ii) Stable isotopes should be used for determination of recharge.	The title of the study has also been modified.

ITEM NO. 51.3 PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2020-21

As per the approved work program, the status of studies carried out in HI Division during 2020-21 is given below:

Type of study/Project	*Completed during 2020-21*	*Continuing in 2021-22*	*Total*
Internal R & D Studies	00	03	03
Sponsored Projects	00	09	09
Total	00	12	12

Details of training Courses/Workshops organised by the Division during 2020-21:

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

Details of samples analysed by the Division Laboratories during 2020-21:

S.N.	Parameter analysed	No. of samples
1.	$\delta^{2}H$ on DI-IRMS	5043
2.	$\delta^{18}O$ on DI-IRMS / CF-IRMS	4815
3.	Tritium	162
4.	WQ samples on IC	800

Details of Research Publications by the Division during 2020-21:

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

Details of important instruments purchased by the Division during 2020-21:

S.N.	Name of Instrument	Qty.	Cost (Rs.)
1	Optical Dissolved Oxygen Meter	01 Nos.	1,03,834.50 + 5% GST
2	pH Meter	2 Nos.	1,70,000.00 + 5% GST
3	EC Meter	2 Nos.	
4	Temp Meter	2 Nos.	
5	Data Logger for Rain Gauge	05 Nos.	70,000.00 + 5% GST
6	Mini Disc Infiltrometer	01 Nos.	40,000.00 + 5% GST
7	Automated Infiltrometer	01 Nos.	5,08,000.00 + 5% GST
8	Software & PC upgradation of Ultra Low Level Liquid Scintillation Counter	-	4,86,000.00

The progress of the various studies undertaken during 2020-21 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***).

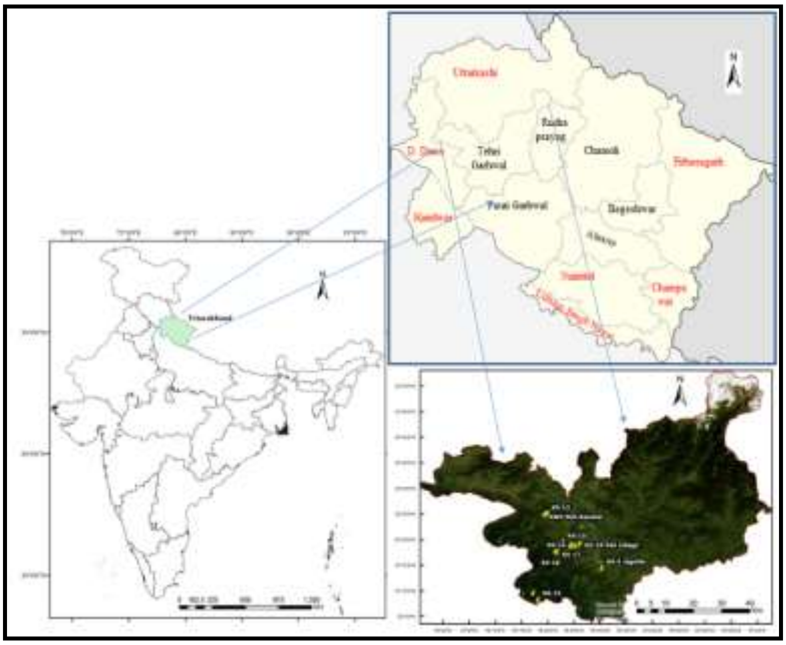


Fig. 1.1 Location of the study area.

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.	• Local Meteoric Water Line (LMWL) has been established using $\delta^{18}O$ and $\delta^{2}H$ of spring water. • Temporal plots of the isotopic composition of spring

	water ($\delta^{18}O$ and $\delta^{2}H$) have been prepared. • The collection of the samples for isotopic composition of precipitation is in progress. • Analysis of the altitude and local factors effect on stable isotopes of precipitation and spring water are 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 visit, 20 natural springs have been identified in the selected blocks of Tehri-Garhwal district (Fig.1.1). The spring related data have been collected (e.g. discharge, pH, EC, location, elevation, water samples). 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 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: The base maps have been prepared for the study area such as DEM, Slope, stream network etc.

Statistical analysis: 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 spring.

Due to COVID-19 situation, additional field visits could not be done for spring inventory and collection of rainwater and spring water for chemical and isotopic analysis from the study area.

Future work plan:

Additional field visits for spring inventory and collection of rainwater and spring water for chemical and isotopic analysis from the study area.

- Establishment of Rain gauge Stations for measurement of rainfall at different altitudes.
- The location of map of springs along with isotopic values of spring water and rainfall will be prepared in the study area.
- Identification of recharge sources and zones of selected springs will be undertaken based on isotopic characterization of precipitation and spring water source.
- The impact assessment of anthropogenic activities/climate variability on hydrologic responses of the selected springs.
- Preparation of a research publications.

Detailed results shall be presented during the working group meeting.

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 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.

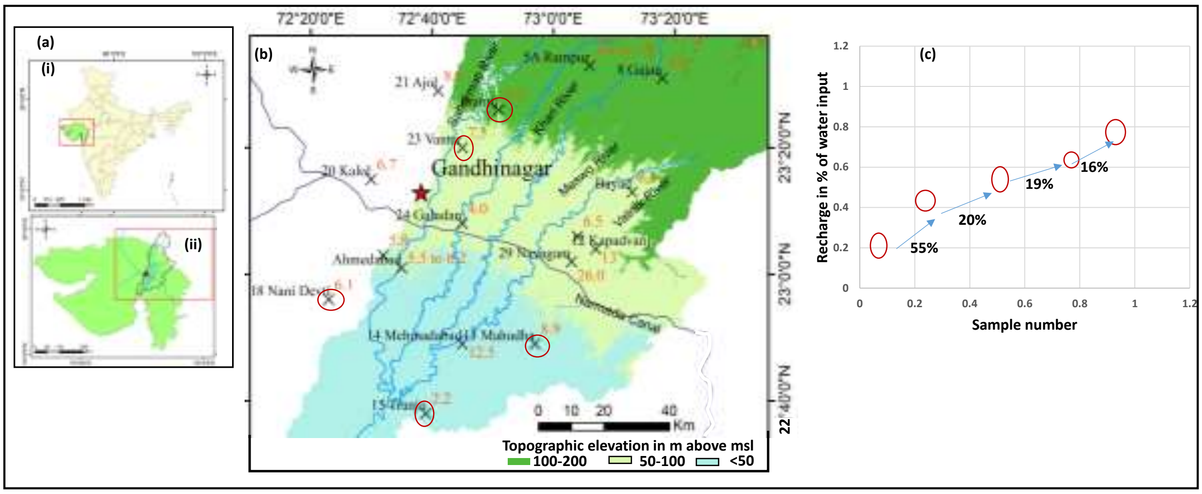


Fig 2.1: Study area. (a) (i) The state Gujarat in India (ii) Sabarmati river basin in Gujarat (b) Rivers and canal in the study area. The values shown in orange colour are the groundwater recharge rates as estimated in the previous study (Gupta et al., 1980). Red circles are the proposed sites for groundwater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

Work Components:

- Data collection
- Preparation of thematic maps
- Stable isotope and water quality analysis of groundwater and surface water resources
- Groundwater dating
- Estimation of vertical recharge to groundwater
- Report writing and publication

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			✓	✓

Budget: 15.0 lakhs

Budget component	**Amount (in lakhs)**
Travel	2.30
Data purchase	2.50
Experimental & consumable charges	3.00
Instruments	1.10
Manpower (Field cum Lab Assistant-FCLA) @Rs 20,000/- pm for 24 months	4.80
Miscellaneous expenses	1.30
Total	**15.00**

Justification:

1. Travel: Travel expenses is for fieldwork and data dissemination (conference/meetings etc). It is for 3-4 field visits of 1 week each for 2 officers & manpower (FCLA). The cost includes lodging, boarding and travel.
2. Data purchase: data related to LULC, hydro-meteorological data, soil & agriculture, RS & GIS, water quality, groundwater data, literature etc.
3. Experimental & consumable charges: chemicals, filters, glassware, plastic ware, minor repairs, stationary, pen drive, hard disc etc. and any analytical expenses in the field or in lab towards analysis of sample and data.
4. Instruments: Minor instruments that will be used in water quality and soil analysis such as sieves, augers, corer, EC, pH, temperature meters etc. that will be required in the project.
5. Field cum Lab Assistant: The person will be used for various works in the field such as for groundwater sampling for radiometric dating, soil coring, support in tritium-injection, raising soil cores, hydrologic data collection and, in laboratory for particle size analysis, soil moisture extraction, chemical analysis, tritium dating etc. As per the requirement of the project, the person will be deployed with experience & qualification as; (i) graduate in any discipline + 1-year experience or 12th pass in science + 4 years' experience or Diploma in any Engineering subject + 3 years' experience. The experience means experience in field and/or laboratory &/or in data processing & mapping on computer etc. As per the O/o No Project/TA&DA/2020-NIH(Admin) dated 29.06.2020, the deployed person will be admissible to TA/DA/HRA as per the post of 'Field Worker'.

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

Title of the Study:	INTEGRATED HYDROLOGICAL INVESTIGATIONS OF RENUKA LAKE, HIMACHAL PRADESH, FOR ITS CONSERVATION AND MANAGEMENT
Study team:	SD Khobragade (PI), Sudhir Kumar; Hukam Singh, Rajeev Gupta, Vipin Agarwal and Scientist from H.P. State Council for Science Technology & Environment.
Type of Study:	Institute Funded R & D Study
Duration:	3 years (July 2020 to June 2023)
Budget:	**Rs.** 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. National Institute of Hydrology 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 to develop a comprehensive conservation and management plan for the lake. The matter has been discussed with the authorities of the Himachal Pradesh, who have agreed upon that systematic and detailed scientific investigations need to be carried out on the Renuka Lake. Therefore, 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:

- Collection, processing and analysis of the available data
- Generation of additional required data.
- Field investigations and field surveys including bathymetric survey
- 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. Morphometric 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 and an altitude of 672 m amsl (***Fig. 3.1***). It has a circumference of 3,200 m, 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.

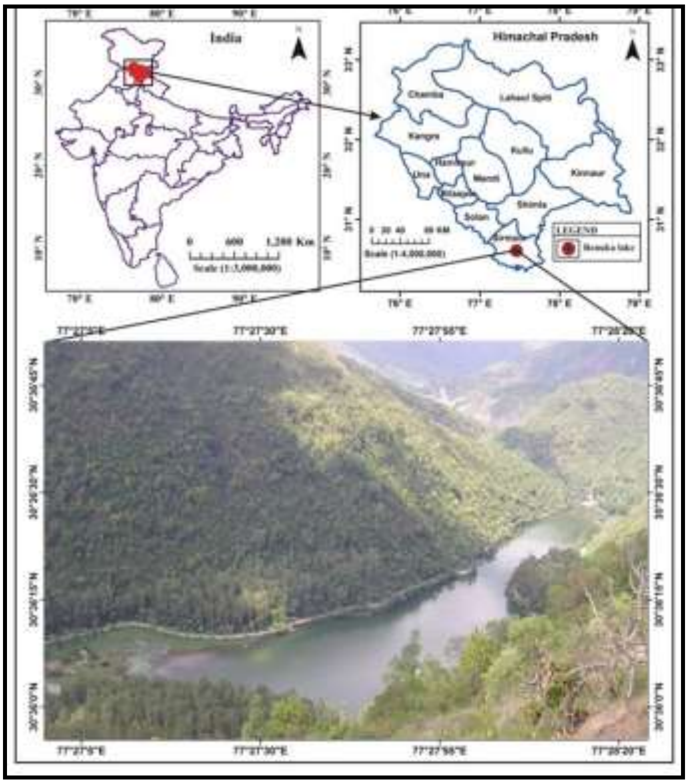


Figure 3.1: Location map of study area

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:

During December 2020, a field visit to Renuka Lake and its catchment was undertaken (***Fig. 3.2***) to carried out following works:

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, therefore 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.

Fig. 3.2: Fieldwork carried out during December 2020

Future work plan:

Subject to the approval of the Himachal Wildlife & Forest Department, following activities are proposed for the next 6 months:

- Bathymetric Survey of the lake

- Preparation of LULC & other required thematic maps
- Installation of Equipment in the field such as AWS, DWLR, ARG etc
- Generation of hydro-meteorological data
- Monitoring of Water quality for summer
- Sampling and analysis of isotopic data
- Preparation of groundwater level contour map
- Infiltration tests

Sponsored Projects:

1.0 *PROJECT CODE: NIH/HID/SPON/12-15*

Title of the Study:	UNDERSTANDING OF 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
Collaborators:	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:	March 2021 (To be extended for next 6 months)

Study area

The study area (***Figure 1.1***). 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 elevations 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.

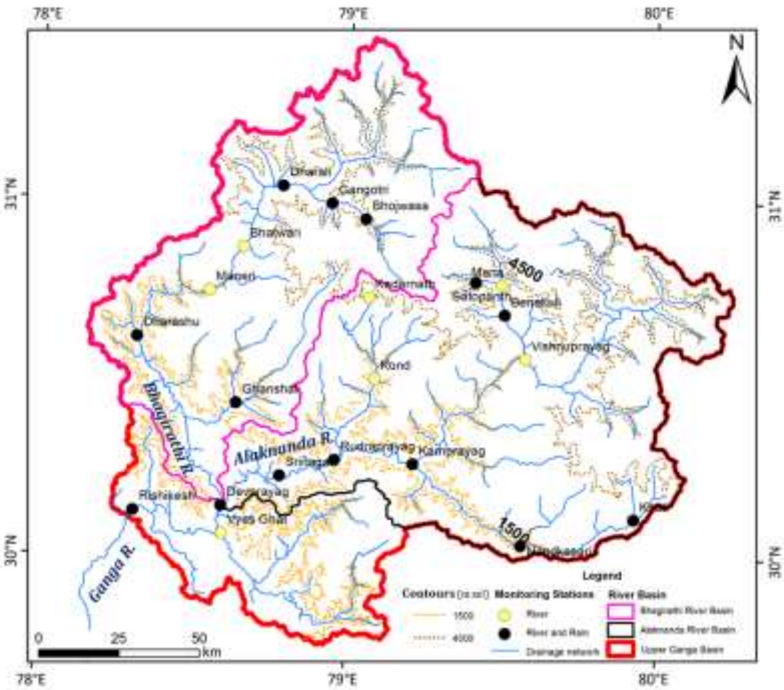


Figure 1.1 Study area map with rain and river monitoring stations

Study Objectives:

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

Statement of the Problem:

The Himalayan mountain system is the source of one of the world's most extensive supplies of freshwater. However, these sources are under threat due to severe environmental degradation and climate change. These changes are likely to affect 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

Achievements vis-à-vis Objectives:

Objectives	Achievements
Isotopic characterization of precipitation and identification of sources of vapor	➢ A meteoric water line for the upper Ganga basin has been established. ➢ Thirteen meteoric water lines have also been established for separate rain gauge stations in the upper Ganga basin. ➢ Isotopic characteristics of rainfall and snow have been studied from 2016 to 2018. ➢ Back trajectories have been identified for extreme rainfall events. ➢ Detail back trajectories analysis is in progress
Runoff generation processes in headwater region of Ganga using isotope and modeling	➢ Rainfall analysis has been completed for the upper Ganga basin up to Rishikesh. ➢ Rainfall anomalies have been identified for the period of 1972 -

	2018 ➢ Correlation between rainfall anomalies and river discharge has been studied at the Rishikesh monitoring station. ➢ Spatial and temporal distribution of isotopic composition of river water have been studied from 2016 to 2018. ➢ A two-component mixing model analysis has been completed for five confluence points of rivers in the upper Ganga basin. ➢ Spatio-temporal variation of snow cover area has been studied from 2005 to 2016.
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	➢ Spatial and temporal distribution of snow/ice melt has been studied from 2016 to 2018. ➢ End-member has been identified for the hydrograph separation approach. ➢ MATLAB coding has been done for uncertainty analysis in the hydrograph separation approach. ➢ Possible causes of snow/ice melt have been studied. ➢ Detail spatial and temporal variation of stable and radiogenic isotopes has been carried out for Satopanth Glacier
The contribution of transient groundwater and its role in the sustainable flow of Ganga	➢ Hydrograph separation approach has been used to identify the relative contribution of groundwater in major streams and river Ganga. ➢ Uncertainty analysis in the hydrograph separation approach has been carried out.
Groundwater dynamics in the mountainous area, including identification of recharge sources and zones of major springs	➢ Spatial and temporal patterns of the isotopic composition of groundwater and springs have been studied. ➢ Analysis of the altitude effect has been carried out. ➢ Groundwater and springs recharge sources and zones are being identified.

Progress of Work/Results and Analysis:

A total of 6,828 water samples from springs (n=333), groundwater (n=303), rain (n=1,003), river (n=4,999), and snow/ice (n=190) have been analyzed for stable isotopes, while a total of 191 water samples have been analyzed for tritium measurements. In addition, 469 water samples have been collected for hydro-geochemical parameter analysis in the study area. The geologic maps have been prepared for the study area.

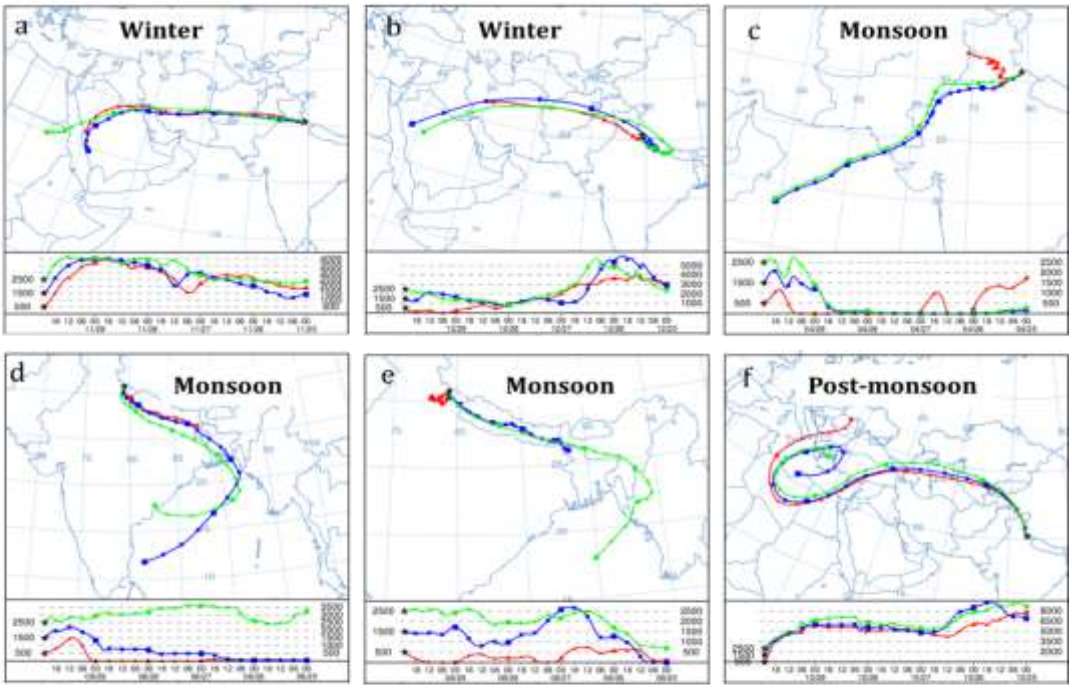
Important results obtained so far:

- ➢ A meteoric water line for the upper Ganga basin has been established. This can help understand the hydrological processes and their relationship with the climate settings in the study area.
- ➢ Local moisture recycling has been observed in the study area using back trajectory and isotopic results of rainfall. A more significant local influence in rainfall patterns has been observed in the rainfall station located very close to the Tehri dam (***Figure 1.2***).
- ➢ No clear amount effect has been observed for any station in the basin, even in the monsoon season. This indicates that local moisture recycling may be significant in some rainfall

events, even in a monsoon.

- Analysis of the relationship between annual rainfall anomalies and river discharge indicates that the annual rainfall anomalies are positively correlated with annual river discharge at Rishikesh, suggesting rainfall to be the primary river discharge source in the study area (***Figure 1.3***).

Figure 1.2: Back tractor analysis to identify the moisture source for precipitation



in the upper Ganga basin.

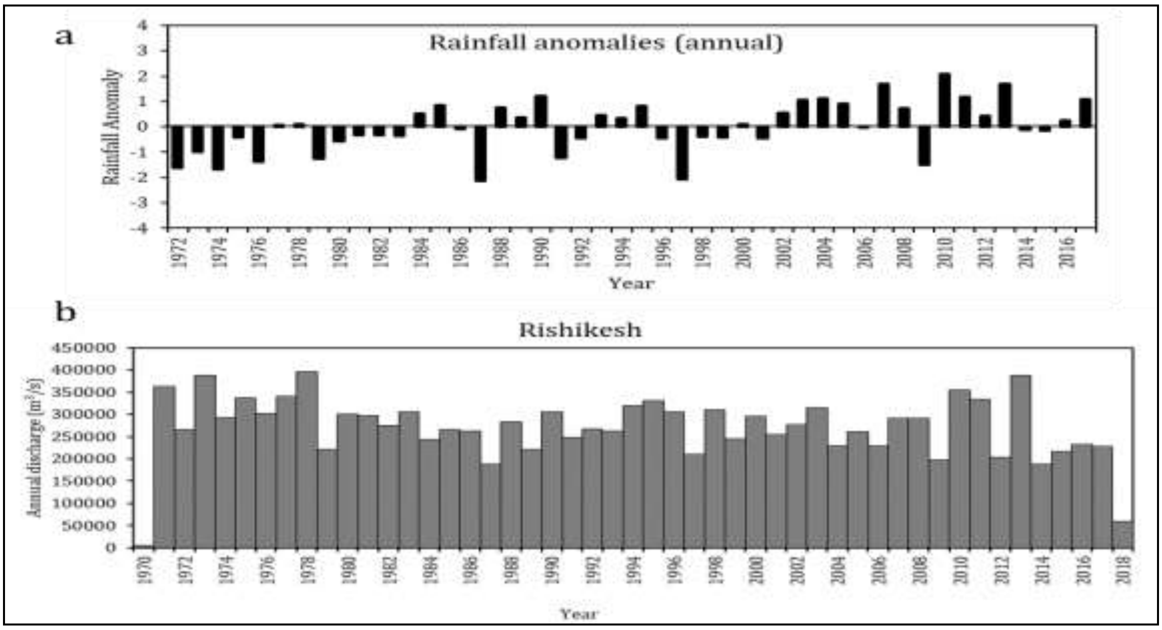


Figure 1.3: Long-term rainfall anomalies (annual) and annual total discharge at Rishikesh from 1971 to 2018.

- The river contribution at different locations indicates the dominant contribution from the

Alaknanda river basin (~74%) in comparison to the Bhagirathi river basin (~26%) in the study area (***Figure 1.4***).

- Snow/ice melt contribution decreases towards the downstream region because of increased contribution from rainfall and groundwater. For example, the annual average relative contribution of snow/ice melt was about 64% at Mana and about 89% at Bhojwasa, compared to 34% at Devprayag and 31% at Rishikesh in the upper Ganga basin.
- Springs and groundwater samples show marked spatio-temporal variation across the study area, indicating a considerable no. of individual aquifers for the springs.

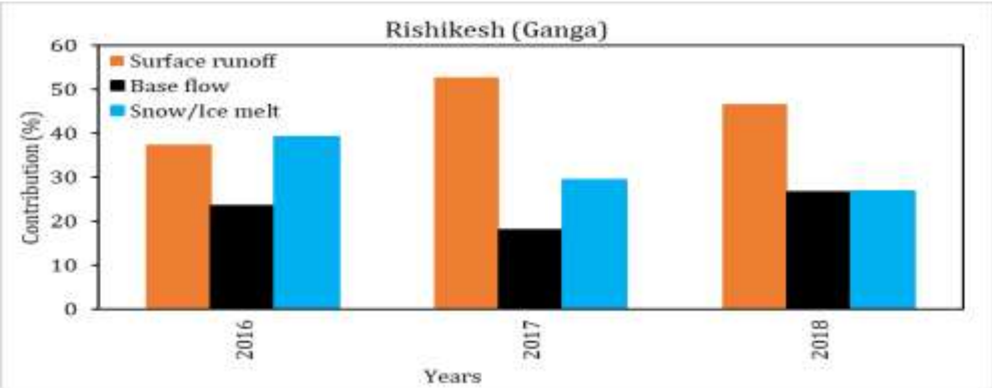


Figure 1.4: Annual average relative contribution from various sources to Ganga river discharge at Rishikesh.

Future Work Plan:

- Analysis of tritium data for residence time and groundwater dynamics analysis
- Further analysis of springs recharge sources and zones identification.
- Additional analysis of stream water contribution to major rivers in the upper Ganga basin.
- Planning for a workshop
- Field planning to selected locations for additional data on springs in the study area.
- Publications in peer-reviewed journals.

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 December 2021)

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.

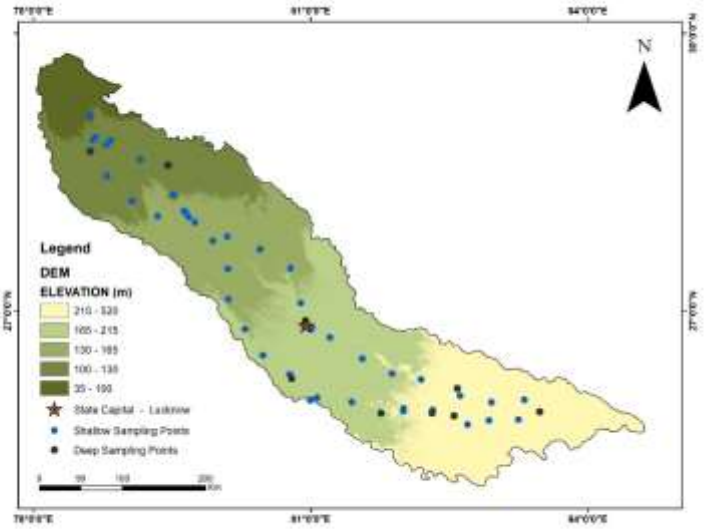


Figure 2.1: Study area, groundwater sampling points on DEM.

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

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 December 2021)

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.

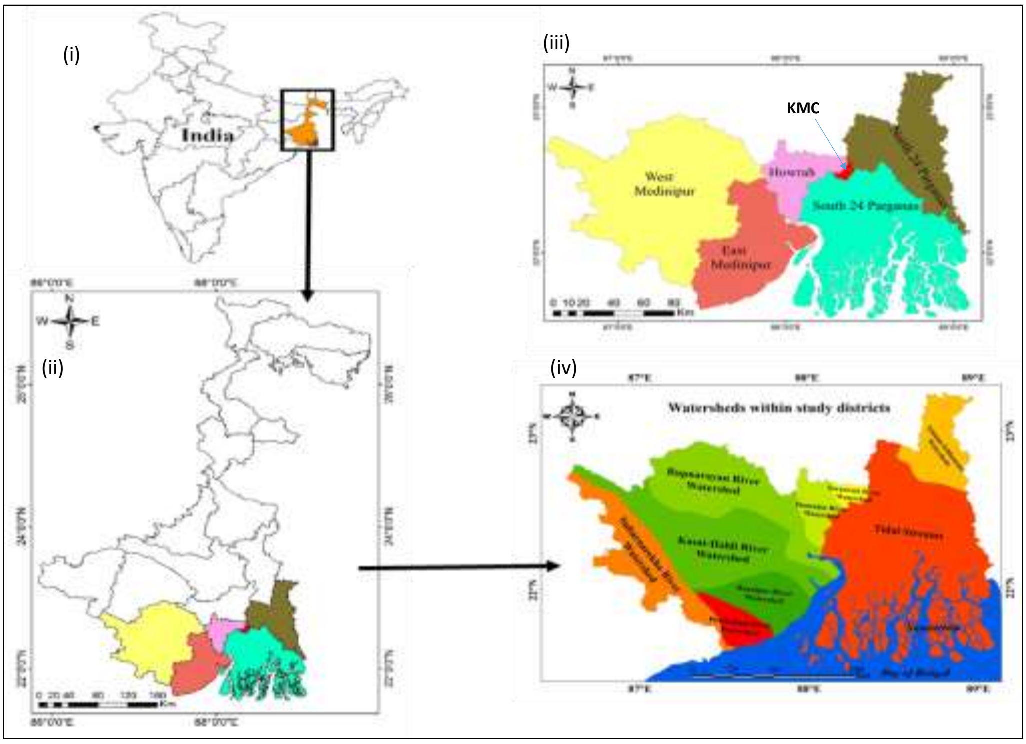


Figure 3.1: Study area. (i) Location of West Bengal in India map (ii) Coastal districts of West Bengal (iii) Map of the 5 coastal districts and the Kolkata Municipal Corporation (KMC) (iv) Watersheds in the study area

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. So, 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) LST (MODIS 2019 & 2020), Resol: 1km SST (2019 & 220)	Completed	-----
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		

4.0 ***PROJECT CODE: NIH/HID/NHP/2018-21/1***

Title of the Study:	DEVELOPMENT OF A COMPREHENSIVE PLAN FOR CONSERVATION AND SUSTAINABLE MANAGEMENT OF BHIMTAL AND NAUKUCHIATAL LAKES, UTTARAKHAND
Study 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
Study Duration:	3 years (January 2018 to June 2021)
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

Methodology:

- Field surveys and field investigations
- Bathymetric survey
- Collection, processing and analysis of the available data
- Generation of additional required data.
- Preparation of base maps and morphometric characterization
- Sample collection and laboratory analysis
- Data interpretation and analysis
- 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 (***Figure 4.1***). 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.

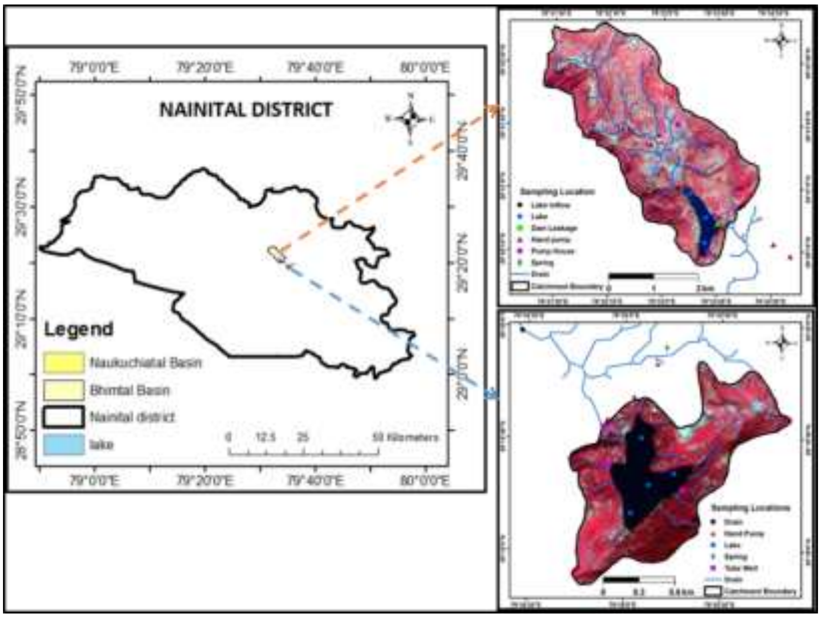


Figure 4.1: Study area map of Bhimtal and Naukuchiatal lakes

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.
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	Bathymetric surveys have been completed for both the lakes and depth area capacity curves have been developed.
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:

Three field visits were undertaken during 2020-21 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 collected until July 2020 has been completed and analysis of samples collected thereafter is under progress. The data required for water balance etc that was supposed to be collected and provided by IRI, Roorkee, has not been collected and provided so far. So not much progress has been made for assessment of water balance.

Important results obtained/Analysis:

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

(ii) 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.

(iii) 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.

(iv) 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.

(v) Analysis of d-excess for the study area indicates higher values during winter and lower values during the summer & monsoon periods ***(Figure 4.2)***. The higher d-excess during winter follows the reported pattern for the western Himalayas, due to moisture source from Mediterranean region.

(vi) 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.

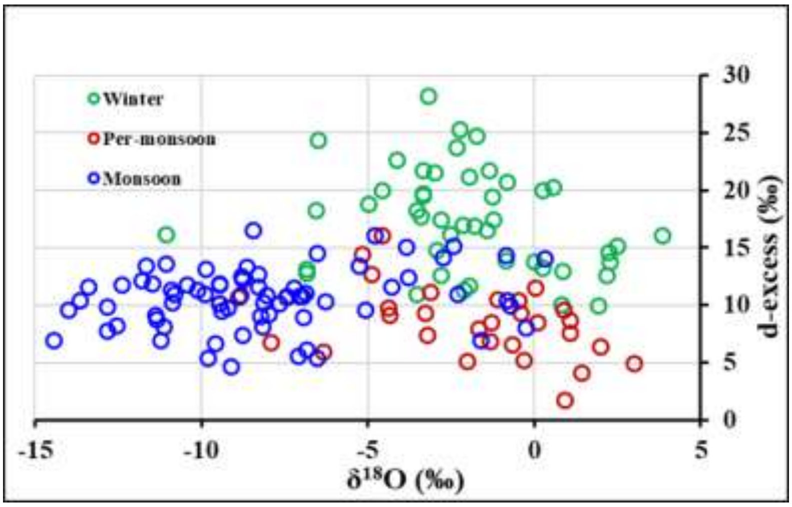


Figure 4.2: Isotopic variation of precipitation

(vii) 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 ***Figure 4.3***. The recharge source for all the springs in upstream of both lake catchments are observed to be precipitation.

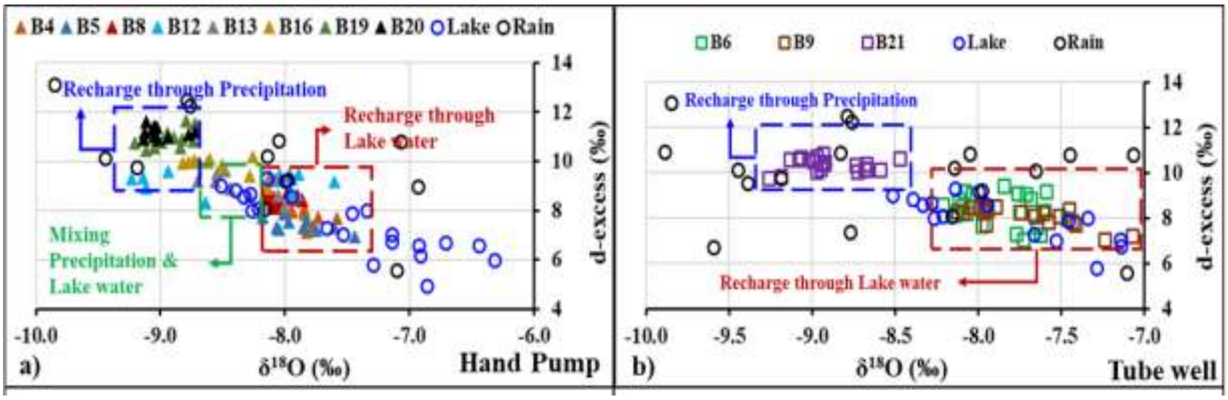


Figure 4.3: Isotopic variation of different source of Bhimtal Lake

(Viii) 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 HCO3– dominates as the major anions. The water type in both the lakes and catchments is basically calcium dominated because of the dominating limestone (CaCo3) as a basement rock. Bhimtal lake also shows some organic pollution.

Future Plan: as per activity schedule

Activity Schedule: Combined activity schedule of NIH & IRI

5.0 *PROJECT CODE: SP-35/2018-2020/HID*

Title of the Study: UNRAVELLING SUBMARINE GROUNDWATER DISCHARGE (SGD) ZONES ALONG THE INDIAN SUBCONTINENTS AND ITS ISLANDS

Study Team: Sudhir Kumar (PI), SM Pingale, MS Rao, BK Purandara, YRS Rao

Collaborating Institutions: National Centre for Earth Science Studies, Thiruvananthapuram, RC Kakinada and Belagavi

Type of Study: Sponsored Project, Ministry of Earth Sciences, GoI

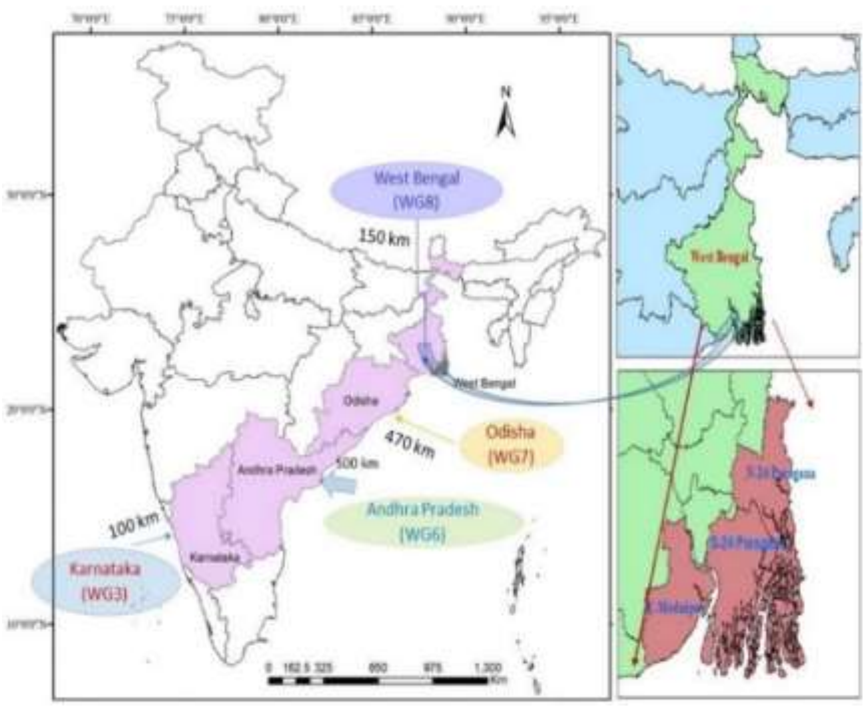
Budget: Rs 46.44 Lakhs

Nature of Study: Applied Research

Duration of the Study: 02 Year (March 2019 to March 2021), Likely to be extended by 6 months

Study area: The study area included the coastal districts of West Bengal (i.e. Purbha Medinipur, North & South 24 Parganas) (***Figure 5.1***).

Figure 5.1: Location of the study area.



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, Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging or hydrogeological surveys.

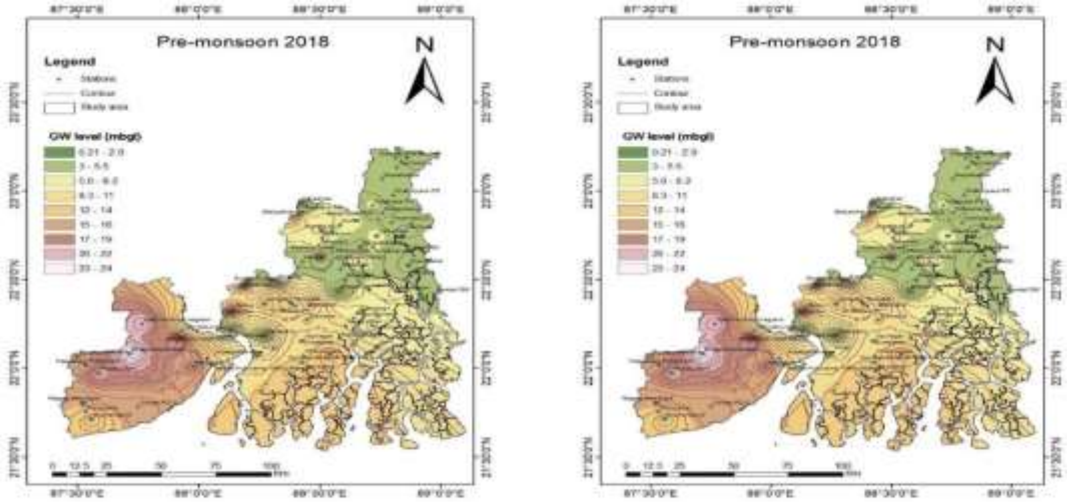
Methodology:

- Literature survey on SGD and archival information and collection of regular monitoring data from CGWB.
- Collection and processing of Landsat 8 thermal infrared images for selected locations.
- Field work & sample analysis: Groundwater samples will be collected at uniform frequency for isotopic and chemical analysis.
- Data synthesis: Field data and archival data will be converted into thematic layers on GIS environment. This will be used to identify the potential SGD zones in the coastal aquifers.
- Management Measures: Data will be interpreted in terms of augmentation of SGD zones in the coastal aquifers.
- End use: Identification of recharge areas, adoptive management strategies for artificial measures, knowledge dissemination and preparing field implementable programs.

Achievement vis-à-vis Objectives:

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 (***Figure 5.2***). • 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 (***Figure 5.3***). • 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.
To measure salinity and temperature of sediment pore water, groundwater and seawater	• The in-situ salinity and temperature of pore water, groundwater and seawater water have been carried out for the selected locations in the Purba Medinipur district.
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 or hydrogeological surveys.	• 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. The tritium samples are under laboratory analysis. • 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

	completed for the collected samples. • The linkage between the isotopic signature of water, it's chemistry and hydrogeological processes is being initiated for identification of possible SGD zones.



(a) Pre-monsoon season (b) Post-monsoon season

Figure 5.2: Groundwater level variation in coastal districts of West Bengal during 2018

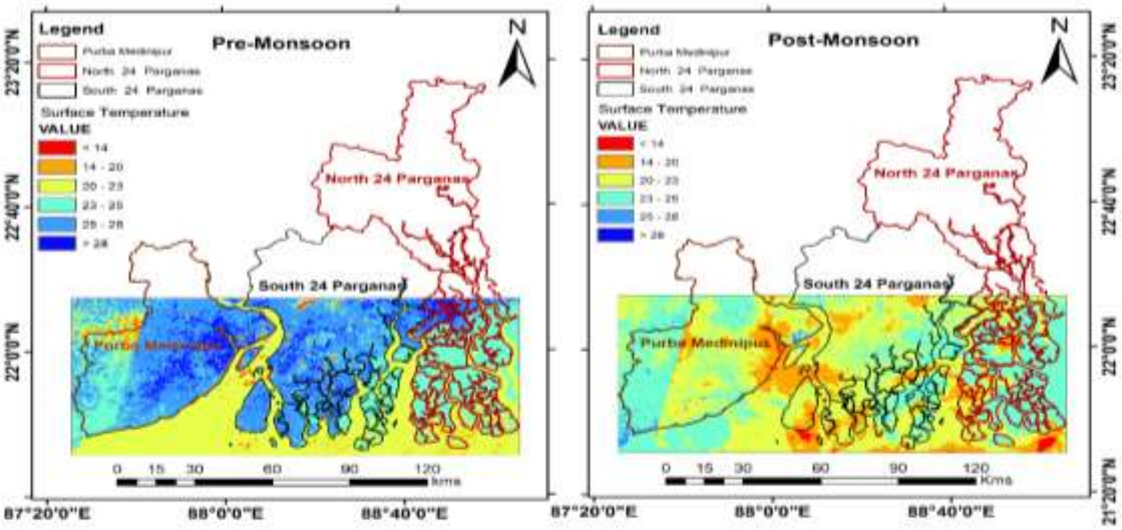


Figure 5.3: Land surface temperature estimation over coastal districts of West Bengal during 2018

➢ Sample collections in the coastal districts of West Bengal is delayed due to COVID-19 restrictions and will be completed after COVID-19 pandemic.

Future Plan:

➢ Field surveys for primary data collection for isotopic and chemical analysis of groundwater, pore water, sea water from remaining coastal districts of West Bengal (i.e. North 24 Parganas and South 24 Parganas) at specified interval.

➢ Analysis and preparation of thematic maps of SGD locations.

6.0 *PROJECT 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), MS Rao, S.M. Pingale
Collaborating Agency:	IHE Delft through IIT Bombay
Type of Study:	Sponsored Project,
Budget:	Euro 18400
Nature of Study:	Applied Research
Duration of the Study:	3 Years (May 2019 to May 2021)

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 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 (***Figure 6.1***), 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

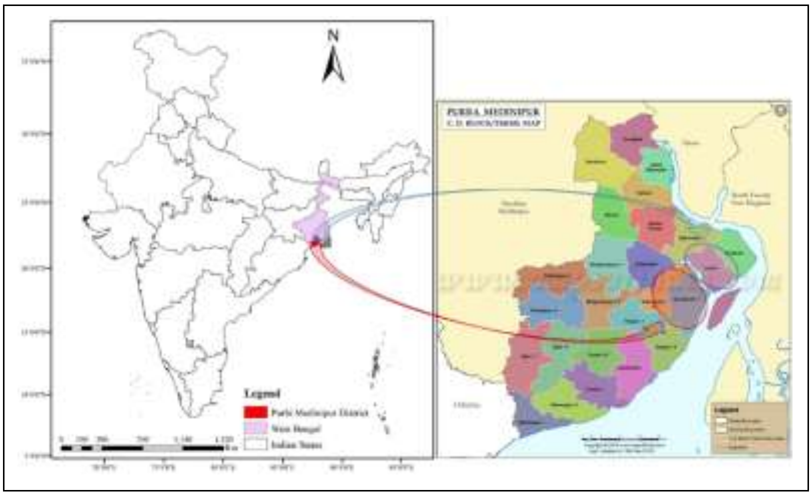


Figure 6.1: Location of the study area (i.e. Nandigram & Haldia blocks)

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.

Methodology:

The adopted methodology involves field investigations and collection of hydrological, meteorological, groundwater quality, geological, topographic and land use 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:

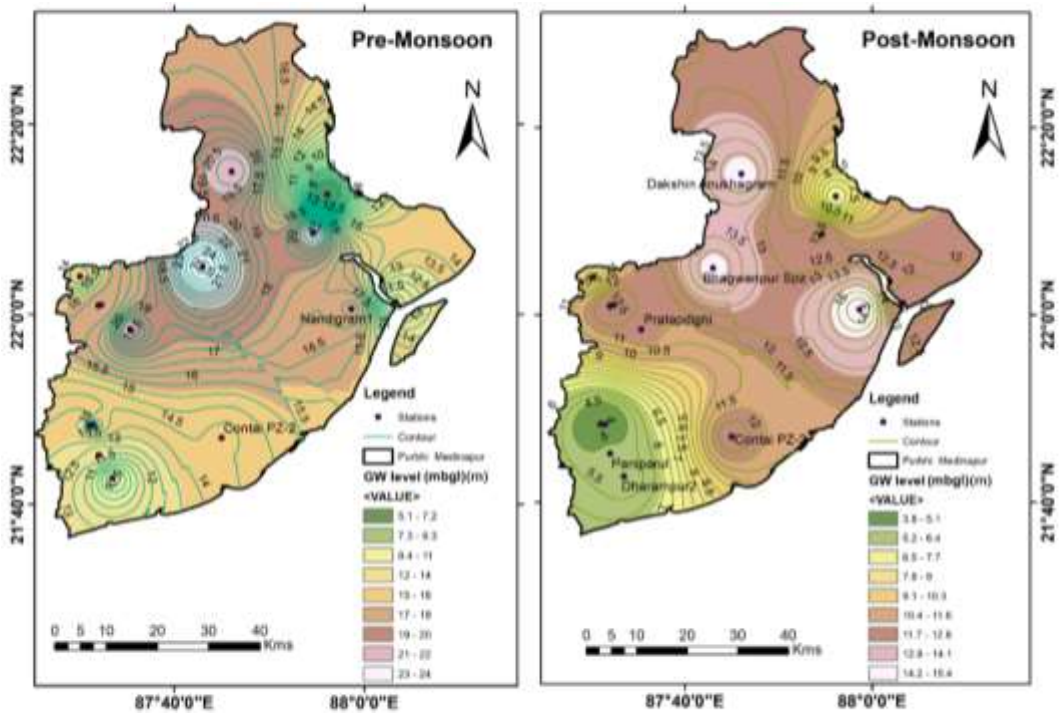
- Literature survey have been completed related with study.
- Primary and secondary data from different sources have been collected.
- We have made field investigations in the coastal district of Purba Medinipur in West Bengal and collected water samples from some of the locations for chemical and stable isotope analysis (***Figure 6.2***).
- In-situ measurement of water quality parameters (e.g., salinity, temperature, EC, DO, pH) of groundwater and river water samples have been performed by using Multi-parameter water quality analyser. Water samples are mainly analysed for the seven major parameters.
- The water samples have been collected for $\delta^{18}O$ and $\delta^{2}H$ isotope for selected locations and have been analysed in the lab. 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 groundwater and river water for the study region.
- Radon concentrations in the groundwater and surface water have been directly determined in the field. While the tritium samples are under laboratory analysis.
- Some of the data related with groundwater and hydrogeology have been collected from CGWB. The archival data information (i.e., groundwater, its chemistry, general aquifer properties and characteristics) have been collected from regional CGWB office at Kolkata.

Figure 6.2: Water sample collection at Haldia and Nandigram block of Purba Medinipur district.

- Historical groundwater level data of different groundwater observation wells in Purba Medinipur have been collected from CGWB and India-WRIS web and analyzed (***Figure 6.3***). This is prepared to understand the groundwater dynamics in the study area.
- Obtained hydro-climatic data for groundwater analysis.
- Detail analysis is in progress.
- Additional field visits are required in the study area (Haldia and Nandigram Block) for data collection, survey and stakeholder's discussions. However, this is delayed due to COVID-19 restrictions and will be completed after COVID-19 pandemic.

Future Plan:

- Additional field visits are required in the study area (Haldia and Nandigram Block) for data collection, survey and stakeholder's discussions.
- Primary data collection for salinity measurement for dry season.
- 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.



(b) Pre-monsoon season (b) Post-monsoon season

Figure 6.3: Groundwater levels in Purba Medinipur district during pre and post monsoon season of the year 2018.

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)

Study Area:

Ravi River catchment of Himachal Pradesh having an area of about 5400 sq. km is the area selected for this study (***Figure 7.1***). 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).

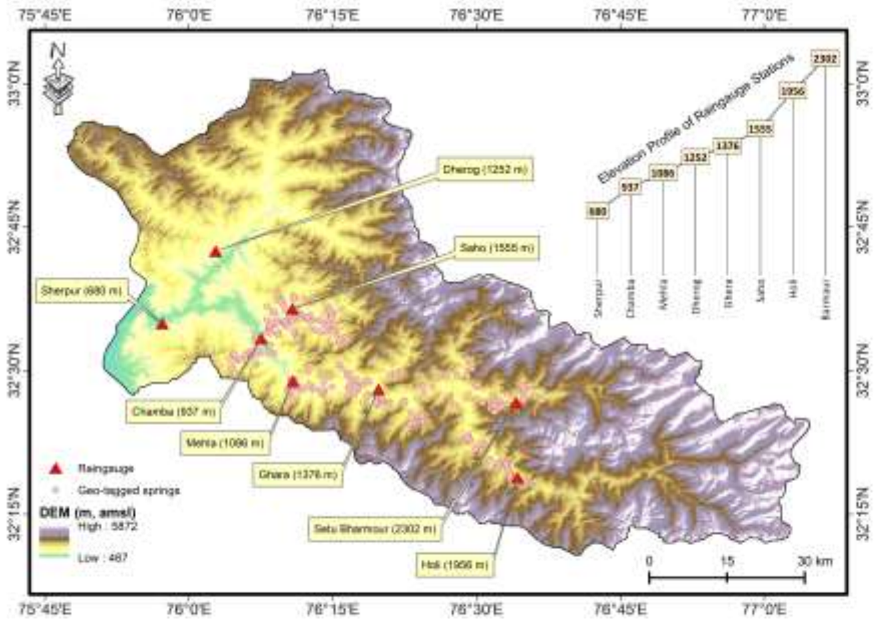


Figure 7.1: Study area and raingauges located at different altitudes of the catchment.

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 of Himachal Pradesh is much higher than in urban areas as a majority of the population 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 to be 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 Ravi River catchment up to Chamba town (3100 sq. km) which was approved as per original proposal of the PDS has completed. Total 424 springs have been surveyed.
- Survey work for the additional area (2300 sq. km) which is increased on the recommendation of sub-committee on PDS during its sixth R&D session held on 08-09 August 2019 at NIH Roorkee has been initiated and about 300 springs have been surveyed.
- 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 623 surveyed springs on 35+ parameters have been created with all supporting GIS layers and geotagged spring photographs (***Figure 7.2***). All springs data are also available in the form of infographics for easy to understand.

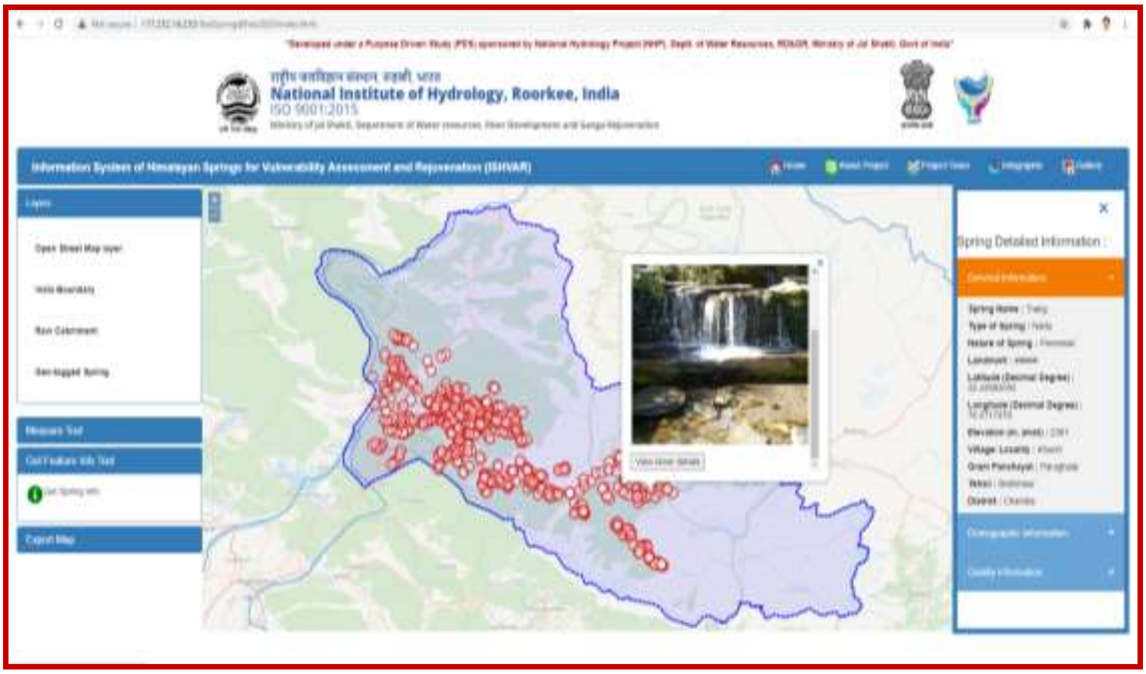
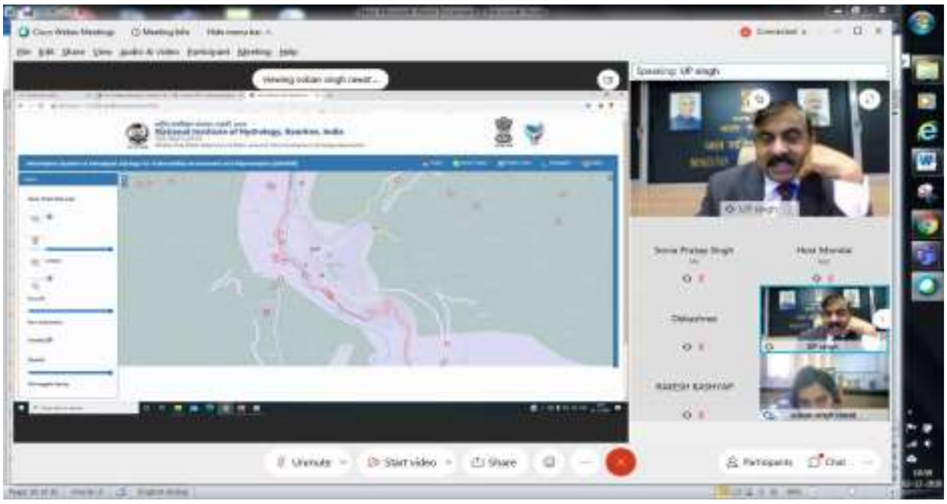


Figure 7.2: Developed GIS based Web-Portal (ISHVAR) under NHP-PDS.

- Daily Rainfall data at 04 different locations of the catchment are being monitored and rainfall samples for isotopic analysis are being collected since July, 2018 for old study area (3100 sq. km). 02 more sites have been identified at Sherpur (680 m amsl) and Dherog (1252 m amsl) in additional area and Ordinary Rain gauges (ORGs) have been installed for daily rainfall measurement and isotopic sampling.
- A two-days' training programme on "Hydro-meteorological data collection for spring mapping in Ravi River Catchment under NHP-PDS" was organized for field staff of PDS and data collector of Himachal Pradesh State Irrigation & Public Health Engineering (supporting department in PDS) during March 23-24, 2018 at Hotel Iravati, Chamba, HPTDC, Govt. of Himachal Pradesh.
- A one-day stakeholder workshop on "Web-GIS based spring information system" was organized on 02.12.2020 in virtual mode for receiving the feedback on the newly developed spring web-portal i.e. ISHVAR (***Figure 7.3***). Workshop was attended by 91 participants from 51 institutions and 16 states within the country and 01 overseas.



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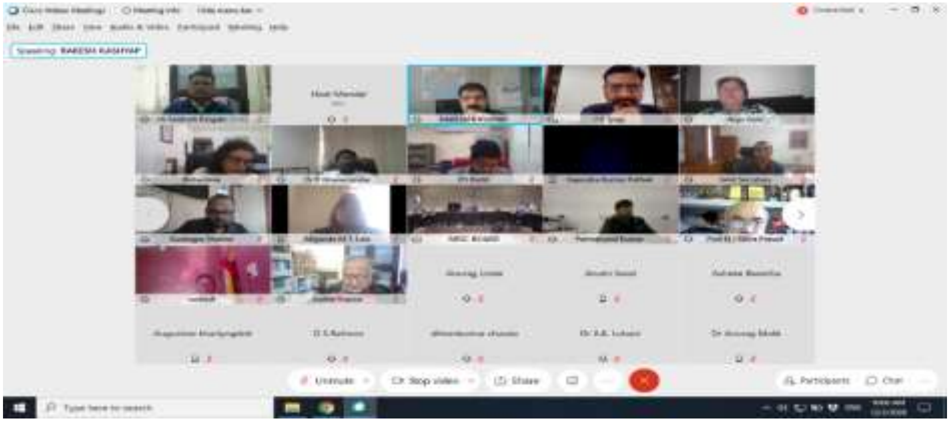


(b)

Figure 7.3: Stakeholder workshop on "Web-GIS based spring information system" organized on 02.12.2020 in virtual mode.

Future Work:

- To complete the survey for the additional area of Ravi catchment
- To Convert the surveyed data in digital-GIS form and upload on the ISHVAR web-GIS portal
- To select springs for detailed study and establishment of discharge sites
- To prepare local geological maps for selected springs

8.0 *PROJECT* 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 December, 2021)

Study Area:

The present study is focused on the Tawi River Catchment (***Figure 8.1***).

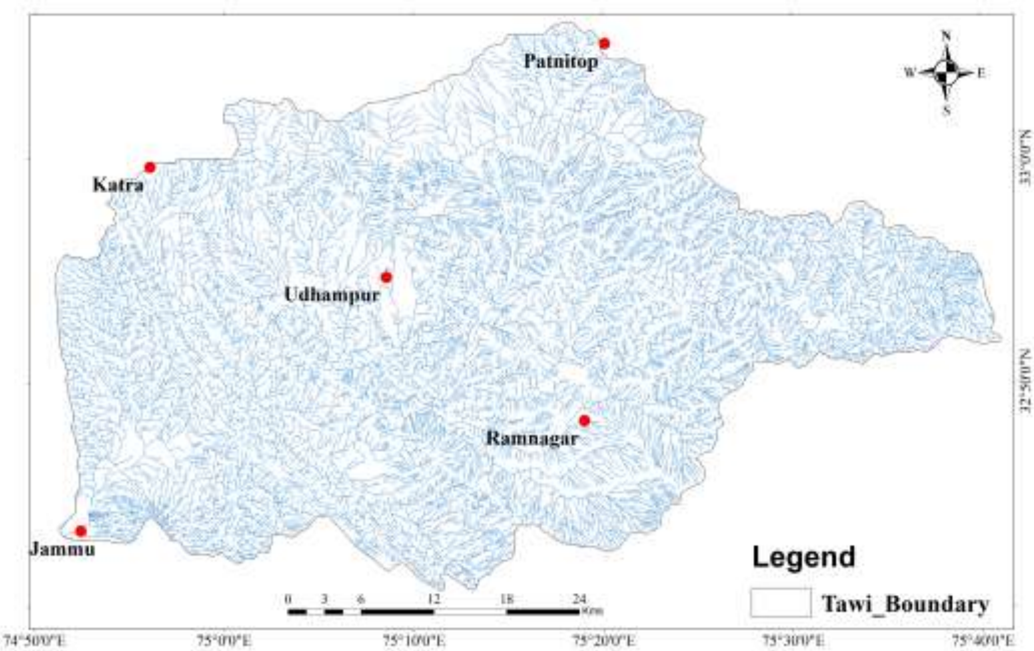


Figure 8.1: Tawi River catchment of Jammu and Kashmir and its drainage network

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.

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 affecting 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 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:

Digitization of major springs from SOI toposheets

Survey of India (SOI) toposheets have been utilized to locate the major springs present in the catchment to assess the status of springs during field visits and further planning. A total of eight toposheets of 1:50,000 scale viz., 43O4, 43O8, 43L13, 43P5, 43P9, 43L14, 43P2 and 43P6 have been first geo-referenced and mosaicked in ArcGIS, followed by delineation of drainage and springs present in the catchment. A total of 357 springs have been identified and digitized from all the four districts (***Figure 8.2***).

Development of spring data FORMAT:

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 (***Figure 8.3***). These parameters have been monitored during field visits and the spring photos have been geo-tagged. 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. The datasheet is divided into different classes which are further subdivided into various categories. The major classes include (i) spring description; (ii) general physical characteristics of spring; (iii) information about land use land cover; (iv) Major stressor, (v) spring water uses (vi) Demographic data etc.

A total of 300 springs have been geo-tagged so far during the field survey and their various characteristics have been collected and converted into various GIS layers.

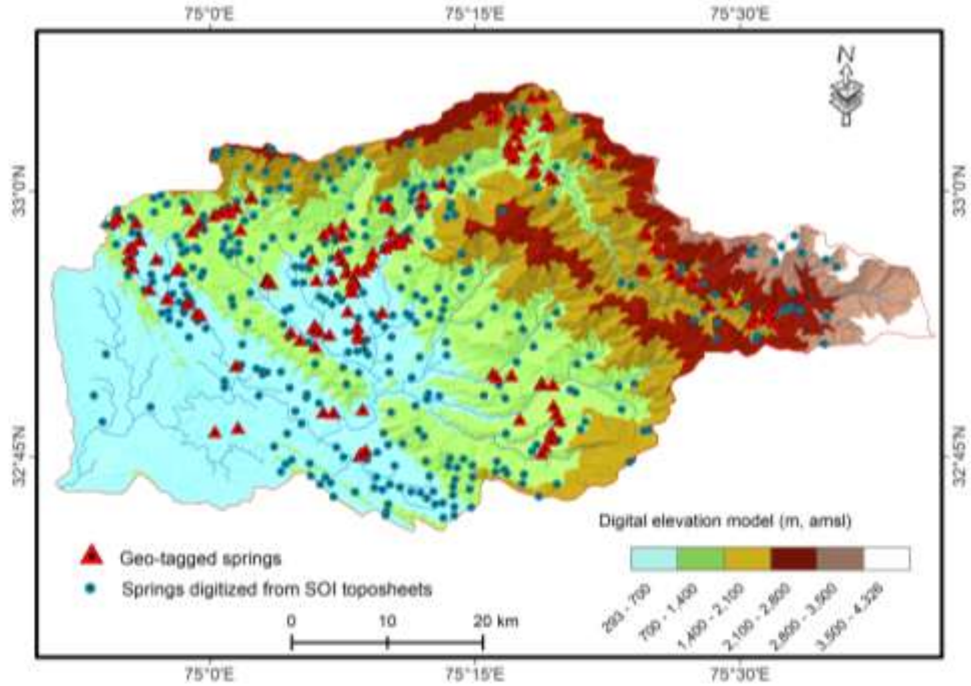


Figure 8.2: Spring location map of the Tawi Catchment.

Figure 8.3: Spring data collection app in KoBo tool box.

Establishment of Raingauge station:

Four raingauge stations i. e. Jammu (282 m, amsl), Udhampur (750 m, amsl), Chennani (1210 m, amsl) and Mantalai (1650 m, amsl) have been established at different altitudes of the catchment and daily rainfall data is being collected since July, 2020.

Future Work:

- To complete the survey for the additional area of Tawi catchment
- To Convert the surveyed data in digital-GIS form and develop web-GIS spring portal
- To established two nos. of Automatic Weather Station (AWS) at Udhampur and Mantalai
- To select springs for detailed study and establishment of discharge sites
- To prepare local geological maps and demarcation of recharge area of selected springs

New Studies Proposed for 2021-22

1.0 *PROJECT REFERENCE CODE:* New Study

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.

Research Outcome from the Project:

Spatial and temporal distribution of radon groundwater in Uttarakhand state.

Work Schedule:

First year:

Sl. No.	Work Element	1^{st} Qr	2^{nd} Qr	3^{rd} Qr	4^{th} Qr	5^{th} Qr	6^{th} Qr	7^{th} Qr
1	Review of literature	√	√					
2	Site selection	√						
3	Collection and compilation of data		√	√	√	√	√	√
4	Field work, sample collection and analysis of water samples	√	√	√	√	√	√	√
5	Data interpretation			√	√		√	√
6	**Project report & publications**				√			√

Head-wise Budget:

S. No.	Head	Amount (Rs. in lakhs)
1	Travelling Expenditure 50 days @ Rs 3000/- per day	1,50,000.00
2	Experimental Charges/ Fieldwork/ Consumables	2,00,000.00
3	Contingency (miscellaneous charges)	50,000.00
	Total	**4,00,000.00**

Justification:

Experimental Charges: The experimental charge include the cost towards measurement of chemical (major ion, heavy metals, etc) and isotopic analysis (uranium, ^{226}Ra ,^{3}H, ^{2}H, ^{18}O etc) of water samples. The required facility if not available in NIH then the analysis will be conducted in the Institute Instrumentation Centre (IIC), IIT, Roorkee at the approved rate. The experimental charges also include purchase of hand-held pH, EC, Temperature meters.

Field work: The project involves approximately 50 days of field work. A project staff will also accompany the scientific team during the field work.

Expected Outcome:

- Variation of radon concentration and stable isotopic composition of groundwater of Uttarakhand.

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. Sanjay Kumar	Scientist E
4	Dr. Archana Sarkar	Scientist E
5	Dr. L N Thakural	Scientist D
6	Sri J P Patra	Scientist D
7	Dr. Ashwini A. Ranade	Scientist C
8	Dr. Sunil Gurrapu	Scientist C
9	Sri N K Bhatnagar	Scientist B
10	Sri Om Prakash	SRA
11	Sri Jatin Malhotra	SRA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

APPROVED WORK PROGRAM FOR THE YEAR 2020-21

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD /16-21	Hydrological modeling 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 March 2021)
2.NIH/SWHD /19-20	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	15 months (Oct. 2019 to Dec. 2020)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
4.NIH/SWHD/ 17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
5.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	2 years (Nov. 2018 to October 2020) Extended up to March 31, 2021)
6.NIH/SWHD/ 15-19	Study of Hydrological Changes in selected Watersheds in view of Climate Change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay K. Jain Sharad K. Jain	4 years (April 2015 to March 2019) Extended upto Dec., 2020
7.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)
8.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	3 years (Nov 2018 to October 2021)
9.NIH/SWHD/ 18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. thakural Reena Rathore	2 years (Oct 2018 to sept. 2020)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
10.NIH/SWHD /20-21	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f	S.K. Singh	One year (April 2020 to March 2021)

11.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 (Aug 2020 to Jul 2022

PROPOSED WORK PROGRAM FOR THE YEAR 2021-22

ONGOING 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	5 years (April 2016 to March 2021) (Likely to be extended to
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	24 months (Oct. 2019 to April 2022)

COMPLETED STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
3.NIH/SWHD /20-21	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f	Sushil K. Singh	One year (01 April, 2020 to 31 March, 2021)
4.NIH/SWHD /17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
5.NIH/SWHD /15-19	Study of Hydrological Changes in selected Watersheds in view of Climate Change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay K. Jain Sharad K. Jain	4 years (April 2015 to March 2019) extended up to Dec., 2020
6.NIH/SWHD /18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. thakural Reena Rathore	2 years (Oct 2018 to sept. 2020)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
7.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	2 years (Nov. 2018 to October 2020) Extended 6 months (upto March 31, 2021) Further extension

			sought for three months (upto 30 June, 2021)
8.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) seeking extension for 6 months
9.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	3 years (Nov 2018 to October 2021)
10.NIH/SWH D/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

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
11.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	One year (April 2021 to March 2022)
12.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)

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: March 2021 (Likely to extend upto Sept 2021)

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.

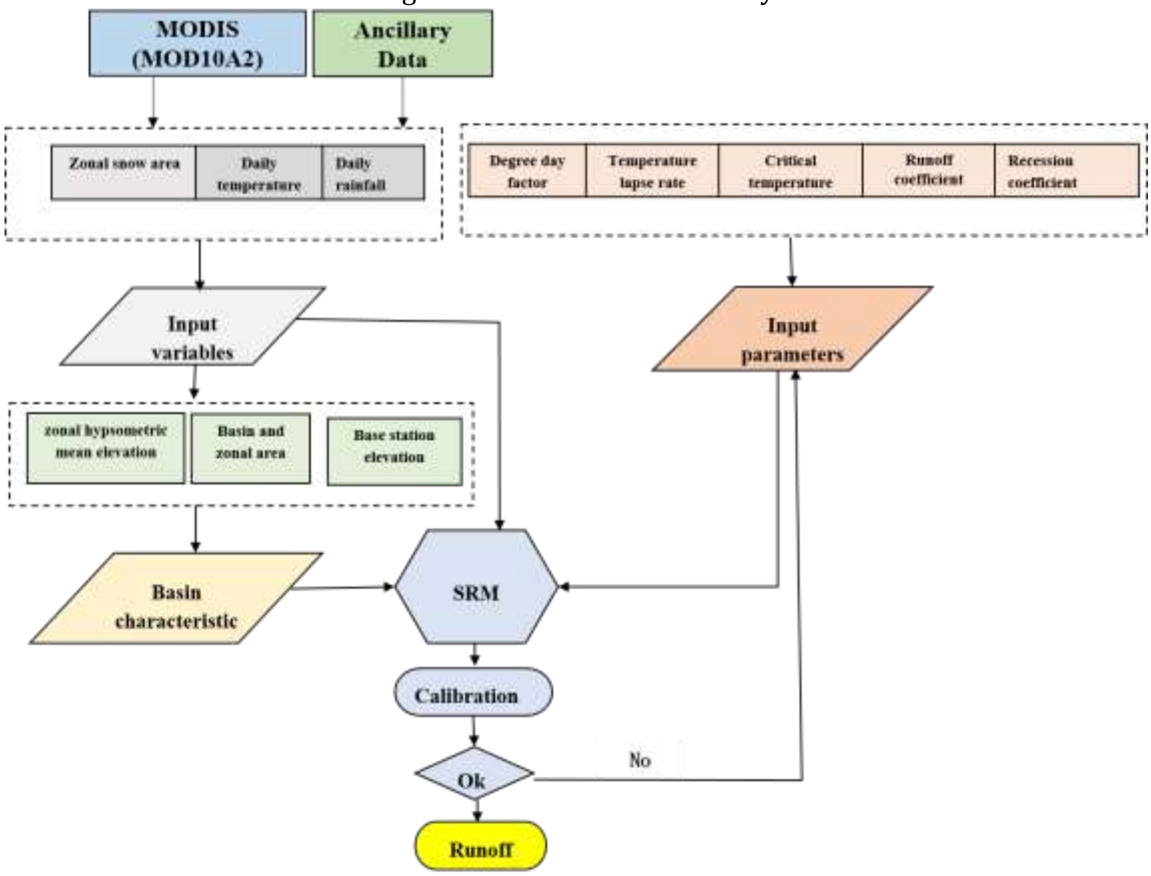
Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Collection of hydrological and hydro-meteorological data from various agencies and entry in SWDES software	←	—	—	—	—	—	→			
Generation/import of spatial data layers for the study area and reference database from different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



Studying impact of climate variability

Using SRM Model

The impact of climate variability on the Upper Ganga basin runoff was studied using the SRM 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. 6.

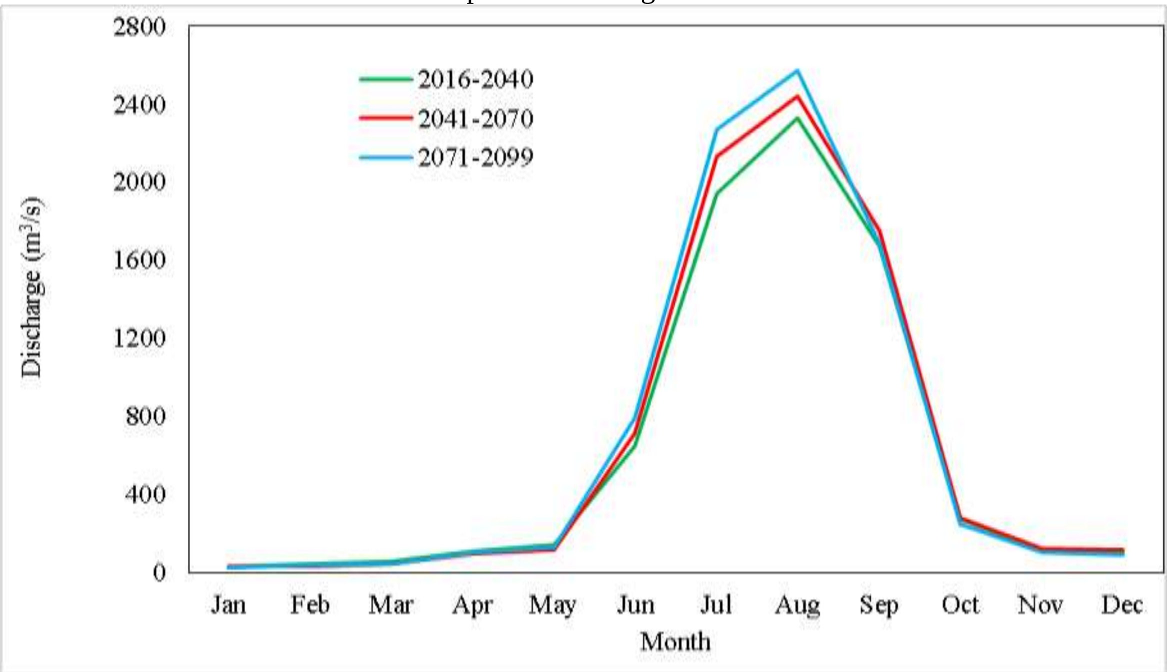


Figure 6: INCCC (Model - CCCma_CanESM2) rcp 4.5 Monthly Discharge at Rishikesh by SRM Model Data

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-Aprilv 2022.

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. WRD Rajasthan has assured to provide reservoir data for the calibration of the models at reservoir sites.

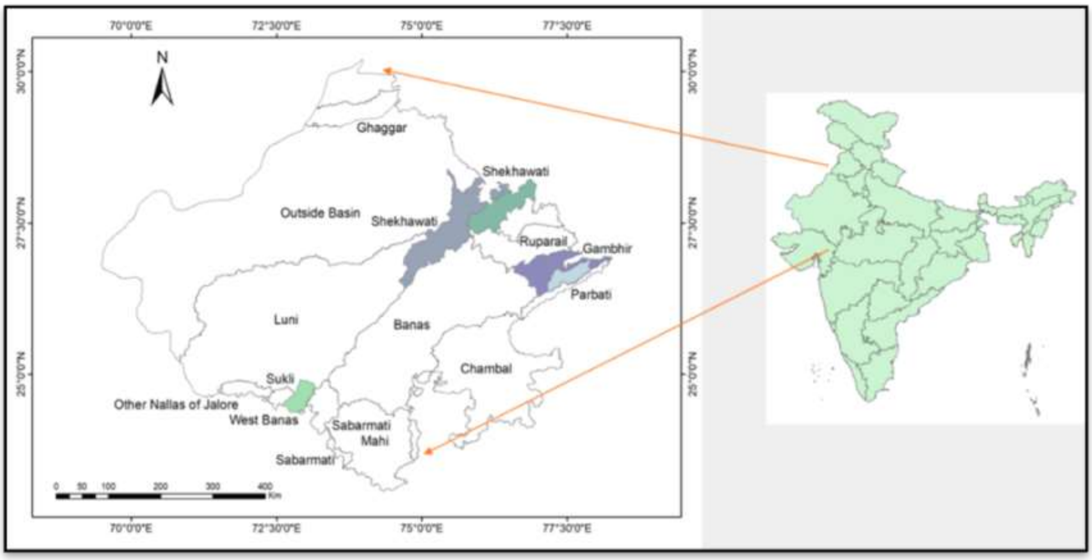


Figure 2 Selected Basin for the study

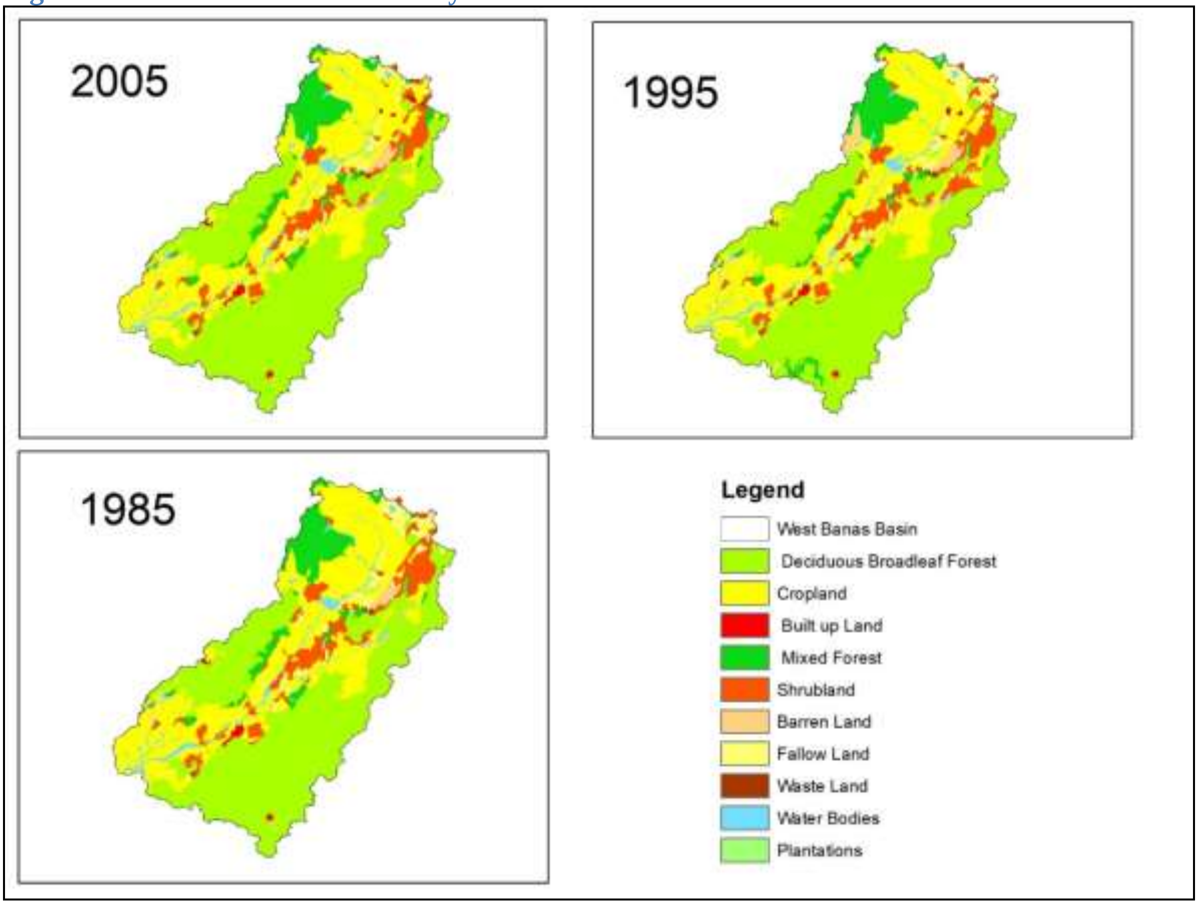


Fig 2.: LULC of West Banas

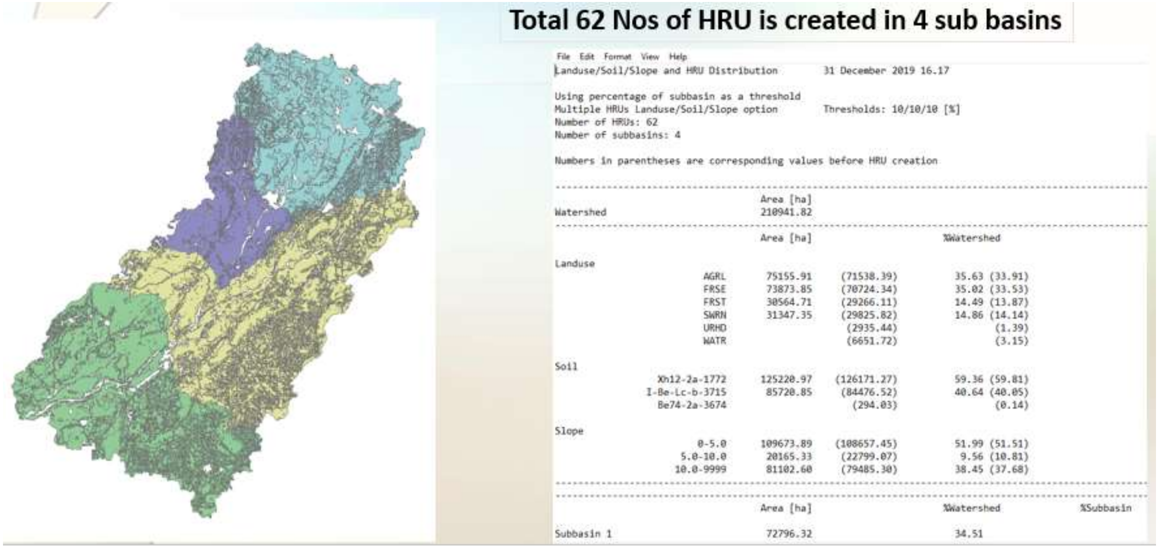


Figure 3. Hydrologic Response Unit

PROJECT REFERENCE CODE: NIH/SWHD/20-21

1. **Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f**

(Research/Application Study)

Study group	Sushil K. Singh, Scientist F
Date of start of study	01 April 2020
Duration and scheduled	One year
Date of completion of study	31 March 2021
Type of study	Internal (without/no funding)

Both report/parts-of-report are completed and will be submitted by 31March2021.

PROJECT REFERENCE CODE: NIH/SWHD/17-21

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

2. **Study Group:** - Sanjay Kumar, Sc-E, PI
Rakeh Kumar Sc-G, Co-PI
J. P Patra Sc 'C'
Pankaj Mani, Sc 'E'

3. **Location Map:**

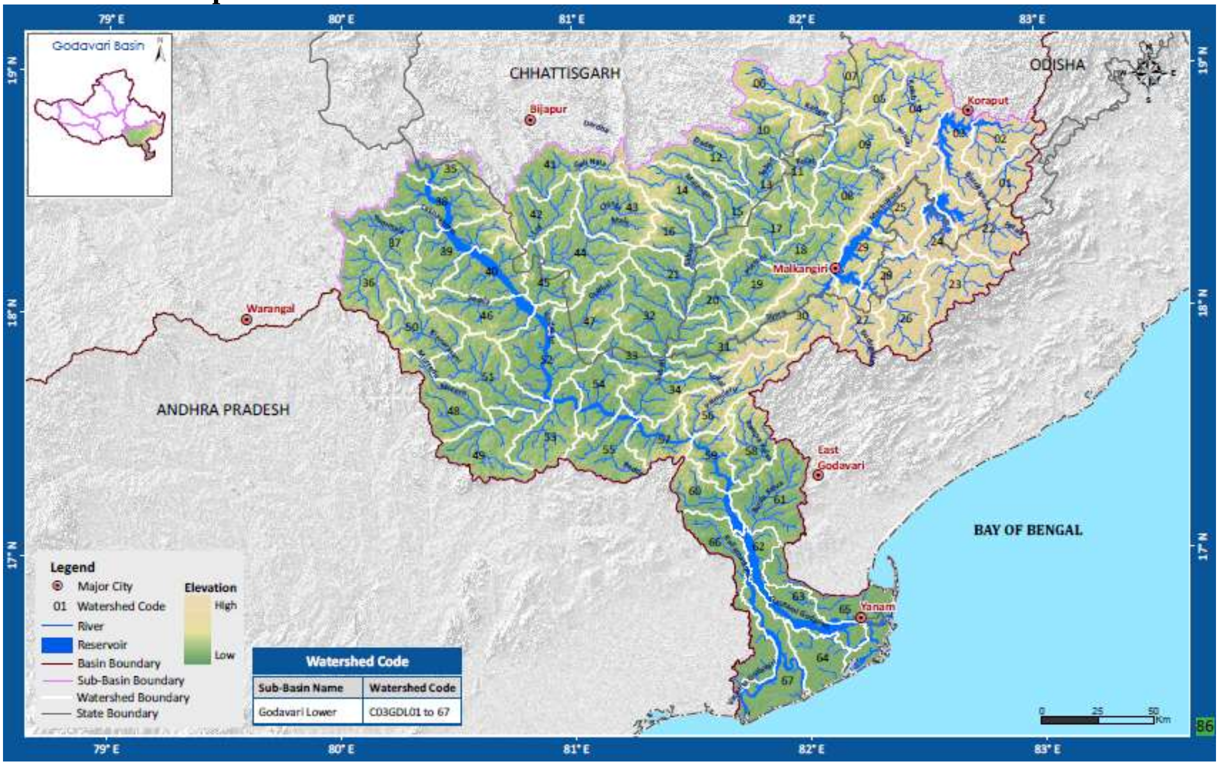


Fig 1: Location Map of the study Area

4. **Objectives of the study:**

The objectives of the study are:
- (i) To develop regional relationships for (surface) water availability analysis.
- (ii) Development of at site and regional flood frequency analysis using L Moments.
- (iii) Development of at site and regional rainfall frequency analysis using L moments.
- (iv) Development of regional relationships for Nash and Clark IUH models parameters.
- (v) Impact of climate change on flood estimates.

5. **Statement of the problem:**

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

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

6. Methodology:

For ungauged catchments regional flow duration curves are developed based on the available runoff/rainfall records for the gauged catchments of the regions which are considered to be hydro-meteorologically homogeneous. As many times field engineers are interested in the evaluation of dependable flow corresponding to limited number of probability of exceedance (say 50% or 90% dependable flow), in such cases the dependable flows itself may be regionalized rather than regionalising the flow duration curve. The form of the typical regional relationships for “d%” dependable flows can be written as

$$Q_{d\%}=a_1A^{a2}R^{a3}$$

Where, $Q_{d\%}$ is d% dependable flow (for example $Q_{50\%;}$ 50% dependable flow). A and R represent the catchment area and catchment rainfall respectively. a_1, a_2, a_3 are the constants to be evaluated by using linear regression approach.

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

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

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

6 Results and Progress

The annual flow duration curves are estimated for the 9 gauging sites and (dependable) flow corresponding to various probability of exceedance are estimated for each site. For example, the flows corresponding to various probability of exceedance for the gauging site Ambabal and Perur are show in the table below

Table 1: flows corresponding to various Probabilities of exceedance

Exceedance probability (%)	10	25	50	75	90
Ambabal (MCM)	1490	1120	760	577	481
Perur (MCM)	145075	102393	72760	49703	25124

As the range of dependable flows varies significantly for different gauging sites, all flows are transformed to normalized flows and are shown in the figure below:

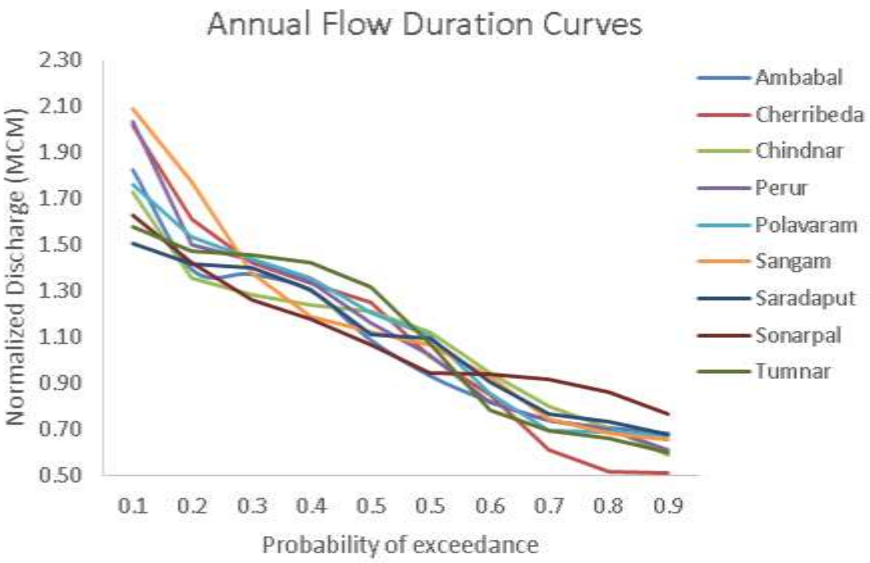


Fig.1: Annual flow duration curves (normalized) for different gauging sites

The regional relationship for each dependable flow are developed relating the dependable flows of the catchments (Nine catchments) with the pertinent catchment characteristics using linear regression approach.

For second objective L moments for annual maximum flood series at 28 different gauging sites have been estimated for at-site frequency analysis. Parameters of different distributions have been estimated for these sites. L moments of some of the gauging sites are shows in the table below. The parameter of GEV distribution are also shows in the Table 3 for the same sites.

Table2: L moments of annual maximum flood series at some of the gauging sites

Site Name	**L Moments**			
	L_1	**L_2**	**L_skewness**	**L_Kurtosis**
Ambabal (Annual max.)	803.76	265.09	0.41	0.25
Cherribeda (Annual max.)	847.71	369.69	0.27	0.13
Chindnar (Annual Max.)	5,169.20	1,540.46	0.24	0.18
Perur (Annual max.)	30,675.35	7,939.15	0.1	0.07
Polavaram (Annual max.)	31,506.85	6,890.04	0.03	0.09

Table3: Parameter of GEV distribution for some of the gauging sites

Site Name	**Parameter of GEV Distribution**		
	Location	**Scale**	**Shape**
Ambabal (Annual max.)	536.06	246.71	-0.344

Cherribeda (Annual max.)	507.58	457.7	-0.145
Chindnar (Annual Max.)	3780.31	1982.05	-0.112
Perur (Annual max.)	24683.54	12577.64	-0.112
Polavaram (Annual max.)	26916.11	11795.6	0.228

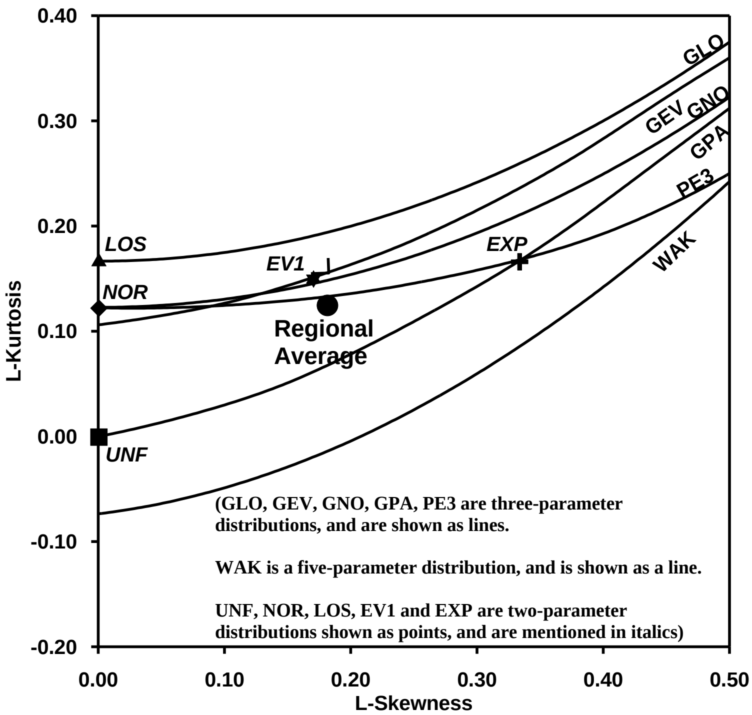


Fig. 2: L moments ratio diagram for Lower Godavari Subzone 3(f)

L moment statistics, i.e. discordancy measures, heterogeneity measures are estimated to evaluate homogeneous regions. Parameters of different distributions are estimated based on L-moments. Based on sample L moments statistics, L moments ratio diagrams are estimated as shown in Fig. 2. Based on goodness of fit statistics (Z statistics) the best fitted distribution is selected. Regional relationship is developed based on index flood method. The results are tabulated for various return periods (2, 10, 25, 50, 100, 200, 500, 1000 years) for gauged and ungauged basins. Similarly, L-moments approach is used for fitting the frequency distributions for one-day maximum rainfall estimates using IMD gridded data in the region.

The hourly rainfall and runoff data of a catchment (in lower Godavari basin) is used for carrying out analysis for derivation of Nash and Clark IUH model and D hour unit hydrograph. Seven hourly rainfall-runoff events has been used for derivation of Nash and Clark IUH parameters. The average Nash and Clark IUH parameters estimated from these events are given in Table 4. The regionalization of these parameters could not be taken up because of non-availability of hourly rainfall runoff data for other catchments in the lower Godavari basin.

Table4: Average parameters of Clark and Nash IUH model for all events

Events	**Parameter of Clark IUH Model**		**Parameter of Nash IUH Model**	
Average of all seven events	**T_c**	**R**	**n**	**K**
	3.59	2.49	4.06	1.39

Trends in annual maximum series due to climate change are examined for only to those sites having long term data. Fig 3 below shows observed annual maximum flood values for some of the sites in the lower Godavari basin showing either no trends or positive trends. The statistical significance of these trends has been evaluated using parametric approach.

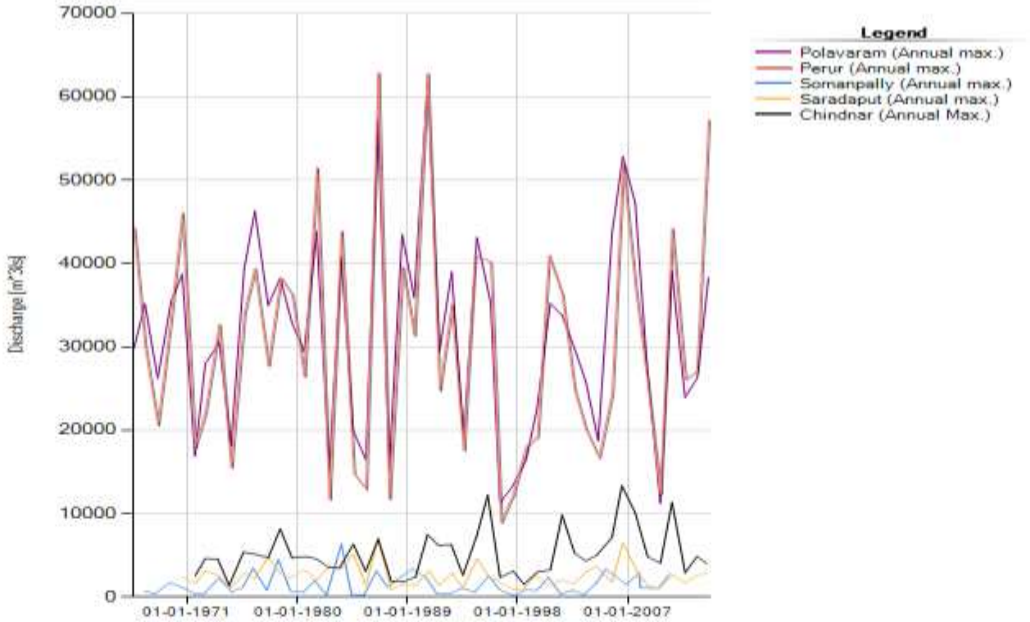


Fig 3: Trends on observed Annual Maximum Flood Series

PROJECT REFERENCE CODE: NIH/SWHD/15-19

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

2. **Project team:**

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

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

4. **Present state-of-art**

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

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

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

6. **Research outcome from the project**

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

7. Analysis and Results

Four different watersheds located in different climatic regions namely Dhadhar river basin (Gujarat), Ramganga up to Kalagarh (Uttarakhand), Bina River basin (M.P) and Chaliyar river basin (Kerala) as shown in Figure 1. have been selected for the present study.

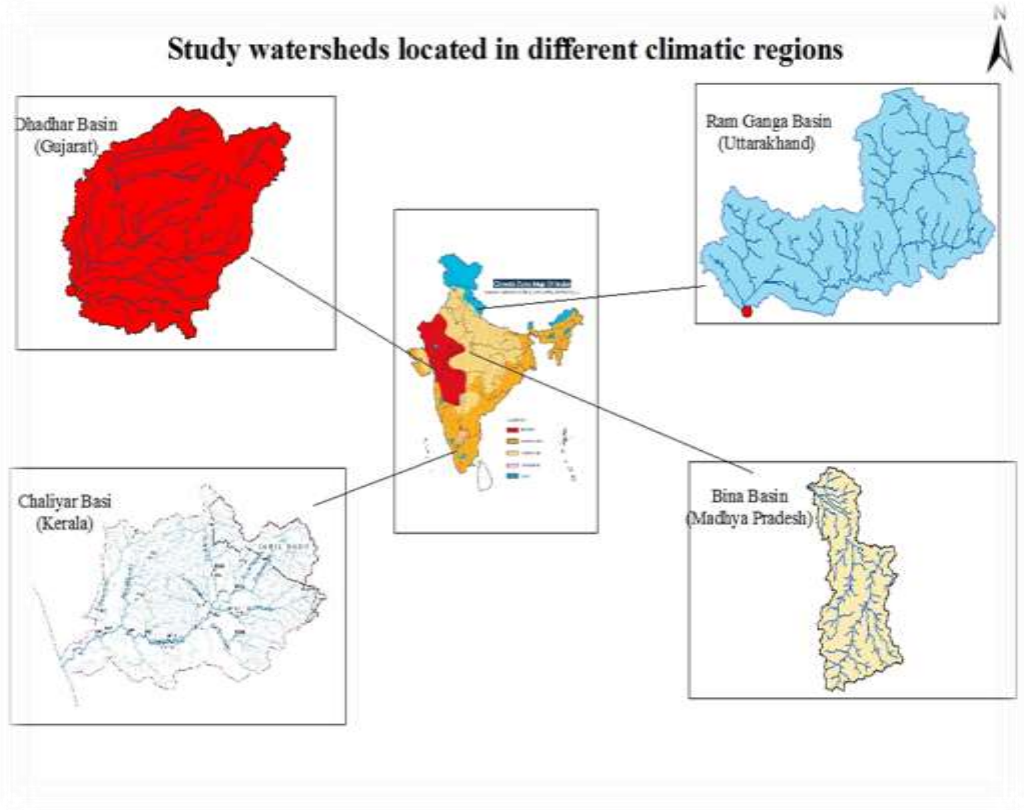


Figure 1: Study watersheds located in different climate regions of India

Initially, hydro-meteorological series of rainfall, temperature and discharge pertaining to the four river basins namely Ramganga, Bina, Chaliyar and Dhadhar have been collected, processed and analysed to meet out different objectives of the study. Also, the spatial datasets namely Digital Elevation Model (Dem), landuse/landcover and soil map which are essential inputs for the hydrological model have been prepared to calibrate and validate the hydrological model for the study areas. The monthly data of metrological stations located in the study area has been used to form seasonal and annual series and thereafter investigated and quantified for the trends and spatio-temporal variations using parametric and non-parametric statistical tools. The spatial distribution of temporal trends in seasonal and annual rainfall for the Ramganga basin are shown in Fig. 2.

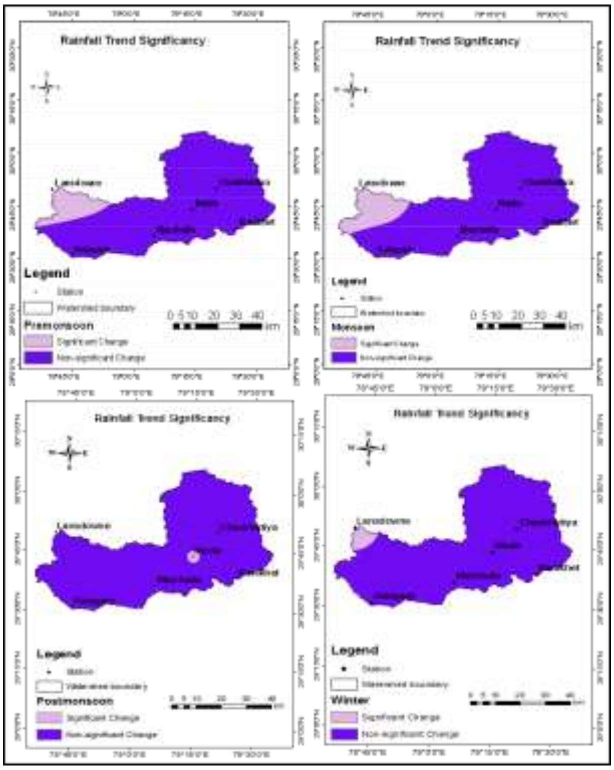


Fig. 2: Spatial distribution of the temporal trends of seasonal precipitation

In Ramganga basin, during monsoon season, the rainfall is rising at three stations namely, Kalagarh, Marchulla and Naula but it is falling at Chaukutiya, Ranikhet and Lansdowne station. The annual rainfall is falling at all the stations except Naula, at which it is increasing although it is not so significant at 95% confidence level. Annual and monsoon rainfall is falling significantly (at 95% confidence interval) at Lansdowne station. However, trends in the rainfall were found to be having mixed increasing and decreasing treands in the study areas.

In the present study monthly precipitation records of rain gauge stations in the study area were used to estimate SPI values for 3-, 6-, 12-, and 24-month time scale. Time behavior of the monthly SPI on 6 and 12-month time scale for Kurwai station in Bina basin is depicted in Figure 3. In the year 2004, on the scale of 6 months severe drought and in the year 1986 and 2002, on the scale of 6 months and 1986/1987 and 2002, on the scale of 12 months extreme drought occurred in Gyaraspur rainfall station as seen in Table 4.6. In the year of 1989, on the scale of 6 months severe drought and 1991 and 2002, on the scale of 6 and 12 months extreme drought were experienced in Kurwai meteorological station as shown in Table 1.

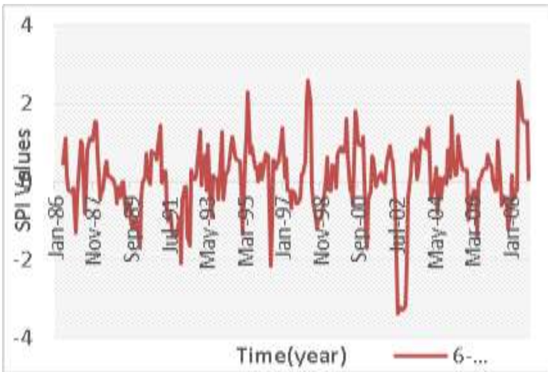


Figure 3: Time behavior of the monthly SPI on 6 and 12-month time scale for Kurwai (1986-2008)

Table 1: Severe and Extreme drought periods and their SPI values in Begumganj station

Severe and Extreme Drought periods for 6-month time scale		**Severe and Extreme Drought periods for 12-month time scale**	
Time	6 month SPI	Time	12 month SPI
Feb-2001	-1.93	Jul-2002	-1.81
Jul-2002	**-2.66**	Jun-2005	-1.73
Dec-2004	-1.98	Sep-2007	-1.55
Jun-2006	-1.6	Oct-2007	-1.53
Aug-2007	-1.8	Nov-2007	-1.62
Sep-2007	-1.52	Dec-2007	-1.62
Oct-2007	-1.54	Jan-2008	-1.84
Nov-2007	-1.57	Feb-2008	-1.92
Dec-2007	-1.62	Mar-2008	-1.92
Jan-2008	-1.96	Apr-2008	-1.92
Jun-2008	-1.71	May-2008	-1.91
Aug-2008	**-2.03**	Jun-2008	**-2.1**
Sep-2008	-1.95	Jul-2008	-1.73
Oct-2008	-1.94	Aug-2008	-1.78
Nov-2008	-1.97	Sep-2008	-1.99
Dec-2008	-1.6	Oct-2008	-1.94
		Nov-2008	**-2**
		Dec-2008	**-2**

The hydrological models (NAM and SWAT) have been finally setup after calibration and validation for the for assessment of surface and ground water availability in river basins of four different climatic zones. Moreover, the validated model is used to develop the surface and ground water availability under different RCP scenarios using SWAT model. Considering the climatic scenarios of 4.5 the SWAT model is used to estimate the daily runoff scenarios. The monthly summary of these daily runoff scenarios for RCP 4.5 for the Chaliyar and Dhadhar basin is shown in Figure 4 and 5 respectively. Similar analysis has also been carried out for other RCPs and basins.

Month	Monthly Average Runoff(2008-2040)	Monthly Average Runoff(2041-2070)	Monthly Average Runoff(2071-2100)
Jan	18.297	14.366	12.723
Feb	4.371	2.5182	2.228
Mar	2.674	2.946	5.593
Apr	20.173	33.972	22.525
May	51.797	93.974	133.002
Jun	183.433	215.906	308.626
Jul	215.101	233.612	245.182
Aug	185.052	168.203	167.515
Sep	139.058	163.209	172.195
Oct	141.042	138.071	126.184
Nov	84.782	71.534	68.346
Dec	42.248	36.489	34.006
Yearly Average Runoff	90.669	97.9	108.177

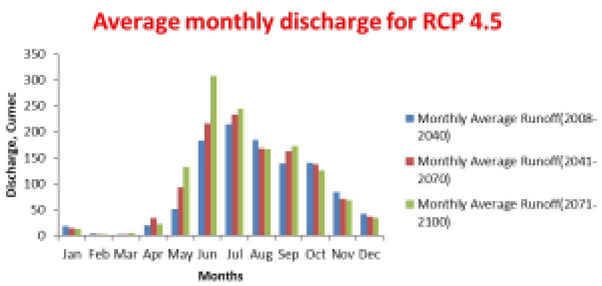


Figure 4:Average monthly runoff for the Chaliyar basin

Month	monthly average runoff (2008-2040)	monthly average runoff (2041-2070)	monthly average runoff (2071-2100)
Jan	0.76	0.91	0.52
Feb	0.16	0.25	0.16
Mar	0.03	0.06	0.04
Apr	0	0.01	0
May	0.03	2.53	8.12
Jun	15.22	49.21	68.43
Jul	67.53	140.8	151.37
Aug	115.86	158.68	160.13
Sep	98.91	131.25	103.32
Oct	56.7	65.38	51.82
Nov	28.74	32.13	22.01
Dec	8.27	9	5.27

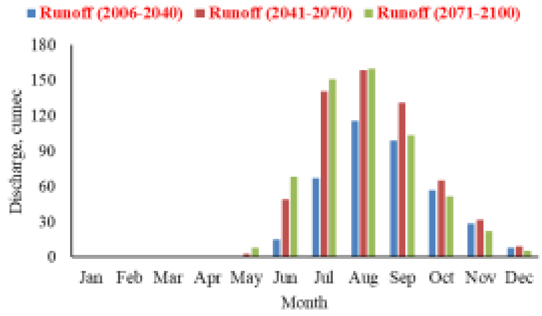


Figure 5: Average monthly runoff for the Dhadhar basin

PROJECT REFERENCE CODE: NIH/SWHD/18-20

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

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

Role of Team Members:

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

Type of Study : Applied research
Date of start : October 2018
Scheduled date of completion: September 2020
Duration of the Study: 2 Years

Objectives of the Study: i) Groundwater quality monitoring in pre-monsoon (April-May) and post-monsoon (October-November) season at identified school locations. ii) To map degraded ground water quality zones and possible sources of pollution and identify specific parameters not conforming to drinking water quality standards. iii) To examine the suitability of ground water quality for drinking purpose using Water Quality Index. 145 iv) To suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking. v) To organize Mass Awareness Programme for school and villagers regarding Drinking Water Quality and Water Conservation.

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

Timeline:

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

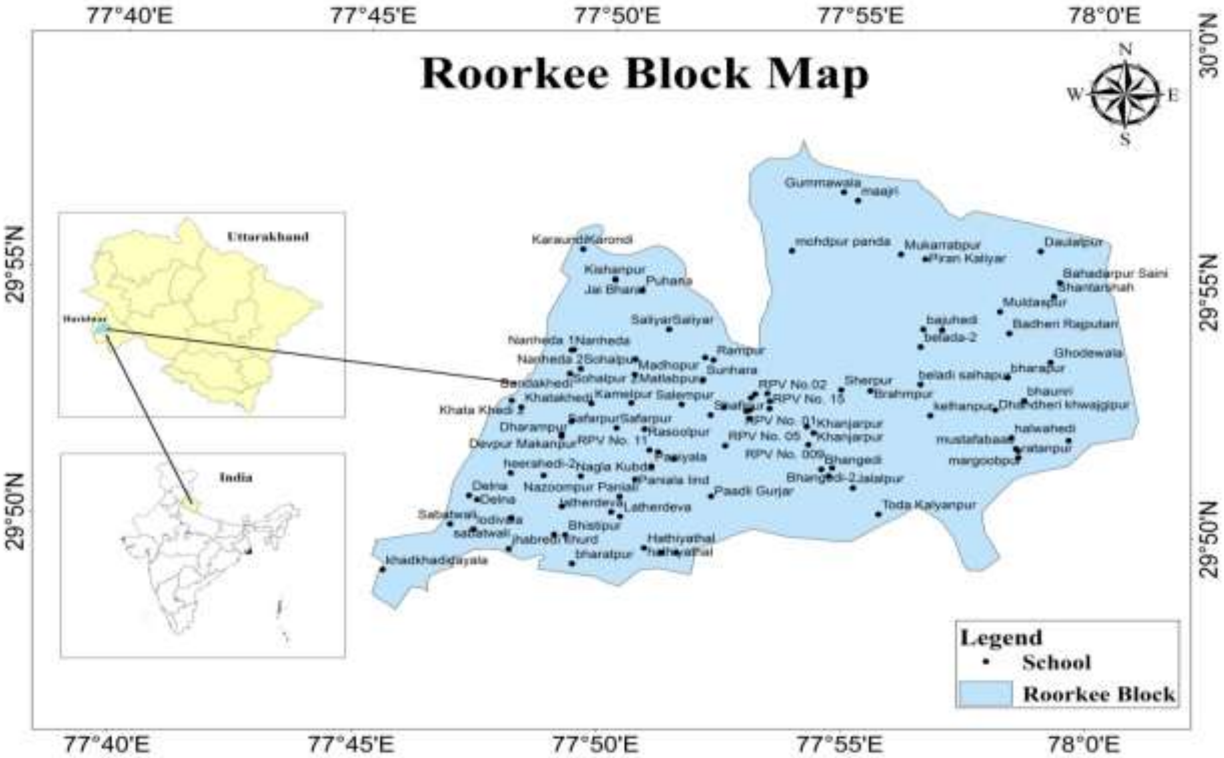
List of deliverables: Technical Report and Research Papers

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

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

Specific linkages with Institutions/beneficiaries: Villagers, Education Authority of District Haridwar and District Administration /Difficulties: None.

Study area Map:



Progress after last working Group:
Testing of metal ions, for post monsoon, in water samples has been completed, Report writing is completed and the report is submitted final results are as undermentioned:
School wise treatment for different parameters is under mentioned here:

Bajuhedi Primary School slightly above the acceptable limit of 100 µg/l requires treatment for Magnesium.
Bandakhedi Primary School needs treatment for Lead and Manganese and Iron.
Bharapur Primary School needs treatment for Potassium, manganese and Iron.
Daulatpur Primary School requires treatment for Potassium and Manganese.
Delna Primary School requires treatment for Potassium, Manganese, Iron and Nickel.
Gummawala Primary School is above the acceptable limit for Nitrate, and Manganese.
Karaundi Primary School needs treatment for Lead, Manganese and Iron.
Khanjarpur Primary School needs treatment for Lead, Manganese, Copper and Iron.
Lodivala Primary Schoolrequires treatment for forMagnisium.
Margoobpur Primary School is required treatment for Alkalinity,Hardness, Potassium, iron, Manganese.
Mohammadpur Panda Primary School needs treatment for Lead.
Paniyala Primary School needs treatment for Fluoride, Iron and Manganese.
Rajkeey Primary Vidyalay no. 4 Roorkee requires treatment for Potassium and Iron.
RajkeeyaPrathmikVidyalaya no.5 Roorkee needs treatment for Lead, Manganese and Iron.
Rampur Primary School needs treatment for Fluoride, Iron and manganese.
Rasoolpur Primary School needs treatment for Lead.
Safarpur Primary School requires treatment for Chloride and Safarpur Junior for Mangnese.
Salempur Primary School needs treatment for Fluoride and Iron.
SarkadiTaharpur Primary School needs treatment for Fluoride and Iron.
Shafipur Primary School needs treatment for Fluoride and Iron.
Sunhara Primary School needs treatment for Fluoride, Iron and Mangenese.
Akbarpurzhozha junior high school requires treatment for Cadmium, Nickel, Manganese and Iron.
Bhangedi Junior High School needs treatment for Lead.

Delna junior high school requires treatment for Nickel.
Jai Bharat Junior High School requires treatment for Potassium, Iron, Manganese, Nickel and Cadmium.
Khatakhedi junior high school requires treatment for Nickel and Iron.
MehvadKhurd Junior High School needs treatment for Lead.
Nanheda junior high school requires treatment for Nickel.
Rahmatpur junior high school requires treatment for Nickel, Iron and Manganese.
Saliyar junior high school requires treatment for Nickel.

The water of these Primary Schools require to be treated for **Iron and Magnesium**: BeladiSalhapur, Sabatwali, Hathiyathal, Delna,Bhounri, Bharapur, Margoobpur,Shantarshah, DhanderiKhwagjipur,Khanjarpur,Ghodewala, Bhangedi–2, Sunhara, Rampur, Salempur, Matlabpur, IbrahimpurDeh, Brahmpur, , Rajkeeya Prathmik Vidyalay Roorkee no. 12, Daulatpur, paniyala-1, paniyala-2, NaglaKubda, DevpurMakanpur, Khatakhedi -2, Rajkeeya PrathmikVidyalayRoorkee no. 19**,** Khatakhedi – 1, Khatakhedi- 2 and Junior High schools Bhangedi, Khanjarpur and Muldaspur.

The water requires to be treated for Iron are Primary schools namely Belada-2, Kelhanpur, Bajuhedi, Tanshipur 2, Bhistipur, Heerahedi 2, Lodivala, Mustafabad, Govindpur, Halwahedi, Shantarshah, BadheriRajputan, Jalalpur, Sherpur, Daulatpur, Rahimpur, NaglaKubda, Kamelpur, PadliGenda, DevpurMakanpur, PaadliGurjar, NazoopurPaniyali, NaubatpurMulewala, RajkeeyaPrathmikVidyalayRoorkeeno. 9, RajkeeyaPrathmikVidyalayRoorkee no. 19, RajkeeyaPrathmikVidyalayRoorkee no. 15, RajkeeyaPrathmikVidyalayRoorkee no. 02, Halwahedi, Govindpur, Jalalpur, JhabrediKhurd, Paadli Genda, RPV no. 4.

Junior High schools requires to be treated for **iron** are Iqbalpur Kamelpur, Paniyala, Madhopur, Jai Bharat. Iqbalpur Kamelpur.

The schools require to be treated for **Manganese** are: Primary School HarzoliZhozha, KhadkhadiDayala, Latherdeva, Ratanpur, BhadarpurSaini, Paniyala – 2, AkbarpurFazilpur, Salempur, Paniyala – 1, NaglaKubda, Devpurmakanpur, NaubatpurMulewala, RajkeeyaPrathmikVidyalayRoorkee no. 19, RajkeeyaPrathmikVidyalayRoorkee no. 1, Puhana, Sohalpur – 2, RajkeeyaPrathmikVidyalayRoorkee no. 18 and Saliyar. Junior High School Karaundi, BalakPadao, Mukarrabpur and Latherdeva Sheikh.

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

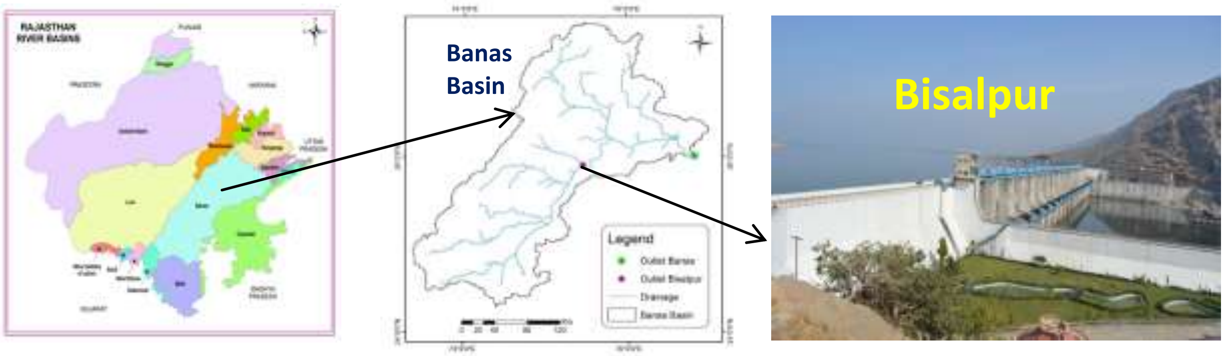
Study Team
Dr. Archana Sarkar, Sc D, SWHD (PI)
Dr. Surjeet Singh, Sc E, GWHD (Co-PI)
Ms. Suman Gurjar, Sc C, GWHD
Dr. Sunil Gurrapu, Sc C, SWHD

Type of Study
Internal

Date of Start
1 Nov. 2018

Scheduled date of completion
October 2020
Extended 6 months (upto March 31, 2021)
Further extension sought for three months (upto 30 June, 2021)

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. Assessment of irrigation demands in the command area of Bisalpur dam (dropped).
5. 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
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	Inflow forecasting for the Bisalpur Dam										
10	Climate change scenario analysis for future water availability										
11	Preparation & Submission of **Final report**										

Progress

Objectives	Achievements
Sept 2020- March 2021	
Trend analysis of bias corrected GCM data of ECVs & CII for future period	In progress

Input data preparation for Rainfall runoff model	In progress
SWAT model runs with default data	In progress

Analysis and Results

Data Used

Essential climate variables of 16 GCMs (Table below) at 0.5 degrees 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, rcp8.5	2.0225	2.5
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, data prepration is under progress using observed data of rainfall at 30 stations and runoff at 1 station.

Results

Relevant climate impact indicators for the basin have been calculated and variability in future periods has been studied.

Initial runs of SWAT model using default data have been carried out.

The results in the form of maps and graphs shall be presented during the working group meeting.

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.

Future Plan

As per the approved/proposed action plan.

PROJECT REFERENCE CODE: NIH/SWHD/18-21

Thrust area under XIIth Plan: Impact of climate change on water resources and hydrology of extremes
Title of the Project: **'Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario'**
Project team: Dr. Ashwini Ranade, Scientist 'C'(PI)
Dr. Archana Sarkar. Scientist 'D'(Co-PI)
Type of Study: Internal
Status: ongoing
Duration: 3 years
Date of Start: 1 April 2018
Scheduled date of completion: 31st March 2021(seeking extension for 6 months)

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 during 1951-2015.	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.	Ongoing
4.	Time series modelling of the longest instrumental monthly rainfall series (1813-2015) of major and independent minor river basins for their extrapolation for 2 to 10 years	Ongoing

1. Statement of the problem

Recent changes in global tropospheric thermal structure show that, global warming is not uniform throughout the globe. Such type of global temperature changes in last few decades are observed to make changes in rainfall pattern also. Few intense rain spells, consequently heavy flooding and disasters occur across the country even in dry monsoons. At such times sudden intensification of the monsoon circulation is seen associated with anomalous warming of the upper troposphere between Tibet and Turkey sector and development of strengthened ridge in upper tropospheric westerlies over there. Few case studies of extreme rain events carried out by us revels that, abrupt warming and cooling in the atmosphere drastically modulates the monsoon circulation and intensify the associated weather systems causing heavier rains over a region. Persistence in temperature and circulation anomalies across the globe are strongly linked to the 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. Locations of warming and cooling across the globe are the determinant of the plausible locations for the origin of various type of weather systems. We are hereby investigating the Interannual variations in longest possible instrumental monthly rainfall data over 11 major river basins, 9 independent minor river basins and 7 homogeneous zones across India and 3D changes in global atmospheric thermal structure and its role in occurrence of large-scale long-period extreme rain events.

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 seven homogeneous subzones (i) South Peninsular India (SPI); ii) West peninsular India (WPI); iii) East Peninsular India (EPI); iv) North west India; v) North Central India (NCI); vi) North East India (NEI); and North Mountainous India (NMI) earliest available from 1813 to 2000 is updated using IMD gridded 0.5 degree rainfall data upto 2019.
- Daily 0.5X0.5 degree gridded rainfall data form India Meteorological department is used to develop area averages daily rainfall series of seven zones of the county for the period 1951-2020.

3. Analysis and results:

3.1 Updation of homogenous monthly rainfall series:

Longest instrumental area averaged basin-scale monthly rainfall dataset for seven homogeneous zones of the country are updated from 2001 to 2019. The starting year of the dataset varies from one zone to another. The dataset was updated using 0.5 degree gridded rainfall with ratio method. For the seven zones the starting years are: *The SPI 1813; The WPI 1817; The EPI 1848; The NCI 1831; The 1826; The NMI 1844; The NEI 1829.* Longest possible monthly rainfall series earliest from 1813 to 2019 were developed in three different phases. In the first phase, for the period 1901 to 2000, simple arithmetic mean of all available gauges in the zone from fixed well spread instrumental network of 316 raingauge stations were used. In second phase the dataset was extended backward from 1900 to 1813 by applying theoretically vindicated numerical method on limited available observations (Sontakke and Singh, 1996). In the third phase, the dataset was updated by using 0.5-deg gridded daily rainfall with the ratio method suggested by Rainbird (1967) and approved by WMO. In the first two phases, station datasets were used for the construction, while in third phase, number of grids are extracted and area averaged for each above mentioned homogeneous zone.

3.2 Chief Statistical Features and Interannual variations

Area-averaged monsoonal and annual rainfall series for all zones have been developed and analyzed. Climatological and fluctuation features of all the time series have been calculated and documented. Normally the mean annual rainfall of all zones varies from 775.2mm over NWI to 2159.6mm over NEI. The coefficient of variation of the annual rainfall varies from 8.2% (NEI) to 18.2% (NWI). The year-wise highest rainfall varied between 367.8 mm (NWI) and 1725.1mm (NEI), while that of lowest from 367.8mm (NWI) to 1725.1mm (NEI). Normally the mean monsoon rainfall of all zones varies from 685.2mm over NWI to 1509.9mm over NEI. The coefficient of variation of the seasonal rainfall varies from 8.3% (NEI) to 19.2% (NMI). The year-wise highest rainfall varied between 950.9 mm (NWI) and 1930.8mm (NEI), while that of lowest from 327.3mm (NWI) to 1242.5mm (NEI).

Inter-annual variations in annual and seasonal rainfall are filtered with 9-point filtering technique in order to suppress the high frequency components and retain the variability in low frequency mode. The smoothed series display many aperiodic fluctuations. Epochs with persistently large-or smaller period under wet or dry condition (with respect to climatological normal) can be seen in the graphs.

3.3. Recent changes in annual and seasonal rainfall

Recent 15-years (2005-2019) and 30-year (1990-2019) changes in annual and seasonal (JF, MAM, JJAS and OND) rainfall relative to last 100 years were documented for all seven homogeneous zones. The significance has been tested using students t-test. In recent 15 years most of the zones shows decrease in JF, MAM and OND rainfall (statistically not significant). The monsoonal rainfall of SPI and EPI has been increased by 8.5% and 7.8% (significant at 1% and 5% respectively), while that NCI and NEI shows significant decrease by -11.5% and -9.7% (significant at 1%) respectively. The annual rainfall of NCI and NEI area also significantly decreased (-11.8% and -11.9% at 1% l.o.s.) respectively.

In recent 30 years, JF rainfall of all zones are decreased relative to last 100 years record. MAM and OND rainfall shows mixed condition across India. In monsoon rainfall, SPI shows significant increase (3.5% at 1% l.o.s.) and NCI and NEI shows significant decrease (-6.6.% and -

5.3% respectively) at 1% level of significance. The annual rainfall of NCI, NMI and NEI also shows significant decrease by -6.7%, -9.5% and -5.9% respectively significant at 1% level.

3.4 Interannual variations in Precipitation concertation Index(PCI)

The Precipitation Concentration Index is an indicator of the temporal precipitation distribution over an area. Changes in seasonal precipitation can be well assessed using this index. Year-wise PCI for each zone have been calculated using monthly rainfall data . The average PCI values for an individual homogeneous zones are as follows: SPI 14.14(±1.3); WPI 20.9(±2,4); EPI 17.3(±1.8); NCI 20.9 (±2.2); NWI 25.1(±3.3); NMI 18.2(±2.7); NEI 13.3(±1.0). On annual scale the mean PCI of all zones indicate the marked seasonal distribution of annual rainfall. In order to understand any temporal changes in the values of PCI, the annual PCI are plotted for each zone. Fig.1 shows the standardized values of PCI, annual rainfall and product of both over NCI during 1842-2019. Similar graphs are plotted for the remaining zones as well. Visual examination revels that, the Interannual variations in PCI for all homogenous zones are homogeneous and random. No considerable changes are observed in time distribution of monthly rainfall across India. However NCI and NMI shows below normal values consistently in recent few years.

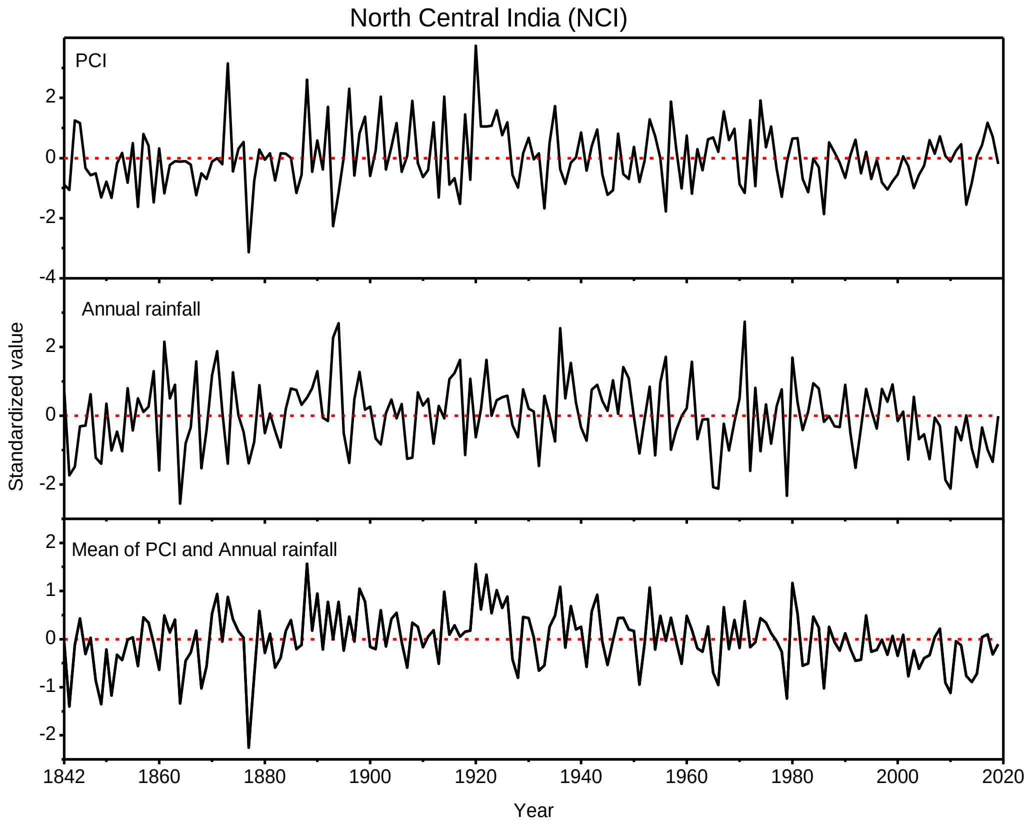


Fig. 1 Standardized PCI, annual rainfall and their products over North Central India during 1842-2019

3.5. Identification of 1- to 10-day extreme rainfall events

In order to understand the variability of extremes over seven homogeneous zones, extreme rainfall analysis has been done using 0.5 degree gridded daily rainfall data. The dataset has been area averaged for seven zones during 1951-2020. Following two types of extremes are calculated on daily scale.

1. 1- to 10-day extreme rain event concerning rainfall amount (ERE-RM):
2. 1- to 10-day extreme rain event concerning rainfall intensity(ERE-RI):

Interannual variations in 1-to 10-day EREs concerning rainfall amount as well as rainfall intensity over 7 zones during 1951-020 are plotted for preliminary qualitative assessment. The climatological fluctuation features of the extreme events for seven zones are in following order.

1. South Peninsular India (SPI): Over the SPI, the mean cumulative rainfall amount of the ERE-RA increases from 30.2mm for 1-day to 143.2mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 31.2mm for 1-day to 14.3mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 25 Jul2005 giving 199.0 mm rainfall over the region, while that of 10-day duration started on 27 Jul 2005, giving 589.0 mm rainfall with the intensity of 59mm per day.

2. West Peninsular India (WPI): Over the WPI, the mean cumulative rainfall amount of the ERE-RA increases from 32.1mm for 1-day to 175.3mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 32.1mm for 1-day to 17.5mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 24 Jul1989 giving 76.8.0 mm rainfall over the region, while that of 10-day duration started on 2Aug 2005, giving 377.1 mm rainfall with the intensity of 37.7mm per day.

3. East Peninsular India (EPI): Over the EPI, the mean cumulative rainfall amount of the ERE-RA increases from 41.2mm for 1-day to 182.5mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 41.2mm for 1-day to 18.3mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 4 Aug 2006 giving 70.6 mm rainfall over the region, while that of 10-day duration started on 14 Aug 2005, giving 277.5.0 mm rainfall with the intensity of 27.7mm per day.

4. North West India (NWI): Over the NWI, the mean cumulative rainfall amount of the ERE-RA increases from 20.3mm for 1-day to 123.5mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 20.3mm for 1-day to 12.3mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 28 Jul 2015 giving 29.5 mm rainfall over the region, while that of 10-day duration started on 29 Jul 2015, giving 174.4 mm rainfall with the intensity of 17.4mm per day.

5. North Central India (NCI): Over the NCI, the mean cumulative rainfall amount of the ERE-RA increases from 27.7mm for 1-day to 158.3mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 27.7mm for 1-day to 15.8mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 29 Sep 2019 giving 40.8 mm rainfall over the region, while that of 10-day duration started on 22 Jul 1975 giving 193.3 mm rainfall with the intensity of 19.3 mm per day

6. North East India (NEI): Over the NEI, the mean cumulative rainfall amount of the ERE-RA increases from 45.2mm for 1-day to 245.1mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 45.2mm for 1-day to 24.5mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 11 Aug 2017 giving 71.3 mm rainfall over the region, while that of 10-day duration started on 16 Jul 2019 giving 370.2 mm rainfall with the intensity of 37.0 mm per day

7. North Mountainous India (NMI): Over the NMI, the mean cumulative rainfall amount of the ERE-RA increases from 28.5mm for 1-day to 97.8mm for 10-day duration. While the mean rainfall intensity of ERE-RI decreases from 31.2mm for 1-day to 9.8mm for 10-day duration. The most extreme ERE-RI and ERE-RA (during 1951-2020) of 1-day duration occurred on 26 Sep 1988 giving 60.5 mm rainfall over the region, while that of 10-day duration started on 25 Mar 1990 giving 197.3 mm rainfall with the intensity of 19.7 mm per day

4. Important Results:

1. Normally the mean annual rainfall of seven homogeneous zones varies from 775.2mm over NWI to 2159.6mm over NEI. The year-wise highest rainfall varies between 367.8 mm (NWI) and 1725.1mm (NEI), while that of lowest from 367.8mm (NWI) to 1725.1mm (NEI).
2. In recent 15 years, the monsoonal rainfall of SPI and EPI has been increased significantly by 8.5% and 7.8% while that NCI and NEI decreases significantly by -11.5% and -9.7% .In recent 30 years, SPI rainfall increase significantly by 3,5% while that of NCI and NEI decreases significantly by (-6.6.% and -5.3% respectively.
3. Interannual variations in PCI for all homogenous zones are homogeneous and random. No considerable changes are observed in time distribution of monthly rainfall across India. However NCI and NMI shows below normal values consistently in recent few years.

Deliverables: It is expected that the results from this study will be useful in order to understand the effect of global warming on rainfall pattern across India

Adopters of the results of the study and their feedback: From hydrology and water resources sectors
Major items of equipment procured: None
Lab facilities during the study: None
Specific linkages with Institutions/beneficiaries: None
Shortcomings/Difficulties: Shortage of manpower
Future Plan: To understand the role of global temperature change in monsoon circulation and extreme rain spells over seven zones of the country.

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

Title of the Project:	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent
Project team:	Dr. Sunil Gurrapu, Scientist C (PI) Dr. Ashwini Ranade, Scientist C Er. Jagadish P. Patra, Scientist D
Type of Study:	Internal
Status:	On-going
Duration:	3 years
Date of Start:	1st November 2018
Scheduled date of completion:	31st October 2021

Objectives:

1. Analyze historically observed streamflow in Godavari and Narmada River basins.
2. Analyze the influence of various low-frequency atmosphere-ocean oscillations on annual peak flow (flood) magnitude and frequency.
3. Evaluate the probability distributions being used in the flood frequency analysis and propose an appropriate probability distribution to address the non-stationarity in the streamflow dataset.
4. Explore the probable maximum precipitation (PMP) estimation methods in design flood studies and prepare a status report on the impact of changing climate on PMP in India.
5.

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, due to lack of standard approach for estimating PMP, it's use in the design and analysis of flood related studies is criticized. 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 the evaluate the PMP estimation methods in flood frequency studies and prepare a status report on the impact of climate change on PMP.

Study Area:
The study is being carried out on several sub-basins of River Godavari and River Narmada. We chose several streamflow gauging stations with a minimum of 30 years observed daily streamflow data. Based on the preliminary survey of the available streamflow data, we chose 19 gauging stations from Godavari and 12 stations from Narmada watersheds, with at least 30 years of data. The maximum length of the available data is 50 years.

Datasets:

1. Observed daily streamflow data for the selected gauging stations is obtained from India-WRIS website.
2. Pacific Decadal Oscillation (PDO) indices is obtained from Joint Institute for the study of Atmosphere and Ocean (JISAO), University of Washington.
3. El Niño-Southern Oscillation (ENSO)is quantified by Southern Oscillation Index (SOI) and 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;

We obtained the daily streamflow data for several gauging stations (19 in Godavari basin and 12 in Narmada basin) from India-WRIS. These stations were selected based on the length of the record, i.e. at least 30 years of observed data. Annual peaks were extracted for the water year (1^{st} June to 31^{st} 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 15 gauging stations out of 19 in Godavari River basin are influenced by ENSO. The correlations between ENSO index and annual mean streamflow show statistically significant correlations (Spearman's $\rho \leq 0.54$). These correlations indicate that the magnitude of annual mean streamflow in Godavari River is more during the El Niño episodes, when compared to that during the La Niña episodes. In addition, we observed that the annual peak flow in 12 gauging stations is significantly influenced by the ENSO. Similarly, annual mean streamflow in nearly 12 gauging stations 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, annual mean streamflow in the Narmada watershed did not show any significant correlations with both ENSO and PDO indices, albeit few stations (nearly 5 out of 12).

Although the correlations are significant for majority of the 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). This data was sufficient to evaluate the effect on ENSO, but the evaluation of PDO signal remains a challenge, although a few stations (≈ 3) were identified with more than 20 years of peak flow data. Currently, we are evaluating various probability distributions used in flood frequency analysis. Based on the results from this analysis, we will be able to propose a suitable distribution that can address the issue of non-stationarity. The first draft of the report (i.e. the last objective of this study) on the impacts of climate change on PMP is compiled and the final revisions are being made. The first draft will be circulated for a brief peer-review to the selected reviewers and the final report will be prepared.

Deliverables:

1. Propose an appropriate probability distribution to address all the concerns over non-stationarity in the streamflow datasets.
2. Research papers based on the established relations between low-frequency climate oscillations and flood magnitude and frequency.
3. Status report on the impact of climate change on probable maximum precipitation (PMP) in India.

PROJECT REFERENCE CODE: NIH/SWHD/20-22

1. 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.

2. 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
3. Duration of study: 2 Years (Aug 2020 to Jul 2022) : Ongoing
4. Type of study: Internal.
5. Location map

Figure 1: Location map of the study area

6. 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.

7. 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.

8. 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.								

S.N.	Work Element	1st Year				2nd Year			
11	Report.								

9. Role of team members

S. N.	Role / Action	Member/(s)
1	Collection of basic data, topography, cross-section, satellite images, thematic maps etc.	JPP, PM, TRS
2	Compilation and analysis of data, satellite images	JPP, PM
3	1-D level pool dam breach model setup	JPP, PM
4	Quantification difference between level pool routing and full unsteady flow routing.	JPP, PM, AK
5	Generation of probabilistic breach parameters	JPP, RK, SG
6	Estimation of probabilistic dam breach outflow hydrograph	JPP, RK, SG
7	Preparation of Exceedance Probability Inundation (EPI) Maps.	PM, JPP, SG
8	Combined general flood hazard classification and preparation of Flood Hazard Maps.	JPP,PM
9	Risk identification, estimation of Population at risk and potential loss of life.	JPP,PM, SG, RK
10	Report	JPP,PM, SG, TRS

JPP = J. P. Patra, RK = Rakesh Kumar, PM = Pankaj Mani, SG = Sunil Gurrapu, TRS =T. R. Sapra

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 approaches are summarized in Table 1.

Table 1: Description of breach parameters.

SN	Approach	Average Breach width (m)	Time of failure (hour)	Side slope of breach section
1	Froehlich (1995)	441	5.63	1.4:1
2	Froehlich (2008)	336	4.91	1:1
3	Von Thun and Gillette (1990)	172	1.42	0.5:1
4	Xu & Zhang	204	28.91	0.92:1
5	Upper bound*	240	4	1:1
6	Lower bound*	24	0.1	1:1
7	Average breach parameters	288.25	3.99	0.96:1
Estimated breach parameters		*200*	*4*	*1:1*

*Upper and lower bound of breach parameters are prescribed by Federal Agency Guidelines

The Mahi dam being earth rock fill dam, a trapezoidal breach section with side slope of 1H:1V 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 and therefore has not been considered for computing average breach time. Average breach time of 4 hour has been estimated for the analysis. Moreover, the trapezoidal breach section has been assumed for the earthen dam with 1:1 side slope. 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 temporal development of breach is defined in numerical model setup as per following details:

Breach Time (sec)	Breach bottom Width (m)	Breach Level (MSL)	Breach Slope
0	0	281.5	1:1
7200	100	260	1:1
14400	200	248	1:1
432000	200	248	1:1

The model setup in HEC-RAS is being prepared to simulate outflow hydrograph due to dam breach and 1-D level pool routing. The probabilistic breach parameters are being generated using Monte Carlo simulation technique, which will be used for developing probabilistic dam breach outflow hydrograph.

12. Action taken on comments of previous working group meeting
    There were no specific comments.

13. 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.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/21-22

1. Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Upper Narmada -3e

(Research/Application Study)

Study group	Sushil K. Singh**,** Scientist F
Date of start of study	01 April 2021 (New Study)
Duration and scheduled	One year
Date of completion of study	31 March 2022
Type of study	Internal (without funding)

Objectives of study

This study is undertaken under 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 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*."

The current year study is intended for the following two subzones:

1. Mahi & Sabermati subzone 3a
2. Upper Godavari subzone 3e

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.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/21-23

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
N. K. Bhatnagar	Sc- B, Co-PI
J. P Patra	Sc –D, 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. **Data Requirements**:

Stage and discharge data. Data sources would be from field organization (CWC or State Water Resources Department) and related literature,.

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)				
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

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. Renoj Thayyen	Scientist E
4	Dr. Manohar Arora	Scientist E
5	Dr. P K Singh	Scientist D
6	Dr. Manish Nema	Scientist D
7	Dr. P K Mishra	Scientist C
8	Dr. Vishal Singh	Scientist C
9	Sri P K Agarwal	Scientist B

APPROVED WORK PROGRAMME FOR THE YEAR 2020-2021

SN	Title	Study Team	Duration	Funding (Rs. Lakh)
Ongoing 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)	
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Singh A. K. Lohani	2 years (12/18-12/20)	
3.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years (04/18-03/21)	
Ongoing Sponsored 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 (01/16-12/20)	DST (52.15)
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar, V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
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 (01/16-12/20)	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 (01/16-12/20)	DST 86.1 (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 (01/16-12/20)	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 (01/16-12/20)	DST (90.99)
7.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema; Renoj J. Thayyen; Sharad Jain (Retd.); Sanjay Jain; P. K. Mishra; AP Dimri	3 years (2016-19) Extended up to Dec. 2020	MOES (Rs. 98 Lakh)
8.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore; L. N. Thakural; Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan	3 years 2017-2020	PDS under NHP (50.23 Lakh)
9.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern	Sanjay K. Jain P. K. Singh; M. Arora	3 years (11/19-11/22)	NMHS-MoEF

	Himalaya	Renoj J. Thayyen; A. K. Lohani; Vishal Singh; Suman Gurjar		(143 Lakh)
10.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Renoj J. Thayyen A. P. Dimri (JNU) Sanjay K. Jain	3 years (06/19-11/22)	(23.19 Lakh)
11.	Permafrost mapping and characterisation of Ladakh Region	Renoj J. Thayyen; A. P. Dimri (JNU); G. Jeelani (KU); V. Agnihotri (GBPNI)	3 years (11/19-11/22)	NMHS-MoEF (197.48 Lakh)
New Internal/ Sponsored Studies				
1.	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
2.	Henvel Experimental Watershed: Observations and modelling (Phase II)	M K Nema Renoj J. Thayyen P K Mishra	3 years (08/20-07/23)	NIH
3.	Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package	D. Chalisgaonkar M. K. Goel	1 year (08/20-07/21)	NIH
4.	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	2 years (08/20-07/22)	NHP (14.50 Lakh)
5.	Preparation of Guidelines for the "Management of Glacial Hazards and Risks especially GLOFs & LLOFs"	Sanjay K. Jain A K Lohani	1 year (12/19-12/20)	NDMA (14.36 Lakh)

PROPOSED 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. Chandramohan	3 years 2017-2020 (Recommended for extension up to June, 2021)	PDS under NHP (50.23 Lakh)

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	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); 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.	Henvel 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; P K Mishra, Manohar Arora; Praveen Thakur (IIRS)	3 years (04/21-03/24)	IIRS-ISRO (Rs. 26.945 Lakh)

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/01

1. **Thrust Area under XII five-year Plan**
   Food security and the sustainable management and use of water resources

2. **Project team:**

a. Project Investigator:	Dr. P. K. Singh, Scientist 'D'
b. Co-PI Project Co-Investigator(s):	Dr. P. K. Mishra, Scientist 'C'
	Dr. M. K. Goel, Scientist 'G'
	Er. Suman Gurjar, Scientist 'C'

3. **Title of the Project**– Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework

4. **Objectives**-The major objective of this study is to apply newly developed WA+ framework for Subarnarekha river basin in India. The objectives of this study includes assessment of:

   1. Agricultural water consumptions using green water and blue water concept
   2. Total water withdrawals and their partitioning in to surface and groundwater withdrawls
   3. Land productivity and water productivity for food security
   4. Consumed and non-consumed water along with beneficial and non-beneficial consumptions
   5. Water scarcity and develop water allocation plans from water demand and water supply statistics
   6. Available, exploitable, utilized and utilizable water resources

5. **Methodology**
   The Water Accounting Plus system (WA+) is based on open access remote sensing data -in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be 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) 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). 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.

6. Present progress (Objective-wise):

Sl. No.	Objectives	Progress
1:	Agricultural water consumptions using green water and blue water concept.	These four objectives have been achieved and completed so far.

<table>
<tr><td>2:</td><td>Total water withdrawals and their partitioning in to surface and groundwater withdrawals.</td><td rowspan="4">Papers from the study:

1. P K Singh, P K Mishra, Sharad K Jain, M K Goel, S K Jain and Suman Gurjar (2019). Water Accounting Plus (WA+) Framework for Estimating Water Productivity and Land Productivity in Subernarekha Basin. IGWC-2019. 8^{th} International Groundwater Conference on ‘Sustainable Management of Soil-Water Resources’ during Oct. 21-24, 2019, IIT Roorkee.
2. P K Singh, Sharad K Jain, P K Mishra, and M K Goel (2020). An assessment of water consumption patterns and land productivity and water productivity using WA+ framework and satellite data inputs. J. of Physics and Chemistry of Earth. (Under review).</td></tr>
<tr><td>3:</td><td>Land productivity and water productivity for food security.</td></tr>
<tr><td>4:</td><td>Consumed and non-consumed water along with beneficial and non-beneficial consumptions.</td></tr>
<tr><td>5:</td><td>Water scarcity and develop water allocation plans from water demand and water supply statistics</td></tr>
<tr><td>6:</td><td>Aavailable, exploitable, utilized and utilizable water resources</td><td>Water resources availability in the basin have been estimated (i.e., Sheet 5 and Sheet 1). The Sheet 5 (also called as the Surface Water Sheet) details about the sub-basin water availability (as per 4 WMC classes) and the availability at the outlet. Sheet 1 (also called as the Resource Base Sheet) depicts in-detail about the resources in total with further classification in terms of the gross inflow, net inflow, exploitable water, available water, utilized water, etc. The findings have been compared with the field/secondary data sources (e.g., CWC) in the basin. Detailed findings will be presented in the meeting.</td></tr>
</table>

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/02

1. Thrust Area under XII five-year Plan

Flood modeling and inundation mapping

2. Project team:

Dr. Vishal Singh, Scientist C
Dr. A K Lohani, Scientist G

3. Title of the Project -

Real time flood modelling in Southern River basin using HEC-RTS modelling framework.

4. Objectives

The present research work shall explore the flood discharge and their inundation in the Southern river basin. During extreme high rainfall events, the frequency of flood events increases. The high amount of flood discharge may cause severe flood conditions in the downstream portion of the river basin. A destructive flood hazard has been recently happened in the Kerala state of India (2018) during monsoon season. Therefore, the purpose of this research work is to provide the advance research and engineering guidelines as per the adopted approaches and methodologies for the hydrological and hydrodynamic assessment of the flood discharge and inundation in the Southern river basin under extreme scenarios. Based on current research needs, following are the research objectives defined:

1) To process and accuracy assessment of the rainfall dataset over the selected river basin by utilizing satellite-based rainfalls (e.g. TRMM+GPM) and measured rainfalls (e.g. IMD gridded rainfalls).
2) Construction of the hydrological model (i.e. HEC-HMS) to generate stream flows at different sections of the river channels.
3) Climate change assessment on Periyar river flood flows utilizing GCMs/RCMs and Statistically downscaled multi-model CMIP5 GCMs datasets.
4) Generation of flood discharges at different sections of rivers and the development of flood inundation maps in a stochastic manner including multiple return periods (e.g. 20 year, 50 year, 100 year, 500 year and 1000 year).
5) Construction of the 2D Flood model by the coupling of hydrological model (i.e. HEC-
6) HMS) and hydrodynamic model (i.e. HEC-RTS) named as HEC-RTS framework.

5. Study Area

For the present research work, the Periyar river basin has been selected as shown in Figure 1.

6. Methodology

6.1 Dataset

For the proposed study, the real time time-series rainfall datasets with high spatial resolution along with other meteorological variables (e.g. temperature, humidity, radiation, wind etc.) will be utilized from different sources such as India Meteorological Department Rainfalls, APHRODITE rainfalls, TRMM rainfalls etc. Similarly, other meteorological variables will also be acquired from these organizations. The high resolution digital elevation model (DEM) and other thematic layers such as land use/land cover (LULC), Soil map will also be utilized. The hydrodynamic parameter/datasets will be collected from the nodal agencies and on the field as per their requirements. The overall methodology has been classified into three components as given below:

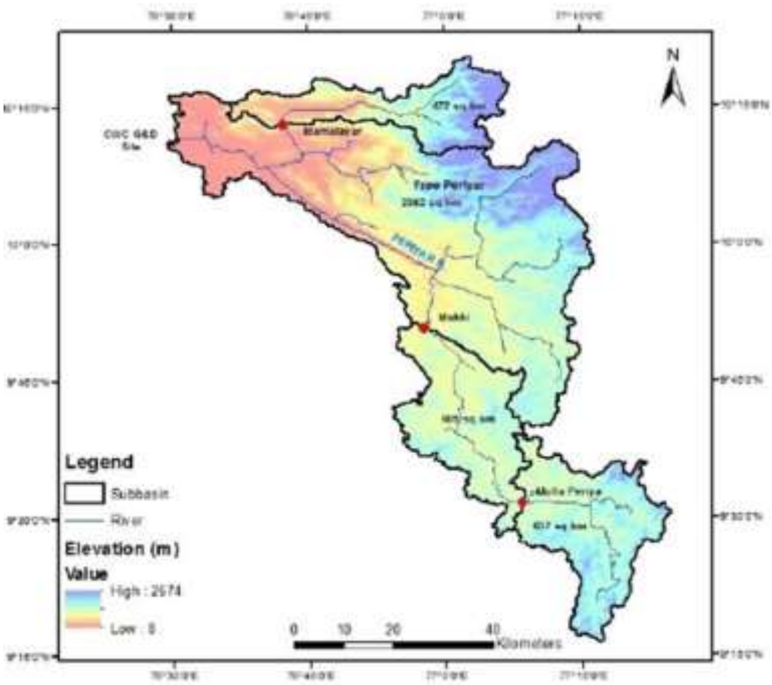


Figure 1: Periyar river basin highlighting the locations of targeted reservoirs (in red circle).

7. Progress & Research Outcomes

7.1 Achievement

1) To process and accuracy assessment of the rainfall dataset over the selected river basin by utilizing satellite-based rainfalls (e.g. TRMM+GPM) and measured rainfalls (e.g. IMD gridded rainfalls). **(Completed)**
2) Construction of the hydrological model (i.e. HEC-HMS) to generate streamflows at different sections of the river channels. **(Completed)**
3) Generation of flood discharges at different sections of rivers and the development of flood inundation maps in a stochastic manner including multiple return periods (e.g. 20 year, 50 year, 100 year, 500 year and 1000 year). **(Completed)**
4) Construction of the 1D and 2D Flood model by the coupling of hydrological model (i.e. HecHMS) and hydrodynamic model (i.e. HecRAS) named as HEC-RTS framework. **(Completed)**

7.2 Rainfall data assimilation and bias correction

The HMS and HEC-RAS model have been proposed to run at 3 hourly time intervals to create the historical Kerala flood event (2018). Therefore, in the absence of hourly IMD rainfalls, the TRMM+GPM satellite-based rainfalls data were downloaded at 3 hourly intervals. Then we aggregate the 3-hourly rainfalls to daily rainfalls for the bias correction with reference to IMD daily rainfalls. Based on the ratio of three hourly TRMM-GPM rainfalls the daily bias computed with reference to the IMD rainfalls has been adjusted and finally the TRMM corrected rainfalls were generated to setup HMS and RAS model. The results are shown in Figure 3.

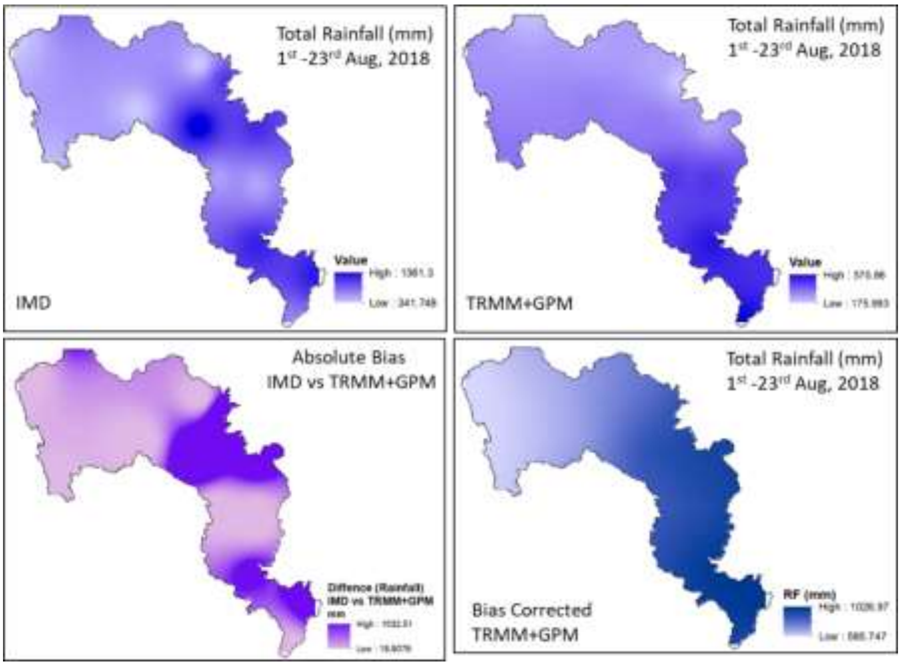


Figure 3: Bias correction of TRMM+GPM based hourly rainfalls with reference to IMD rainfalls.

7.3 HEC-HMS model Simulation and Calibration

After computation of the inputs, input flows and output hydrographs are generated in HMS. The three reservoirs are taken into consideration for the computation of hydrographs for each sub-catchment. The local flows and outflows are simulated at different catchments to further setup HECRESSIM reservoir simulation module and HEC-RAS routing module. The calibration is done at Neeleswaram gauge station in Periyar river basin (Figure 4).

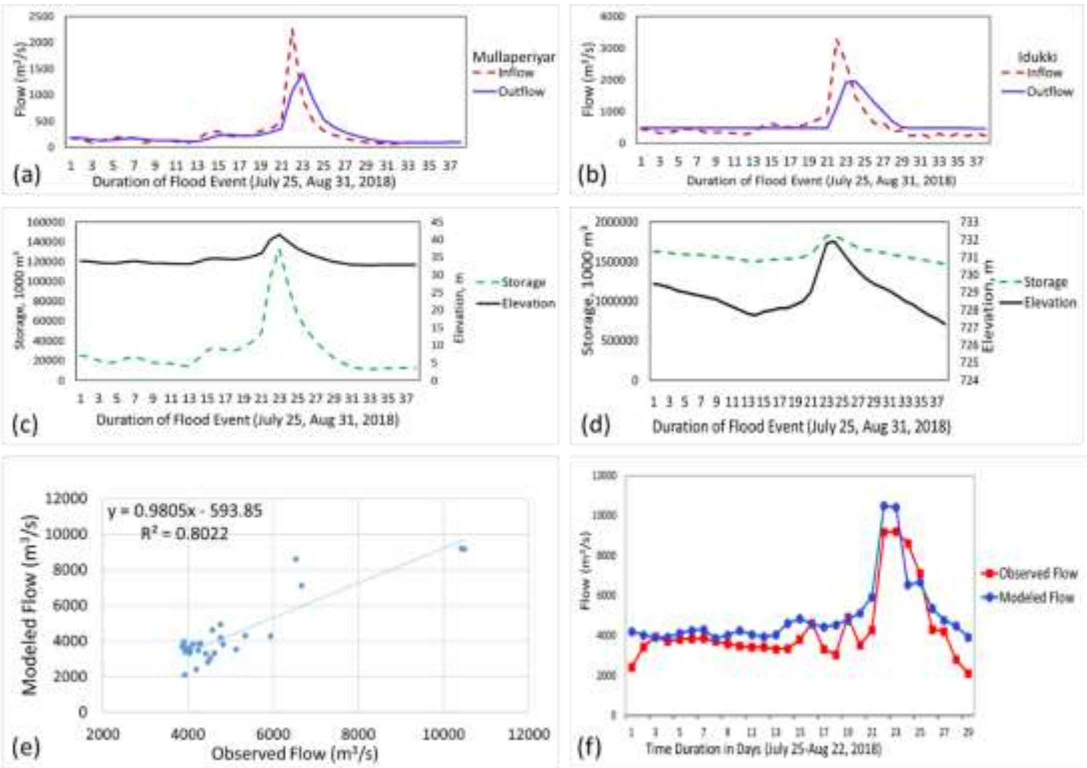
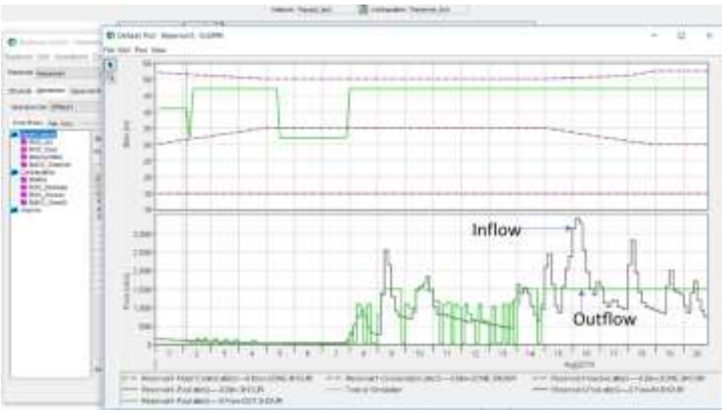


Figure 4: (a-d) Regulated flood flows computation for Mullaperiyar and Idukki dams using HEC-HMS and **(e-f)** Comparison of calibrated discharge versus observed discharge on a monthly time step at Neeleswaram gauge as per Kerala flood event 2018 (Aug 1 to Aug 31, 2018).

7.4 Reservoir Optimization through HMS and HEC-RESSIM

The reservoir simulation has been in progress (Figure 5). The reservoir parameters are computed from empirical equations and several datasets are collected from Central Water Commission and published report. The Mullaperiyar dam situated at the upstream portion of the Periyar river and Idukki and Idamalayar dams are situated in the downstream portion. Initially, the reservoir operation rules are constructed for the Mullaperiyar dam and regulated flow has been simulated and the flood peaks are significantly minimized.

(a)



(b)

Figures 5: Reservoir operation setup and simulation using HEC-RESSIM at (a) Mullaperiyar dam and (b) Idukki dam.

7.5 Flood Frequency Analysis

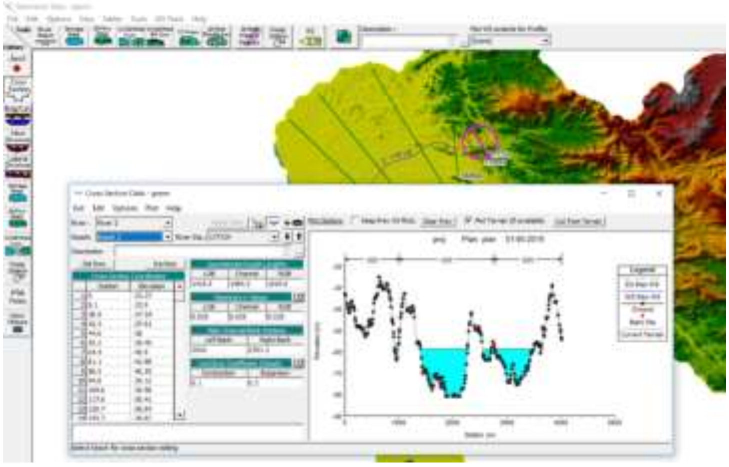
Flood Frequency analysis has been done utilizing historical rainfall (2002-2018) at different rainfall stations and HEC-HMS generated flood flows for different historical events and at sub-basin scale. Gumbel and Log Pearson Type III distribution methods have been used to generate different return period flood maps. Some results are given below (Table 1):

Table 1: Different return period based rainfalls extreme values (mm) at different stations (or grids).

Return Periods	Gumbel			Log Pearson Type III		
	G-75	G-167	G-183	G-75	G-167	G-183
10	169.8	237.0	204.9	166	213	192

20	203.4	289.3	247.1	238	352	289
50	247.0	357.0	301.8	308	515	389
100	279.6	407.7	342.8	392	742	516
200	312.1	458.2	383.6	490	1042	669
500	355.0	524.9	437.4	740	1732	1039

8. HEC-RAS 1D SETUP – For the Flood Event "1st Aug to 18 Aug, 2018".



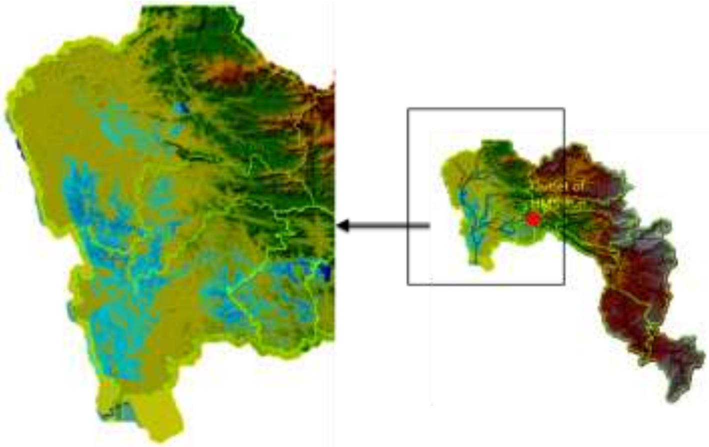


Figure 6: Flood Inundation Map as per the Flood Event "1st Aug to 18 Aug, 2018.

9. Results & Conclusion

1 – Long Term flood flows simulation for Idukki and Mullaperiyar dams as per the available datasets.
2 – Historical flood events simulations and generation of flood values and unsteady flows in HEC-HMS.
3 – Calibration of long-tern flood flows and historical flood events using observed flood data in HEC-HMS.
4 – Reservoir operation rule curves and optimization of Mullaperiyar and Idukki for the historical flood event (2018).
5 – Rainfall and Flood frequency analysis and computation of different return period flood maps at different rainfall stations and subbasins using Gumbel and Log Pearson Type III distribution methods.
6 – Integration of HEC-HMS, HECRESSIM and HECRAS models to generate flood flows, and other hydrodynamic variables such as velocity, surface water elevation and rating curves at different cross sections for extreme event conditions and long-term flood flows.

7 – The current integrated system using HEC-HMS, HEC-RESSIM and HEC-RAS can be used to generate forecasted floods (volume, velocity and inundation area) if future rainfall data is available.

8 – Generation of probabilistic flood maps using different return period floods, which can be useful to make flood plain zoning and to prevent from long-term and extreme event-based flood hazards.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/01
NMSHE STUDIES

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

2. Study team

13. Dr. M. K. Goel, Scientist 'G'
14. Dr. M. Arora, Scientist 'E'
15. Dr. A. K. Lohani, Scientist 'G'
16. Mr. D. S. Rathore, Scientist 'F'
17. Mrs. D. Chalisgaonkar, Scientist 'G'
18. Dr. A. R. S. Kumar, Scientist 'F'
19. Dr. Surjeet Singh, Scientist 'F'
20. Mr. P. Mani, Scientist 'E'
21. Dr. A. Sarkar, Scientist 'E'
22. Dr. M. K. Nema, Scientist 'D'
23. Smt. Suman Gurjar, Scientist 'C'
24. Dr. P. K. Mishra, Scientist 'C'

3. 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.	Temperature data processing is in progress
Assessment of adequacy of hydro-meteorological network in study area.	In progress
Investigation and referencing of available spatial database from various sources.	In progress
Capacity building for use of hydrological data entry and processing software.	To be taken up after the processing of temperature data
Development of interactive project web site with hydrological information system.	Has been developed and is being continuously updated.

4. Sponsored by DST, New Delhi

5. Project Cost Rs.113.22 Lakh

6. Present Progress

The study has been transferred to Ground Water Hydrology Division after Dr. M. K. Goel, PI & Scientist G taking over the charge of headship. The present progress has been provided in the agenda note of the GWH Division.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/02
NMSHE STUDIES

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

2. Project team

a) Project Investigator:	D. S. Rathore, Scientist 'F' (Now Deepa Chalisgaonkar is 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

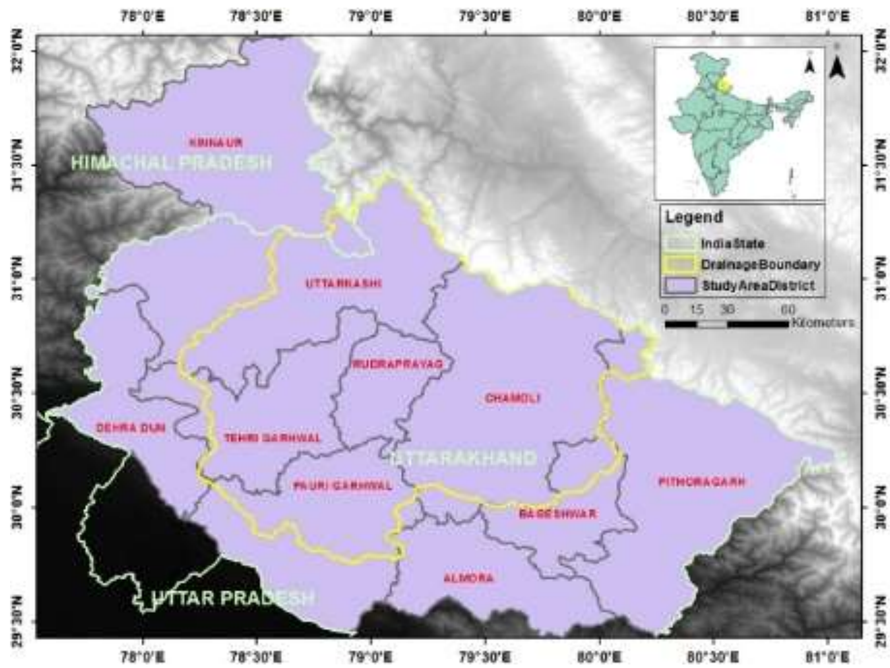


Figure 1: Upper Ganga basin

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.

Draft report has been prepared

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/03
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

Draft Report has been prepared.

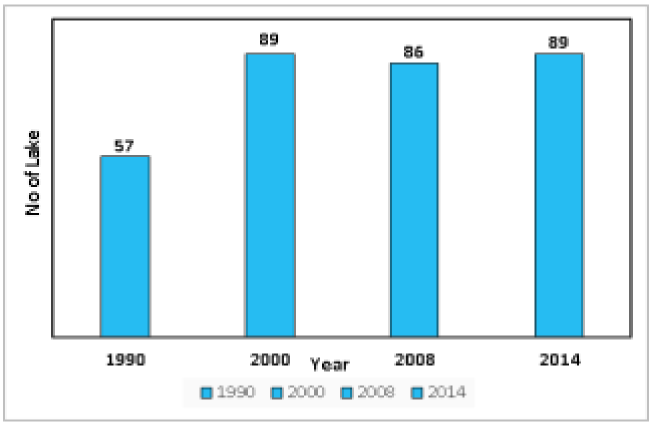


Figure 1: Number of Lakes of different years in Chenab basin

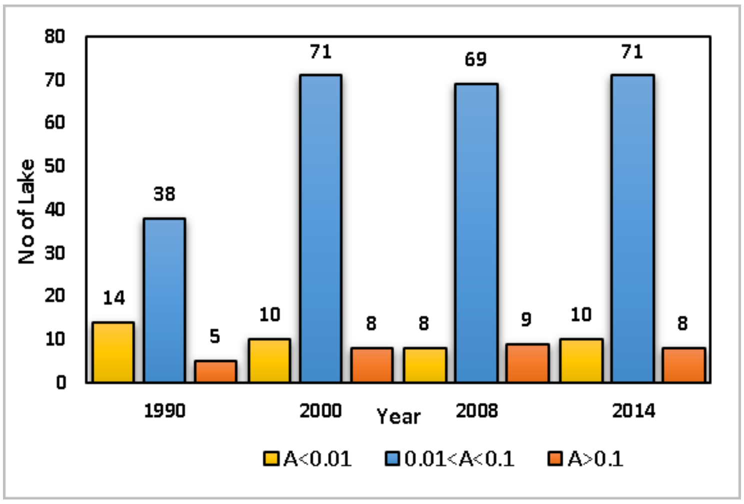


Figure 2: Number Frequency of lakes of different area ranges in Chenab basin

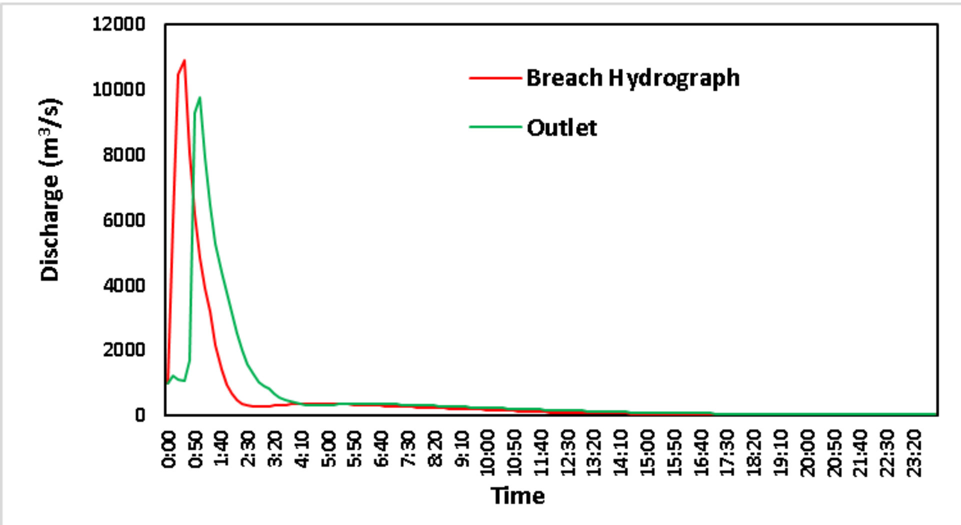


Figure 3: GLOF Hydrograph at Outlet from Lake

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/04
NMSHE STUDIES

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
    1. Dr. Renoj J. Thayyen, Scientist 'E'
    2. Dr. Sanjay K. Jain, Scientist 'G'
    3. Dr. Sharad K. Jain, Retd.
    4. Dr. P. K. Mishra, Scientist 'C'
    5. Dr. M. Arora, Scientist 'E'
    6. 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.	Included complete UGB area till Rishikesh. Refinement in progress

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/05
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. R. J. Thayyen, Scientist 'E'
	:	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. Surjeet Singh, Scientist 'F'
	:	Dr. P. K. Singh, Scientist 'D'
	:	Dr. P. K. Mishra, Scientist 'C'
	:	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}. Report preparation is under progress.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/06
NMSHE STUDIES

1. Title - Water Census and Hotspot analysis in selected villages in Upper Ganga basin

2. Study team

1. Dr. P. K. Mishra, Scientist 'C'
2. Dr. Renoj J. Thayyen, Scientist 'E'
3. Dr. M. K. Nema, Scientist 'D'
4. Dr. Pradeep Kumar, Scientist 'D'
5. 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	Ongoing

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/07

1. Title of Project: Investigating water stress using hydro-meteorological and remote sensing data, Purpose Driven Study (PDS), National Hydrology Project (NHP)

2. Project team:

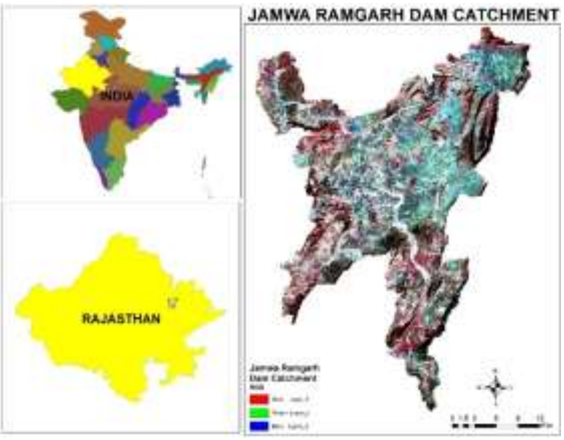
- **a) Principal Investigator:** Mr D.S. Rathore, Scientist ‘F’ (Now Dr. L N Thakural Scientist D is PI)
- **b) Project Co- investigators:** Dr Sanjay Kumar, Scientist ‘F’
  Dr R. K. Jaiswal, Scientist ‘D’
  Dr M.K. Jose, Scientist ‘E’
  Dr T. Chandramohan, Scientist ‘D’

Partner Organization: Water Resources Department, Rajasthan
Principal Investigator: Sh Sanjay Agarwal, Deputy Director
Co- investigators: Sh Shailesh Awasthi, Assistant Engineer

3. Objectives

- Characterizing water stress using hydro meteorological, remotely sensed data and vadose zone modeling
- Analysis changes in water stress conditions due to drought response and mitigation measures
- Field level measurements of vadose zone moisture
- Forecasting and regionalizing drought indices
- Devising reservoir operating policy

4. Location map/ study area



Jamwa Ramgarh reservoir catchment is selected as study area. The dam is located on Banganga river. The study area falls in Jaipur district of Rajasthan. Area is located in East Rajasthan meteorological sub- division. Main aquifer system consists of alluvium. Quartzite, gneiss, schist and granite have localised occurrances. Catchment area is nearly 820 sq. km. The dam was built in 1903. The reservoir is dry since 2006. Mean annual rainfall is 492 mm with 36% COV. Normal annual rainy days are 110.

5. Approved action plan and time line

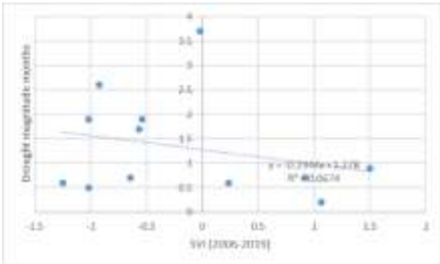
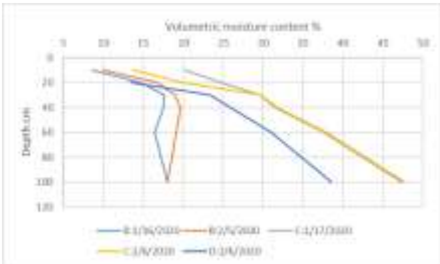
Activity	1st yr				2nd yr				3rd yr			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Data collection												
Satellite data procurement												
Field observation												
Data pre processing												
Computation of drought indices												
Regionalization of drought indices												
Forecasting												
Drought identification												
Unsaturated zone modeling												

Reservoir operation												
Scenario analysis												

8. Recommendations/ suggestions in previous WG

SAVI can be used in addition to NDVI.

9. Achievements

Year	**Objectives**	**Achievements**
2020-21	Characterizing water stress	 SPI for scale 1 to 4 and 12 months were calculated for 1974- 2017. Average drought magnitude its frequency were estimated. Drought magnitude for exceedance probability of 0.1, 0.2, 0.3 was 2.8, 2.1 and 1.9 respectively. Average SVI estimated using MOD13Q1 NDVI for a location. For SVI- drought magnitude regression, R^2 of 0.07. Variation in magnitude of drought magnitude was high for negative SVI. Vadoze zone modeling was done for sandy clay loam and wheat crop. ET was estimated to be 88% for irrigation application of 480 mm.
2020-21	Vadoze zone measurement	 Soil moisture measurements were carried out for two sites (three profiles) using PR6 profile probe during Jan and Feb 2020. Average soil moisture for flood and sprinkler irrigated fields were 30 and 18% respectively.
2020-21	Catchment modeling	Monthly reservoir inflow was estimated using water balance for period 1974- 2006. Catchment area was delineated using ALOS data to determine inland basins of 62 sq. km in extent. Mike SHE model was set up with single aquifer (fine sand), two vegetation classes, crop sequence of maize and wheat, sandy clay loam soil and groundwater pumping and irrigation (21 wells, 9.5% of precipitation). For period 1974- 1985, simulated ET and river flow were 76 and 13% respectively.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/08

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. Renoj Thayyen, Scientist 'E'
Dr. A K Lohani, Scientist 'G'
Dr. Vishal Singh, Scientist 'C'
Er. Suman Gurjar, 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. Progress till-the-Date

- Database preparation has been done in GIS. The satellite data have been downloaded and processed. Snow cover area maps have been prepared.
- SWAT model has been applied and preliminary results have been obtained.
- Stake holder workshop was oragnised at Gangtok on 23rd. Feb. 2021.
- Field visit for site selection of instruments was done during Nov., 2020 and Feb. 20201. The process for instrumentation procurement is in final stage.

8. 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					■	■

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/09

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

2. **Project Team:**

   1. Dr. Renoj. J. Thayyen, Scientist 'E'
   2. Dr. Sanjay K. Jain, Scientist 'G'
   3. Collaborator: Dr. A. P. Dimri, Professor, SES, JNU, New Delhi

4. **Title of the Project:** Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin

5. **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

6. **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.

7. **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.

8. **Cost Estimate:**

Total cost of the project:	Rs. 23.19 lakhs
Source of funding:	NRDMS-DST

9. Progress of the project

Sub-Objectives	Work Done
1. Seasonal Snow loading and unloading estimation from GRACE and comparison with other RS products	Snow cover variation in the Upper Ganga basin is carried out for 2000-2019 period and seasonal loading and unloading pattern established
2. Seasonal mass fluctuation of glacier regime and regional mass balance assessment	Glacier boundaries remapped for 2014. Mapping of 2000 is in progress.
3. Seasonal soil moisture fluctuation in the basin with an emphasis to ISM (JJAS) and IWM (DJF)	Soil moisture data of three existing AWS sites in the Upper Ganga basin has been generated and various RS product is being tested, smap, SMOS etc.
4. Inter-comparison between seasonal river runoff and basin scale mass anomaly from GRACE	Preliminary run of SPHY runoff modelling completed and various Runoff/ water balance components established up to Rishikesh. Need further improvement

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/10

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

2. **Project Team:**

    1. Dr. Renoj. J. Thayyen, Scientist 'E'

Institutional Collaborators:

2. JNU, New Delhi: Prof. A. P. Dimri, SES
3. GBPNIE, Almorah: Vasudha Agnihotri
4. Kashmir University: Prof. G Jeelani

3. **Title of the Project:** Permafrost Mapping and Characterization of Ladakh District.

4. **Objectives:**

1. Modelling of permafrost extent in Leh district of Ladakh region **(NIH).**
2. Modelling active layer thickness of Permafrost in selected study areas **(NIH).**
3. Assessment of regional climate and fluxes over permafrost regions (JNU).
4. Assessment of water quality and bio-geochemistry of permafrost horizon with special emphasis to DOC, DOM, DON and DIN in active layer (GBPNIE).
5. Assessment of Ground ice melt contribution to Regional Water resources and estimate the sources of local, and transported moisture using isotope technique (KU).

5. Methodology (NIH Component)

Modelling of Permafrost extent and active layer thickness (NIH): Permafrost extent can be estimated only through modelling exercise. Soil temperature is the key input data required for this purpose. Number of soil temperature sensors (30 Nos) will be stablished in selected plots across the Ladakh region. Relationship between Potential Incoming Solar Radiation(PISR) and Mean Annual Ground Surface Temperature (MAGST) will be established and spatial permafrost map will be generated using the GIS. Active layer thickness will be modelled by using "GEOtop" 1D model at select sites with MAGST data.

6. **Research Outcome from the project:**

- Permafrost extend maps of the study region
- Permafrost active layer thickness information at select sites
- Model development for permafrost processes
- Contribution from permafrost to regional water resources
- Regional climate model coupled with permafrost area and surface flux
- Quantification Dissolved Organic matter (DOM), DON and DIN in permafrost soil and meltwater and water quality implications

7. **Cost Estimate:**

Total cost of the project:	Rs. 197.48 lakhs
NIH	Rs. 56.78 lakhs
Source of funding:	NMHS-MoFCC

8. **Progress of the project**

- Singed MoU with collaborating institutes
- Fund transferred
- Project fellows appointed
- Equipment procured

- 30 sensors installed in the field in September expedition.
- 4 years assessment of permafrost characteristics of 24 sensors in the Ganglass catchment were carried out and its relationship with prevailing weather is established.

ONGOING STUDIES

SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/11

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 'C'
   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.

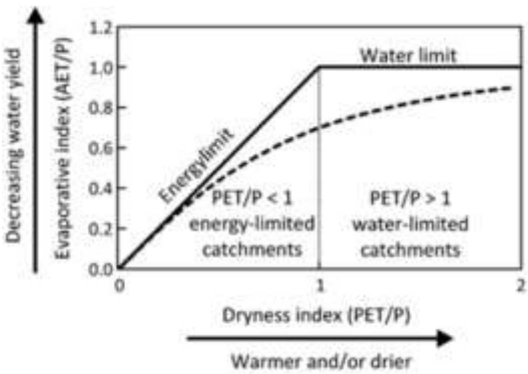


Figure 1: Budyko Framework **Figure 2: WA+ Based WMC**

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:

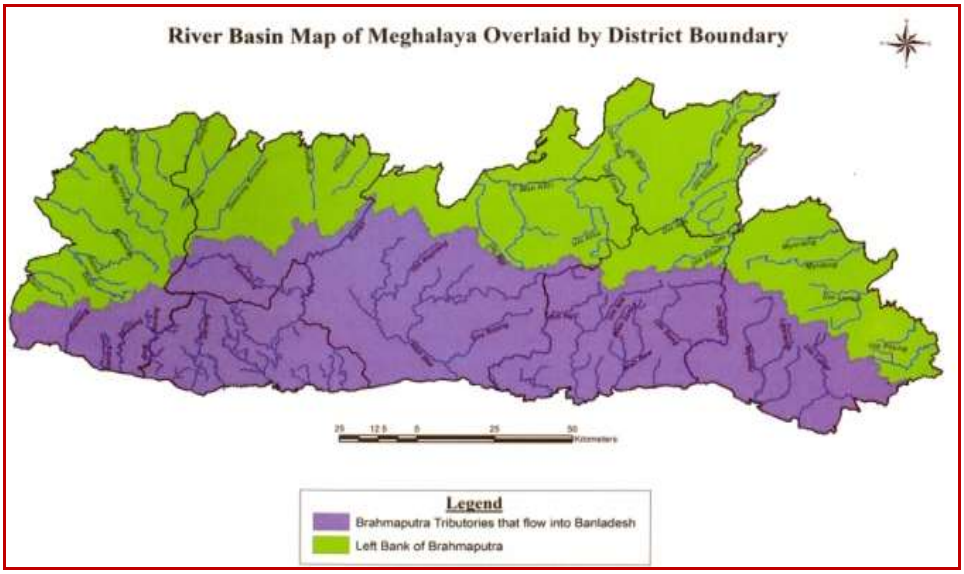


Figure 3: River basin map of Meghalaya overlaid by district boundary
(Source: WRD, Meghalaya)

- 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:

- Data downloading, processing, and generation of data bases and maps.
- Standardization of Codes for development of WALU, Sheet-2 and Sheet 3
- Online-training on WA+ Framework was organized during Nov. 16-20, 2020 for participants from Meghalaya state.
- Spatial maps of precipitation, ET variability and water yield has been generated at the sub-basin level.
- WA+ based LULC map and Sheet-2 generation is under progress.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/12

1. Title of the Study: Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

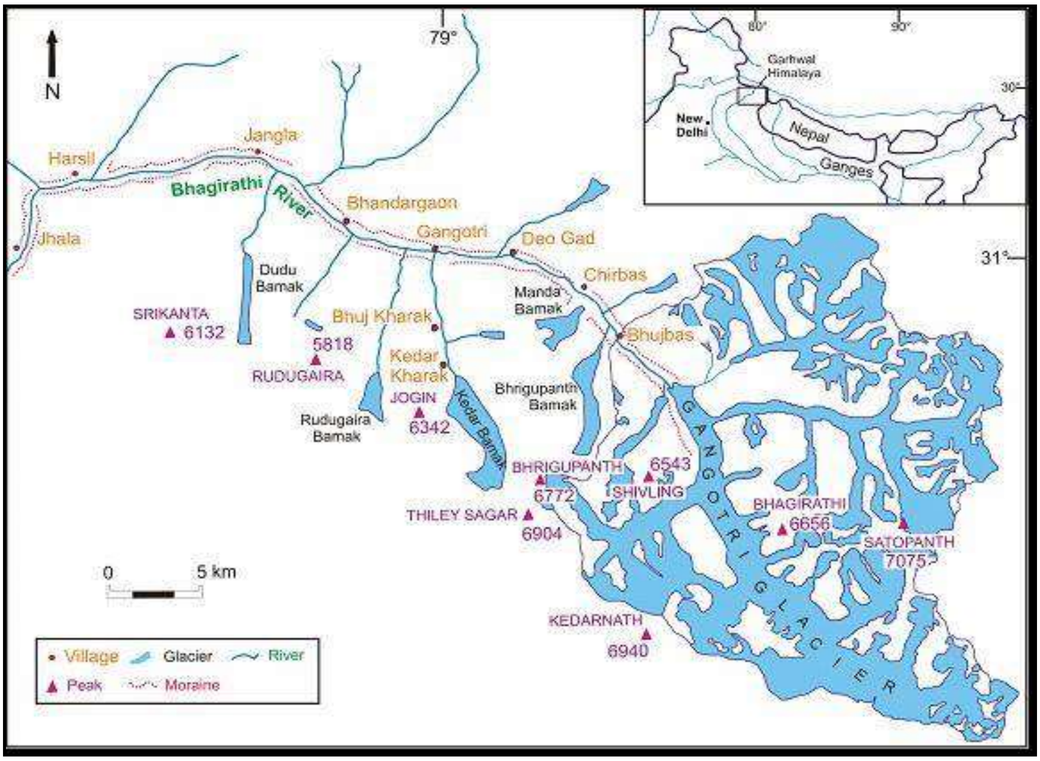
2. Study Group: Dr Manohar Arora, Scientist 'E'
Dr P K Mishra, Scientist C

Dr. Vishal Singh, Scientist C

3. Type of Study: Internal. Project

Date of start: 01.04.2018
Scheduled date of completion: 31.03.2021. (Extended for 1 year)

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.

6. Action Plan

Year	**May to October**	**November to April**	**Remark**
All Years	Field investigations & Data Collection	Data analysis	Report preparation after three years

7. Objectives vis-à-vis Achievements :

Objectives	**Achievements**
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 2020. The field investigations for 2021 will be started in the first week of May 2021.
To improve the hydrological model for simulating daily streamflow	The simulation of flow will be carried out after collection of three years of data. The future climate scenarios have been downscaled for BNU_ESM, CCCma_CanESM2, CNRM_CM5, MPI__ESM_LR and MPI_ESM_MR models for RCP 4.5 Scenarios. Analysis will be carried out to finalize the best model suitable for the Gangotri grid.

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/13

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**

   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.

   1. 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.
   2. To study the impact of snow and glacier changes on the runoff.
   3. To analyze the impact of climate change and the long-term (21st 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 Collection and Analysis:

Table – 1

Details about the input datasets and their sources

Sl No.	DATASET NAME	SOURCES
1	Digital Elevation Model	SRTM/CARTOSAT - Freely available
2	Land use – Land cover Map	Waterbase/ Bhuvan - Freely available
3	Soil map – FAO Global	Waterbase - Freely available
4	Soil map – High Resolution	Future Water, Netherlands – Freely available
5	Satellite data – LISS4, LISS3	NRSC - to be procured
6	Satellite data – Landsat, MODIS, Sentinel	Earth Explorer, NASA – Freely available
7	Precipitation data and other Meteorological datasets	IMD – to be procured
8	Precipitation data and other Meteorological datasets	CHIRP, TRMM/GPM, Other Sources – Freely available
9	Observed discharge	CWC – available on request
10	Climate Models Data (CMIP5/CMIP6	IPCC – to be used/downloaded as per the availabil

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.

6.2 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).

6.3 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.

6.4 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.

6.5 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. Work Progress:

7.1 Preparation of Basic Data Layers and Study Area Map

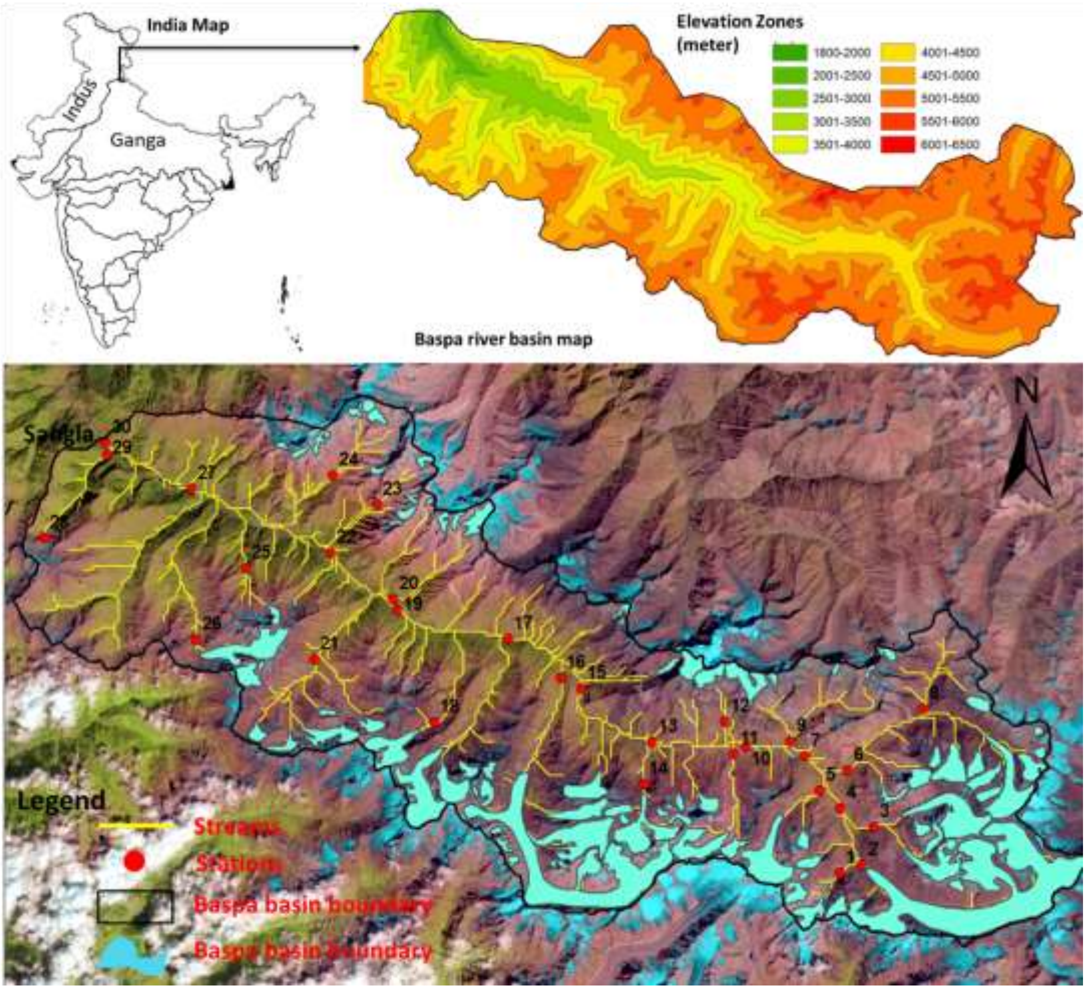


Figure: Study area map showing stations and elevation zones.

7.2 Temporal variations in Glacier Maps in Baspa river basin

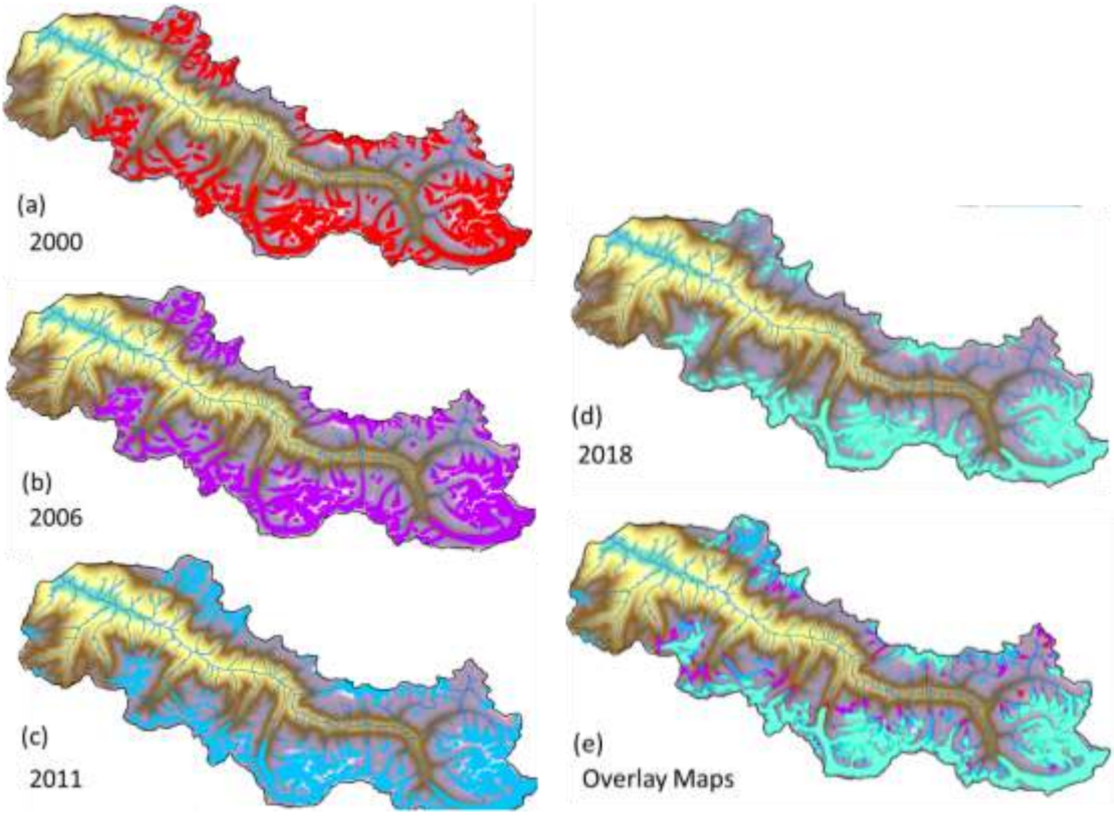
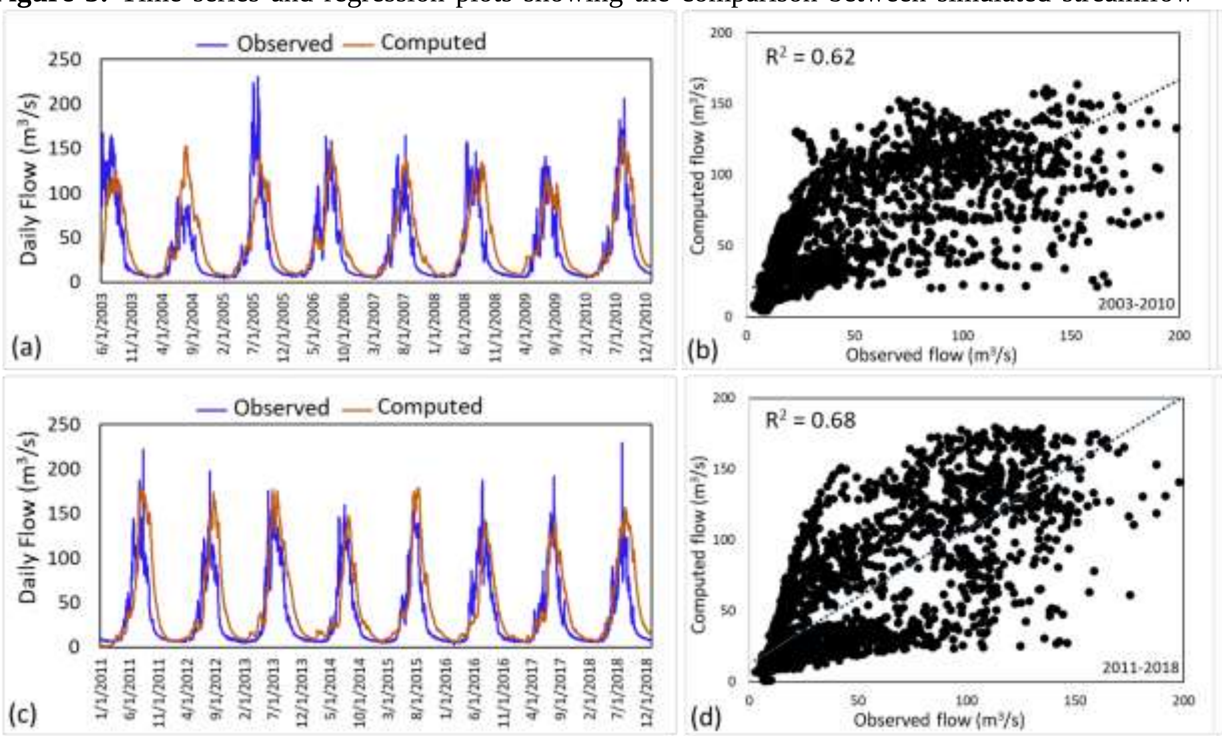


Figure 2: Temporal variations in glacier maps of Baspa basin highlighting reduction in the glacier area from 2000 to 2018: (a) 2000, (b) 2006, (c) 2011, (d) 2018 and (e) overlay of all year maps.

7.3 SPHY Model based simulation of snow-glacier melt induced discharge at the outlet gauge i.e. Sangla.

Figure 3: Time series and regression plots showing the comparison between simulated streamflow



(including snowmelt and glacier melt) against observed streamflow at Sangla gauge during: (a, b) 2003-2010 and (c, d) 2011-2018.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/14

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 Renoj J. Thayyen, Scientist 'E'
   Dr P. K. Mishra, Scientist 'C'
   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**

Experimental hydrology still has a unique place with no alternative for testing and development of new research hypothesis and models. Given the importance of the 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 has been established with a variety of 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 various hydro-climatic variables. This study is planned as the second phase of the project.

The field monitoring of the various variables and development of baseline datasets for 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 the partitioning of rainfall into infiltration and runoff, thus playing a fundamental role in runoff modelling and flood forecasting. Moreover, less accurate measurements can be obtained at a coarse scale (~20 km) using satellite sensors. Finally, spatial downscaling/upscaling approaches can be used to integrate the different techniques, as well as 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 until date:

The various instrumented sites in the experimental catchment was visited by the PI during the strict lockdown period forced by Corona pandemic outbreak, and after lifting up of the lockdown to collect the data and maintenance of the systems. Due some technical glitch in power system of the data logger of Nagini AWS there are some data gaps and we are working on it to fill it scientifically. Based on the available data from the initial three years (2016-18) the SWAT model has been setup up to the gauging site (near to UJS pumping station). Then, the model was calibrated and validated with the observed values. The R^2 value for the calibration period was found to be 0.63, and NSE value was to be 0.55. The SWAT has underestimated the simulated runoff, but it was able to capture the trend of the observed runoff. Also, the rainfall value matches with the observed and simulated runoff. With the calibrated parameter values, the model was validated for the period from 01/01/2018 to 31/12/2018. The R^2 value for the validation period was found to be 0.58, and NSE value was found to be 0.53. During the validation of the model, the hydrological response is slow, and the precipitation over the watershed, at first, saturate the dry surface of the watershed and then the streamflow is initiated. The results of this model are satisfactory, but in order to further improved, we have started revisiting all the basic inputs to the model in terms of more precise DEM, LULC map and a longer and updated time series of climatic inputs. The work is still going on and findings shall be shared in coming working group meeting.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/15

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

The software is being developed on VB.NET platform which offers more features for application development and user-friendliness. The modules are being developed as per the suggestions received during the organization of training courses, in last one decade, from the field engineers. The main focus is :

e) To reduce the input variables for easy preparation of data minimizing the data entry errors.
f) Fixation of the units of different variables so as to avoid confusion and have a uniform input structure.
g) Improvement of menu structure
h) Modification of various programs for more detailed analysis.

Following modules have been developed/modified:

- Capacity computation
    - Sequent-peak analysis
    - Storage yield analysis
        - ✓ Storage yield analysis with working table
        - ✓ Storage yield reliability relationships
- EAC table
    - EAC interpolation
    - EAC approximation
- Inflow estimation
    - Table for different rate of rise
    - Instantaneous results
    - Using reservoir working tables
- Reservoir Routing
- Reservoir sedimentation
- Hydropower analysis
    - Firm power determination
    - Hydropower simulation
- Conservation operation
    - Probable flow estimation
    - Initial rule curve derivation
    - Operation of reservoir systems
- Flood operation
    - Operation of reservoir systems
- Gate Regulation
    - Development of regulation table
    - Real time flow estimates

Few more modules like inflow estimation using rainfall-runoff model, real time operation for conservation purpose, operation of reservoir systems for flood etc will be developed/modified shortly.

NEW STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-22/1

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 'C'
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 develop water accounts for the study basins/sub-basins.
2. To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
3. To develop accounts for agricultural services (i.e., land productivity and water productivity).
4. To prepare the detailed WA+ report for study basins/sub-basins.
5. To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

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%) as given in Figure 1.

The river basins (catchments) are the basic hydrological units to perform/investigate any hydrological phenomenon. The basin size may vary from petals to the size as big as the major river basin systems such as Ganga, Brahmaputra, Barak, Narmada, Cauvery and Mahanadi river basin systems. The CWC classifies the basin on the basis of the catchment area into three major categories as: (i) Major river basins (catchment area> 20,000 km^2), (ii) Medium river basins (20,000<catchment area<2,000 km^2), and (ii) Minor river basins (catchment area< 2,000 km^2).

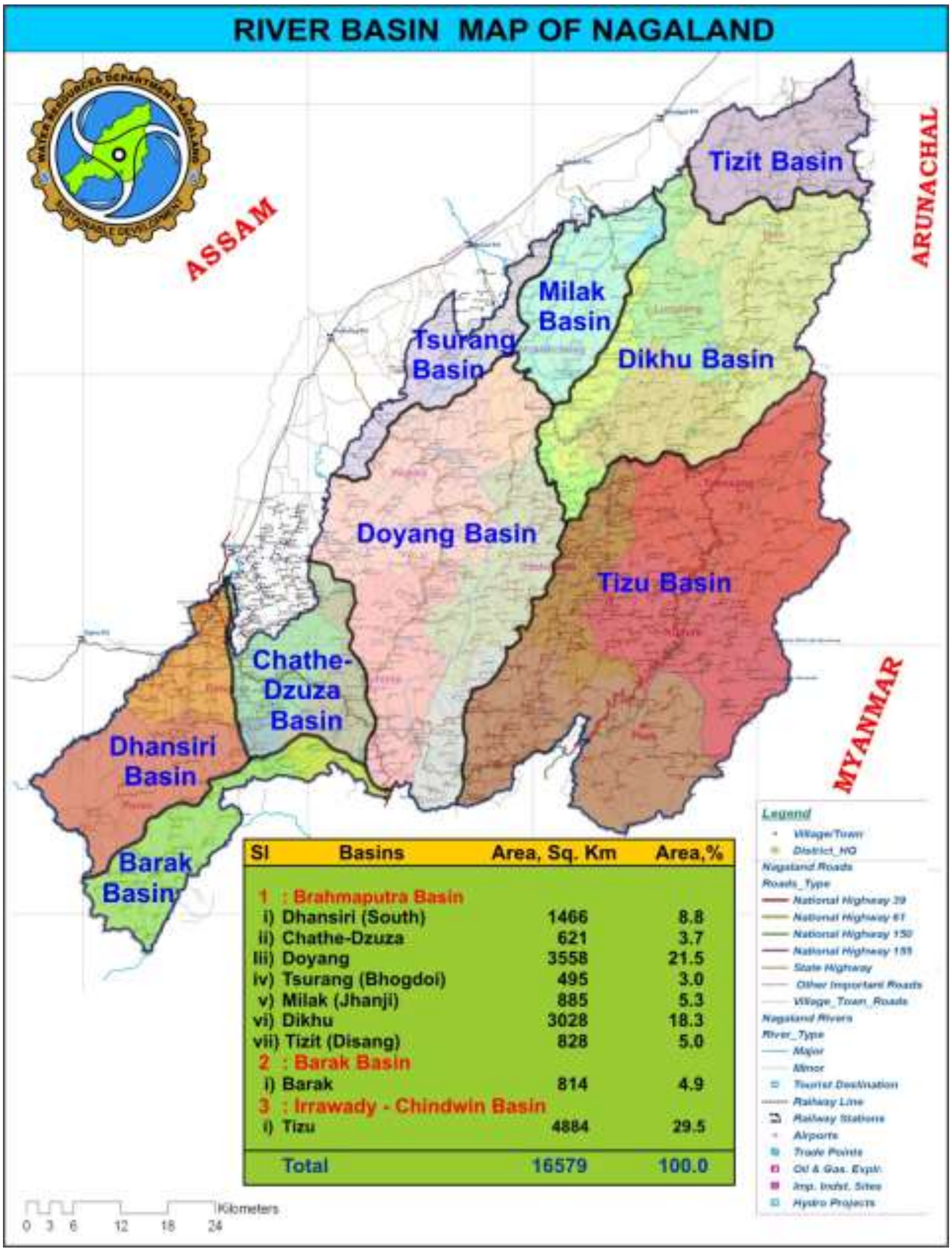


Figure 1: River basin map of the Nagaland (Source: WRD, Nagaland).

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. If we closely look at Figure 1, then we find that out of 9 sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in Meghalaya, only three sub-basins, i.e., Doyang (catchment area = 3558 km^2), Dikhu (catchment area = 3028 km^2), and Tizu (catchment area = 4884 km^2)) are medium river basin and rest six are minor river basins having catchment area ranging from 495 km^2 to 1466 km^2.

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). A detailed information about the data sources and their resolution is provided in Annexure I. 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. Advantages, Challenges and Limitations

- WA+ Framework is a relevant tool for getting well classified (as per the landuse) information describing supply, demand, and consumption in a basin.
- It is very useful for data scarce regions as it uses satellite data/Open source datasets.
- Applying RS data limits the application of the WA+ framework only to past and current situations.
- WA+ Framework may not be relevant for small sub-basins due to existing uncertainties that would be amplified as the spatial scale of application grows finer. These limitations could pose a legitimate obstacle for the application of WA+ beyond regional studies, however may be explored for its applicability to such scales.
- All satellite data products have some level of uncertainty and error that needs to be taken into account because satellites are measuring hydrological processes indirectly.
- The main limitation is that the WA+ cannot replace hydrological models in their function to provide detailed information on water flows in a basin.
- In India, WA+ has been applied on Cauvery (85000 km^2), Subarnarekha (25000 km^2) and Tapi (65000 km^2), i.e. all the applied basins are major river basins.

10.Expected Timeline against the Deliverables: (Tentative)

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+								

NEW STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-22/2

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**	:	**2.5 year (30 months)**
3.	**PI and Co-PI from Lead Organization**	:	PI: Dr. Vishal Singh, Scientist- C Co-PI: Dr. M.K. Nema, Scientist- D
4.	**Investigators from Partner Organization**	:	1. Mr.K. Hamlet, Sr.E.E 2. Mr. Vanlalpekhlua Sailo, AE

5. Origin of the Proposal & Problem Definition

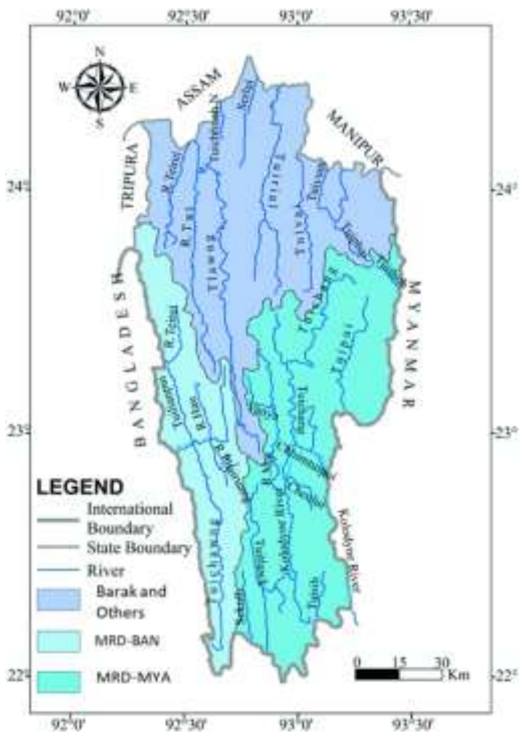


Figure 1: River basin map of the Mizoram showing river basins namely Barak and Other, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA).

Mizoram is a land of rolling hills, rivers and lakes. As many as 21 major hills ranges or peaks of different heights run through the length and breadth of the state with the highest peak 'Phawngpui' (Blue Mountain) towering 2,065 meters above the sea level. The average annual rainfall in Mizoram State is about 2,550 mm for the last 14-year period, and in Aizawl, it is 2,343 mm. The period from November to March is the dry season called 'Rabi', March to May is the summer season and the rest is the rainy season called 'Kharif'. The Kharif's rain concentration is distinct, having 75% rain in a year. Meteorological data other than rainfall are available only in Aizawl. The average maximum and minimum temperature recorded during 2007 to 2012 are 29°C in April and 12°C in January. The humidity ranges from 91% to 99% in the rainy season and 80% to 87% in the dry season. The wind is generally mild, being observed at Aizawl Airport ranging from 1.0 m/sec in the rainy season to 0.4

m/sec in the dry season. Due to increasing population, agricultural demand, changes in LULC conditions, the water resources of the Mizoram state is under threat and thus there is an urgent need to conduct a detailed hydrological assessment within the state to secure water availability for all important needs. It may be worth mentioning here that Water Security Plan has never been prepared for the state of Mizoram by any agency and this will the first of its kind for the state.

6. 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) subbasins 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.

7. Scope of the Study:

The scope of this study is as follows:

i. 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.
j. Long-term Rainfall trend analysis based on rainfall frequencies and intensities to analyse the effect of climate change as per the standard guidelines.
k. 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).
l. 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.
m. Analyzing the effect of climate changes on the hydrological systems, with possible thresholds for resilience under different conditions and combinations anticipated.
n. 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.
o. 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.
p. 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.
q. Selection of dam sites with suggested capacity to meet the growing demand of water in the state.

8. Brief Methodology

A detail methodology diagram of overall approach has been shown in the Figure 2.

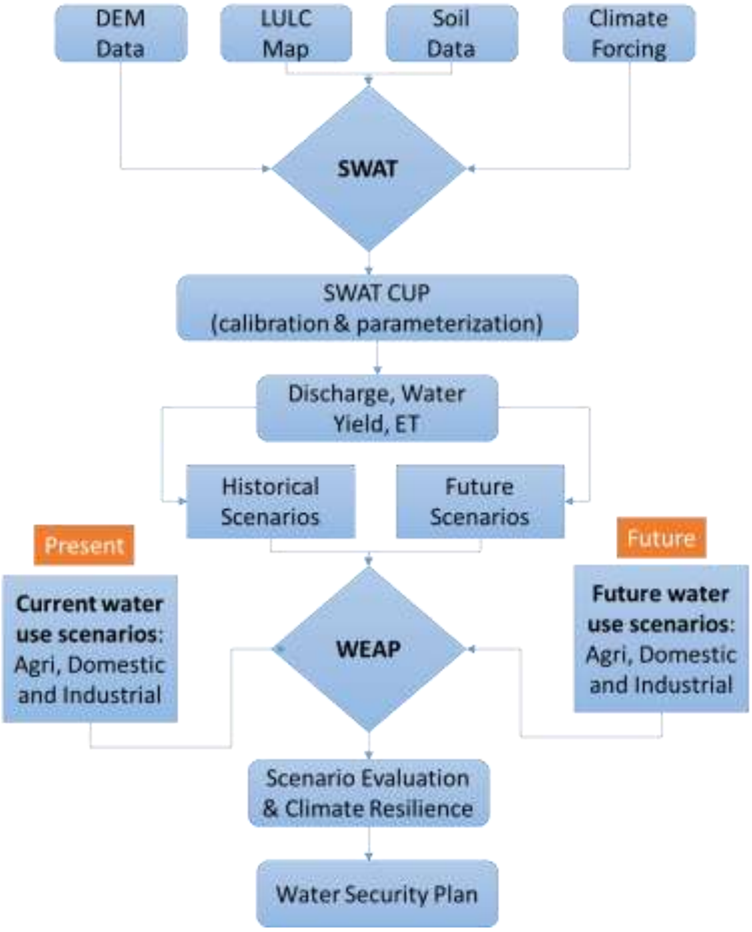


Figure 2. Methodology flow chart.

9. 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.

10. Advantages, Challenges and Limitations

- The proposed Framework including SWAT and WEAP models is a relevant tool for the analysis of hydrological components, water availability, and consumption in the three basins in the state of Mizoram.
- Rainfall extreme and trend analysis under the ETCCDI guidelines will be helpful to explore the future water availability scenarios in Mizoram state under the influence of climate change.
- SWATCUP based model calibration and parameterization would enhance the accuracy of the modelling outcomes in the historical and future projected scenarios.

- WEAP will be utilized to assess the water demand and water utilization as per the availability of water.
- Identification of the best possible locations of the storage/ diversion structures will be helpful for the state in planning
- The resilience limits will guide the state to plan for mitigation measures

11. Expected Timeline against the Deliverables: (Tentative):

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						

NEW STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-22/3

1. **Title:** Monitoring of Hydrological Processes in Glaciated and NonGlaciated Watersheds of North-West Himalaya

2. **Project Team:**

   Dr M. K. Nema, Scientist 'D'
   Dr Sanjay K Jain, Scientist 'G'
   Dr. P K Mishra, Scientist 'C'
   Dr Manohar Arora, Scientist 'D'
   Dr Praveen Thakur, Scientist 'SF' (IIRS)

3. **Project Duration :** 03 Years (04/21 – 03/24)
   Budget: 26.945 Lakh (The cost of instrument and RS data etc. is not covered in the budget of NIH).

4. **Objectives**

   The overall objectives of the study are as follows. NIH will be mainly involved in two watersheds i.e. Henval and Gangotri.
   a) Establishment of instrumented experimental watersheds at different altitudes of NWH.
   b) To improve monitoring and estimates of various hydrological processes and parameters of high altitude watersheds using RS-GIS. (Surface water, sediment load, snow cover, snow pack properties, glacier dynamics and runoff/melt)
   c) To study the response of glaciers on hydrology of high altitude watersheds through on-field observations and modeling approach and upscaling to basins level through hydroglaciological modelling.

5. **Study Area:**

   The study area for this project will be selected watersheds from major river basins of NWH viz. Jhelum, Chenab, Satluj, Beas, Bhagirathi and Alaknanda. Experimental watershed in the different altitude zones will be established for understanding and quantifying various hydrological processes in the above mentioned basins.

6. **Tentative Work Plan:**

S. No.	Activity/Milestone	Time period (in months from date of start)
1	Collection of RS data	
2	Collection of ground based weather & climate data + other datasets	Historical data in first year, con-current data throughout the project
3	Watershed & Glacier Development (Field Instrumentation & Data Collection)	Watershed & Glacier Development in first two years of project, data collection throughout the project
4	Analyses of RS & hydromet. Data + WebGIS interface	All years (Nov-Feb, April, July-August)
5	Field work & ground data for snow, flow, glaciers, watershed, basins +	Watershed field work each season, detailed field work in monsoon, glacier field work in May-September
6	Development, testing and modelling using hydroglaciological model in watershed/glacier scale at test areas	Development, testing in first one and half years, validation in 1 ½ years

7	Up-scaling and testing of watershed based hydroglaciological model to selected river basins of NWH	Testing in second year, validation in last year
8	Publications and project report(s)	Throughout the project, final report in last 3 months of project

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 C
6	Sri. Rohit Sampatrao Sambare	Scientist B
7	Sri Subhash Kichlu	PRA
8	Sri Rajesh Agrawal	SRA
9	Sri N. R. Allaka	RA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हि ष्ठा मयोभुव

APPROVED WORK PROGRAM FOR THE YEAR 2020-21

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	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	On-going
2	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	Jul 2020- Dec 2022	New
3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020- Jun 2022	New
4	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.	Jul 2020- Jun 2022	New
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-Mar 2021	On-going
2	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS (through Scheme funds)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018-Dec. 2020	On-going
3	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/Workshops during 2020-21

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Training on ‘Water security for resilience to deal with	Nov. 2020	Virtual training	Youth and YPs associated with	V C Goyal, Jyoti P Patil,

	disasters and outbreaks', under aegis of INC-IHP (proposal approved by Director, NIH)			WR Assessment & Management	Amrendra Bhushan, Victor Shinde (NIUA)
2	Hands-on training on 'Life Cycle Approach for rejuvenation of ponds and lakes using Nature Based Solutions', to be funded by SERB, DST, GoI (proposal approved by Director, NIH)	Dec. 2020	NIH Roorkee	PG and PhD students of Water resources management/ engineering	Jyoti P Patil, V C Goyal, Omkar Singh, T Thomas, Rajesh Singh, Rohit Sambhare
3	Three-day training program on "Hydrology of water bodies and their development under climatic uncertainty"	Jan 2021	NIH Roorkee	Engineers in Irrigation/PHE/ SWC departments	A. R. Senthil kumar, Santosh M Pingale, Rohit Sambare, N R Alakka
4	Awareness program on Ecohydrology for Wetland Conservation	Feb./ Mar. 2021	NIH Roorkee	Research scholars, and PG students	Rohit Sambare, Suhas Khobragade
5	Awareness Program for School Children	Oct/Nov 2020	5 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
6	Awareness Programme on "Water quality and water budgeting in 5 sub Villages of Ibrahimpur Masahi", Dist. Haridwar	Feb/Mar, 2021 (5 days)	Vill. Ibrahimpur Masahi,	Progressive Farmers	Omkar Singh, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka

Outreach Activities during 2020-21

S.N.	Activity
1	Preparation of a guidebook on 'Role of hydrology in district level planning' (V C Goyal, Jyoti Patil)
2	Preparation of Short Videos (5-10 min) on v) CW & FW/Nature Based Solutions/ Pond Rejuvenation vi) Wetland Hydrology vii) Crop diversity, water productivity & farmer's income viii) On studies and projects of NIH Scientists
3	River Walk of Solani River (stretch to be identified)
4	Any other outreach activity on demand/assigned

PROPOSED WORK PROGRAM FOR THE YEAR 2021-22

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	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 (Extension sought until Sep 2021)	On-going
2	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	Jul 2020-Dec 2022	On-going
3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020- Jun 2022	On-going
4	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.	Jul 2020- Jun 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-Mar 2021 (Extension may be given upto Sept.2021)	On-going
2	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS (through Scheme funds)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018-Dec. 2020	Complete d
3	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	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
2	Awareness Programme for School Children	May-Sept. 2021	3 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
3	Awareness Programmes on “Water Conservation/Pond Rejuvenation” for Stakeholders in Ibrahimpur Masahi village/schools	Sept-Dec, 2021	Ibrahimpur Masahi/ schools	Villagers/ School children	Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka
4	Recorded webinar on ‘Water for public health (W4PH): Preparing for disasters and pandemics’	Starting in June 2021	Online		V C Goyal, Jyoti Patil, Varun Goyal
5	E-module on ‘Urban Hydrology for Water Security’	June 2021	Online		V C Goyal, Jyoti P Patil, Victor Shinde (NIUA)
6	Webinar on ‘Water and Environment: Documentation and Communication Vistas’	June 2021	Online		V C Goyal, Archana Sarkar, Ashwini Ranade, Md Furan Ullah, Charu Pandey, Varun Goyal
7	Training program on “Hydrology of water bodies and their development under climatic uncertainty”	Sep 2021	NIH Roorkee	Engineers in Irrigation/PHE/ SWC departments	A. R. Senthil kumar, Santosh M Pingale, 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	• Any other Outreach activity on demand/assigned

Title of the Study: Conservation of ponds in Ibrahimpur-Masahi village and performance evaluation of natural treatment system.

1. **Study Group:**

<table>
<tr><td rowspan="3">Lead Organization</td><td>Project Investigator
Er. Omkar Singh, Scientist F, RMOD</td></tr>
<tr><td>Co-Investigators
Dr. V. C. Goyal, Scientist G & Head (RMOD)
Dr. Rajesh Singh, Scientist D, EHD
Er. Digambar Singh, Scientist C, RMOD</td></tr>
<tr><td>Scientific/Technical Staff
Sh. Subhash Kichlu, PRA
Sh. Rajesh Agarwal, SRA Sh.
N.R. Allaka, RA</td></tr>
<tr><td>Partner Organization</td><td>Prof. Laurence Carvalho & Team, UK Centre for Ecology & Hydrology, Edinburgh, United Kingdom</td></tr>
</table>

2. **Type of Study:** Mainly Internal funded study with partial assistance from UK-CEH (under UK India SUNRISE Scheme) to cover expenses towards O&M of CW, WQ sampling/analysis, etc.
3. **Nature of Study:** Applied
4. **Date of start:** April 2018
5. **Scheduled date of completion:** March 2021 (Proposed for extension upto Sep. 2021 vide email dated 9/12/2020 from UK-CEH)
6. **Duration of the Study:** 3 Years

7. **Study Objectives:**
   - Water quality investigations of identified ponds, village wastewater and adjacent groundwater sources (hand pumps)
   - Performance evaluation of CW based Natural Treatment System and assessment of treated wastewater for some beneficial uses
   - Societal impact assessment of NTS and Mass Awareness Activities

8. **Statement of the Problem:**

Ponds are a common feature of many villages in rural India, and are widely used as important sources of water for agriculture, aquaculture and groundwater recharge. Water conservation and restoration of village ponds is, therefore, essential for delivering secure water supplies for beneficial use for society. Realising the importance of village ponds for water conservation and sustainable development, the Institute (NIH) has led a demonstration project aimed at rejuvenating a severely degraded pond in Ibrahimpur Masahi village in the Haridwar district of Uttarakhand state. This has been achieved through the establishment of a Constructed Wetland (reed-bed and Canna Lily) Natural Treatment System for the treatment of domestic wastewater that flows into the pond. Constructed wetlands are a low-cost, low energy solution for treating wastewater that use passive filtration and plant growth to improve the water quality and also provide natural habitat.

For an effective evaluation of the constructed wetland treatment system, and assessment of its potential replicability in other village ponds, NIH has collaborated with UKCEH.

The water quality of the rejuvenated pond in Ibrahimpur Village has been compared with a control pond (without any constructed wetland treatment) in a nearby village (Masahi Kala). The role of NIH is to carry out major field investigations related to water quality and groundwater quality and level. The main role of UKCEH has been to carry out joint field investigations pertaining to ecological quality, greenhouse gas emissions and social surveys of village attitudes to the constructed wetland and pond rejuvenation. The sampling locations at village pond having CW-NTS located at Ibrahimpur Masahi is given in Fig. 1.

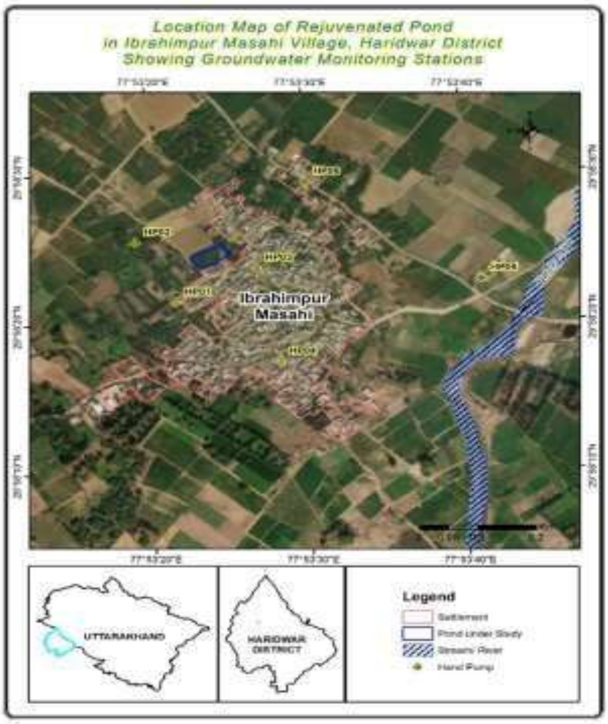


Fig.1a: Location Map of CW NTS site at Village Ibrahimpur Masahi, Dist. Haridwar

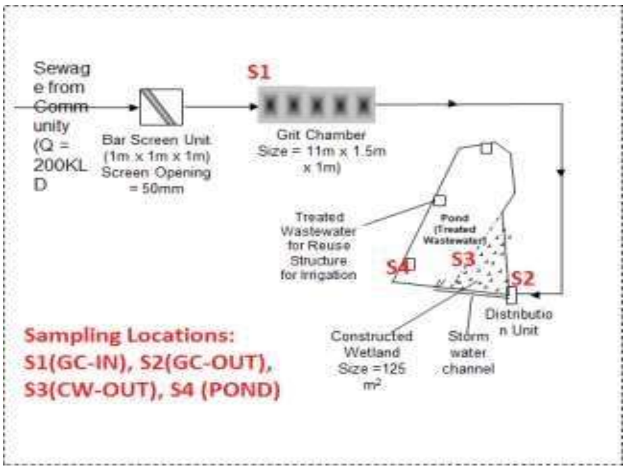


Fig.1b: Flow diagram of CW-NTS showing sampling locations at pond
(Village: Ibrahimpur Masahi, Dist. Haridwar)

9. Action Plan/Methodology:

In this study, requisite water quality parameters from two ponds, CW-NTS and groundwater (handpumps) quality will monitored per standard procedures (APHA 2012). GWL adjacent to ponds will also be monitored during pre & post monsoon periods. Along with UK-CEH team, the health of the water bodies (performance evaluation of CW-NTS pond at Ibrahimpur Masahi with a control pond at Masahi Kala) and its possible impact on society will also be assessed through social survey. Options for the use of treated wastewater will also be explored in the study. The water quality assessment for agriculture purposes (BIS-1987/2001; USDA 1954) and fishery will be performed as per recommended procedures. Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977).

10. Timeline:

S. N.	Work Element	2018-19				2019-20				2020-21			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Review of literature												
2	Water quality investigations of identified ponds, village wastewater and adjacent groundwater sources (hand pumps)												
3	Data compilation & performance evaluation of NTS												
4	Societal impact assessment												
5	Mass awareness activities (i/c dissemination of results through workshop)/HH support to GP for maintenance of CW-NTS pond & utilization of pond water												
6	Report Preparation												

11. Objectives and achievement during last twelve months:

Objectives	Achievements
Water quality investigations of identified ponds, village wastewater and adjacent groundwater sources (hand pumps)	• Water quality monitoring from two ponds (CW-NTS pond: at Ibrahimpur Masahi; Control pond: at Masahi Kala) was carried w.e.f. Nov. 2018 to Oct.2020 at out at regular intervals (no. of samplings=25). • UK-CEH team also visited in the study area (4 times) to collect water quality samples for specific parameters (viz. GHGs, phyto-planktons, zoo-planktons, etc.) and social survey of villager's during study period. • Main WQ Parameters analyzed: pH, EC, DO, BOD, COD, Nitrate, Phosphate, ammonia, TC, FC, GHGs (Methane, Nitrous Oxide, CO_2) and planktons. • GWL & GWQ monitoring of identified hand pumps adjacent to both ponds in the study area.

Performance evaluation of CW based Natural Treatment System and assessment of treated wastewater for some beneficial uses	• The water quality data of treatment chain (Grit Chamber Inlet, Grit Chamber outlet, CW Outlet) as obtained from 25 water quality samplings has been analyzed. • Accordingly, the performance evaluation of CW-NTS (at Ibrahimpur Masahi) has been completed. • Report under preparation (NIH&UK-CEH)
Societal impact assessment of CW-NTS and Mass Awareness Activities	• Outreach activity conducted for villagers/Gram Panchayat Members and concerned local State Govt. officials at village Ibrahimpur Masahi (on dated 20/11/2018). • Transfer of CW-NTS to Gram Panchayat was done on 20.11.2018. The SOP for proper operation and maintenance of NTS was also provided to Gram Pradhan, Ibrahimpur Masahi. • Social survey in Ibrahimpur Masahi village with CEH-UK team member (Er. Elliot Hurst) during March 2020 for assessing societal impact due to pond rejuvenation • Awareness activity was conducted with GP (on dated 18.3.2021).

Recommendation / Suggestion:

Recommendation / Suggestion	**Action Taken**
Nil	-

12. Analysis & Results:

Natural treatment system i.e. constructed wetland has been established in Ibrahimpur Masahi village. In order to evaluate the performance of CW-NTS, water quality of the samples from the treatment chain/units at CW-NTS pond (Ibrahimpur Masahi) and control pond (Masahi Kala) were collected at regular interval. The samples were analyzed for indicator parameters like pH, EC, DO, BOD, COD, NO_3-N, PO_4 and NH_3-N. A schedule of water quality monitoring from both ponds and CW-NTS is given in Table 1. The variation of key water quality parameters (BOD, COD, DO, Nitrate) is given in Fig. 2 to 5. The results of statistical analysis of data pertaining to BOD, Phosphate & E-coli are given Fig. 6&7, respectively. The variation of ground water levels (DTW, m bgl) are given in Fig. 8, which indicates improvement of groundwater levels as compared to pre rejuvenation period of pond (Jan. 2017) with post rejuvenation period (Nov. 2017 onwards). Impact of pond rejuvenation on various indicator parameters (CW-NTS pond and control pond) is given in Fig 9.

Table 1: Schedule of water quality monitoring from both ponds and CW-NTS

Month	**Date of Sampling**	**Months**	**Date of Sampling**
November, 2018	2/11/2018	April, 2019	24/04/2019
	14/11/2018	May 2019	09/05/2019
	20/11/2018		23/05/2019
	28/11/2018	June 2019	04/06/019
December, 2018	12/12/2018	July 2019	2/07/2019
	27/12/2018	August , 2019	28/08/2019
January, 2019	15/01/2019	September, 2019	13/09/2019
	30/01/2019	October, 2019	10/10/2019
February, 2019	13/02/2019		25/10/2019
	28/02/2019	November, 2019	19/11/2019
March, 2019	13/03/2019	December, 2019	05/12/2019
	27/03/2019	March 2020	02/03/2020

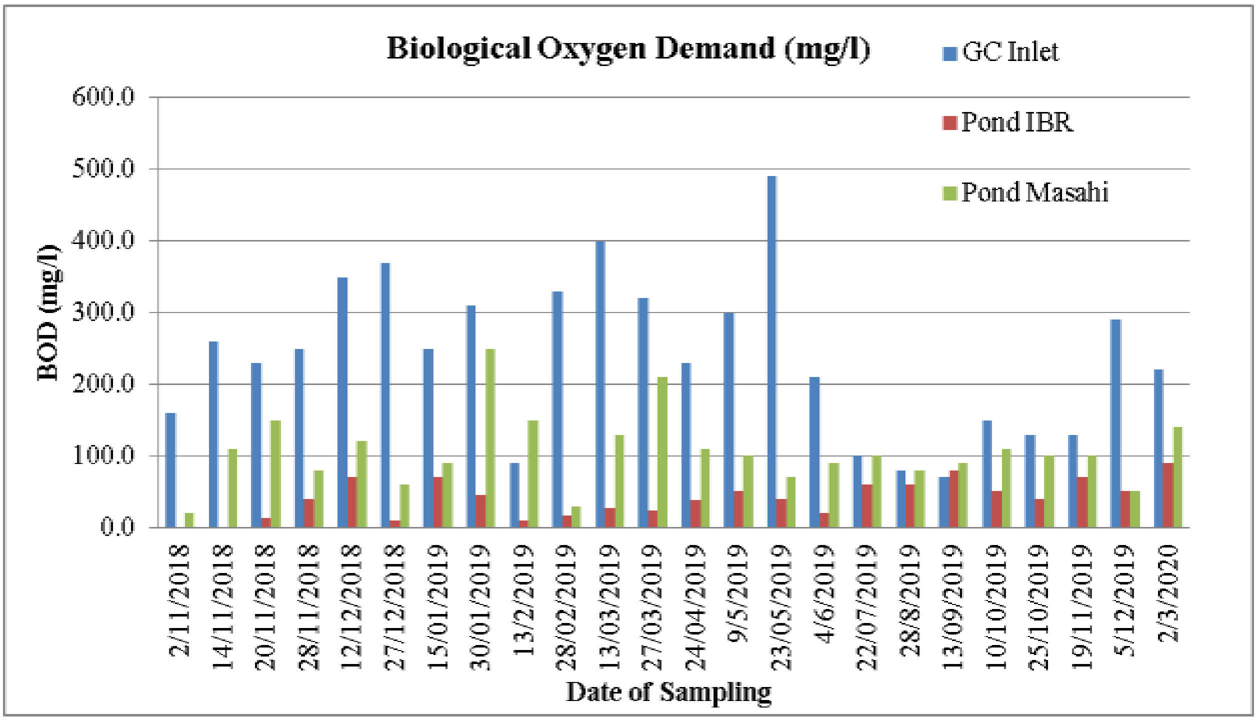


Fig. 2: Biological Oxygen Demand (mg/l) of Ibrahimpur and Masahi pond

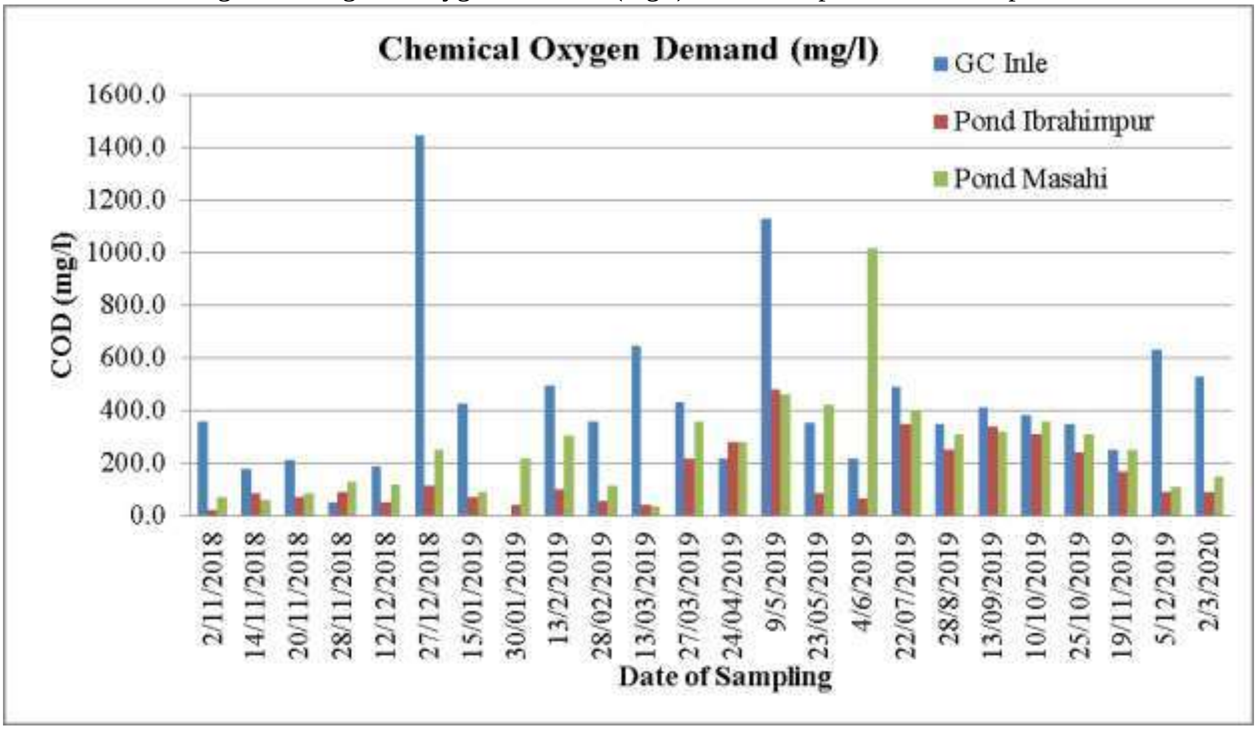


Fig. 3: Chemical Oxygen Demand (mg/l) of Ibrahimpur and Masahi pond

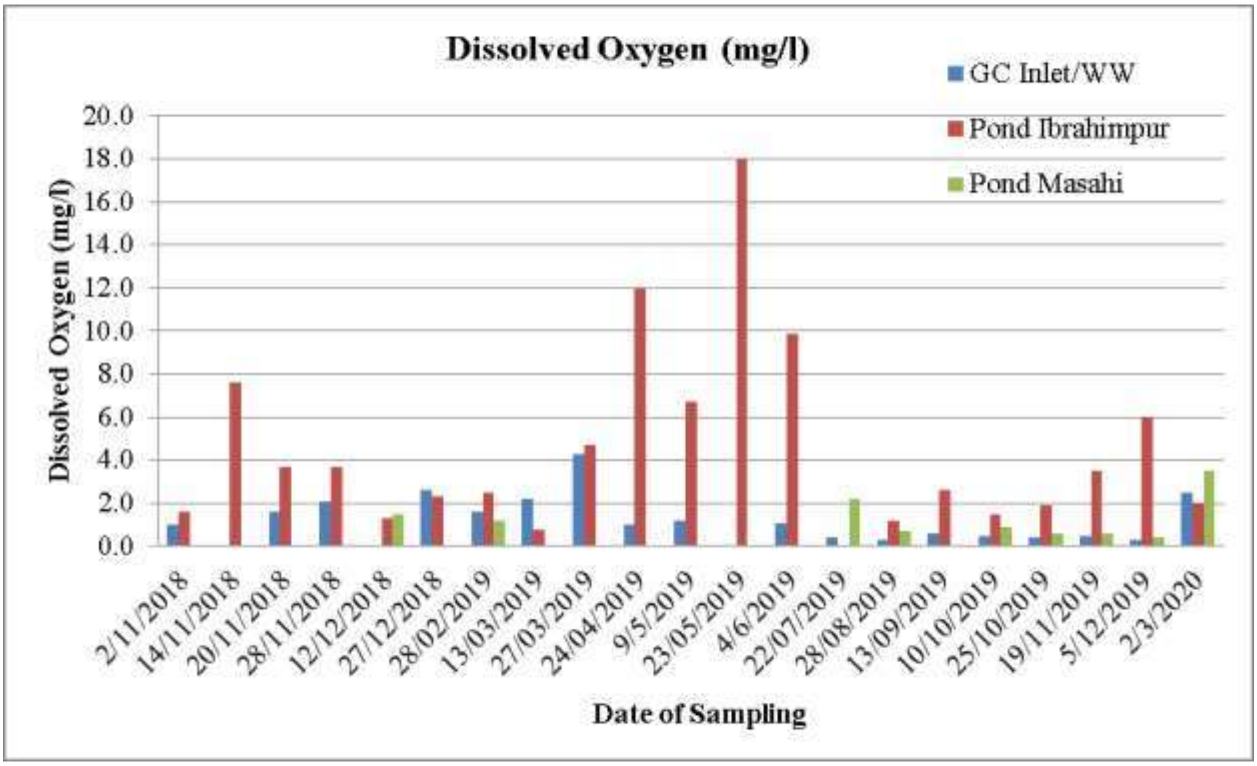


Fig. 4: Dissolved Oxygen (mg/l) of Ibrahimpur and Masahi pond

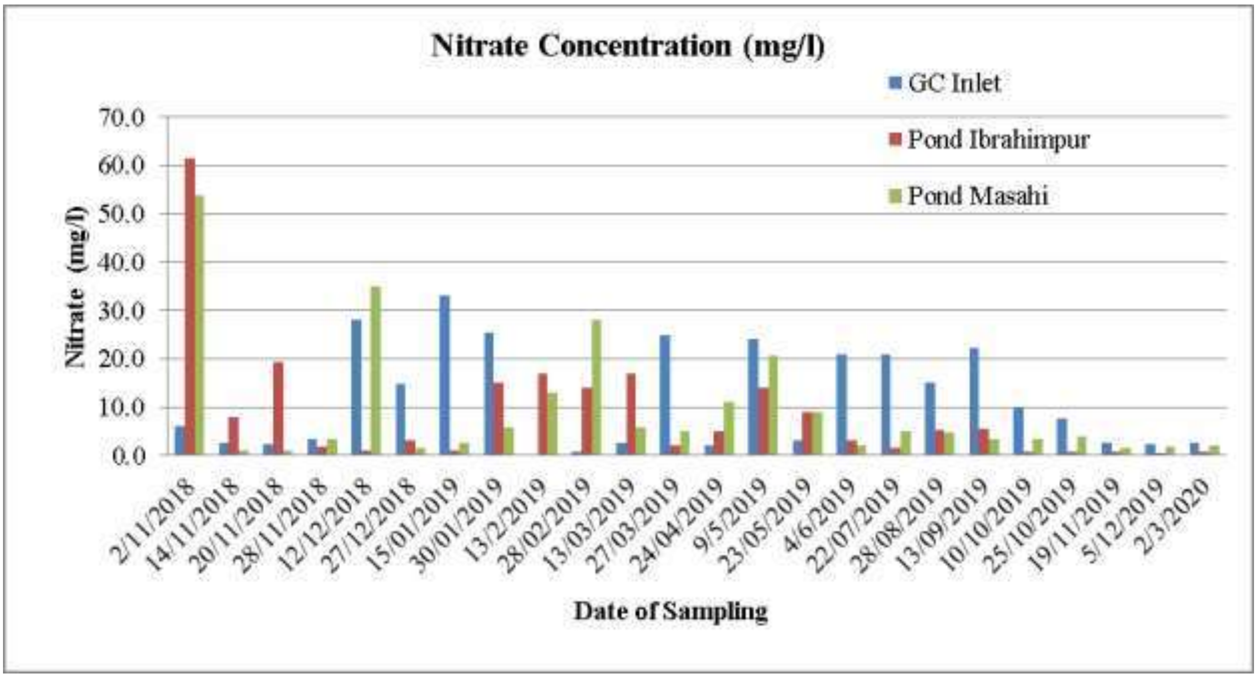


Figure 5: Variation of nitrate concentration (mg/l) at Ibrahimpur and Masahi ponds

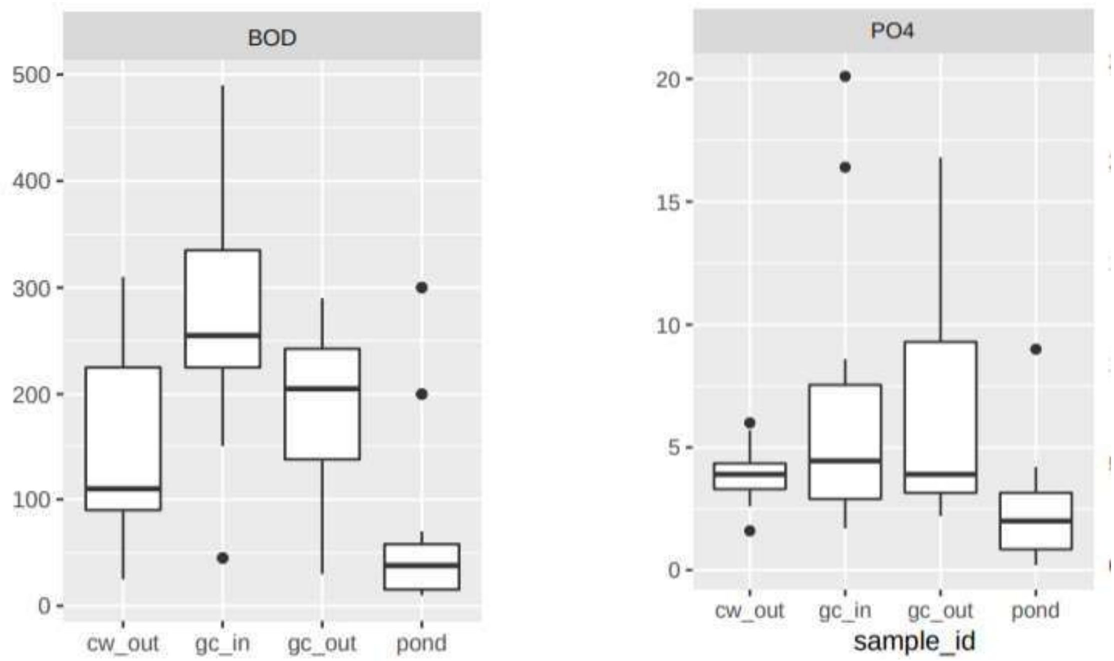


Fig. 6: Analysis of BOD and Phosphate concentrations along the treatment chain (CW-NTS site)

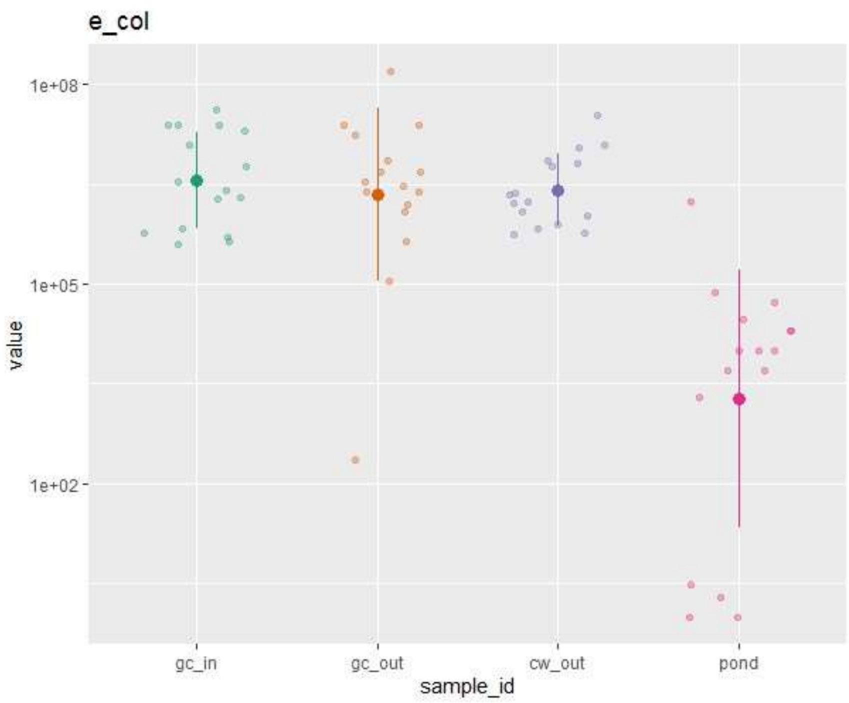


Fig. 7: E. coli concentrations along the treatment chain (log scale on y axis) at CW-NTS pond (Ibrahimpur Masahi)

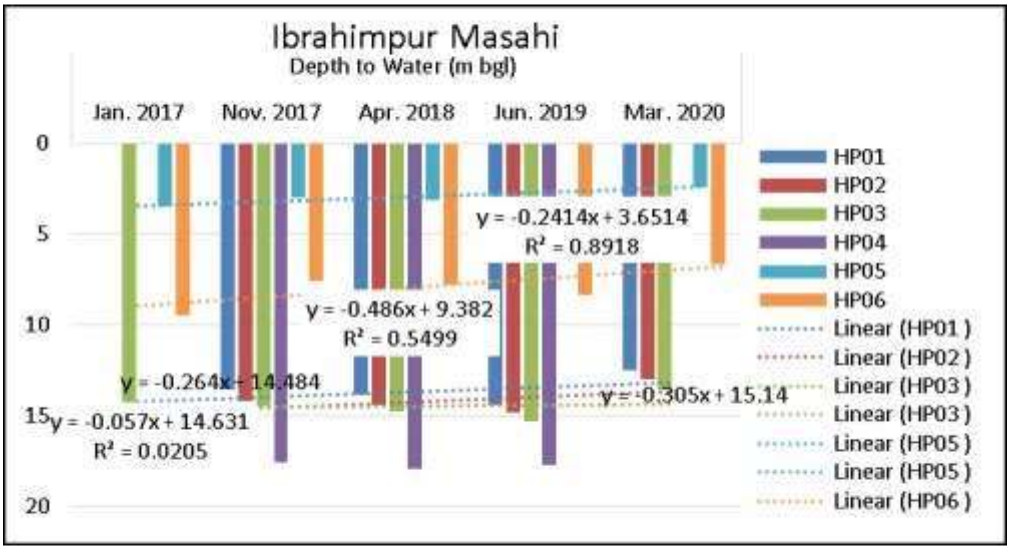


Fig. 8: Trend lines showing improvement of ground water levels (DTW, m bgl) around rejuvenated pond at Ibrahimpur Masahi (Dist. Haridwar)

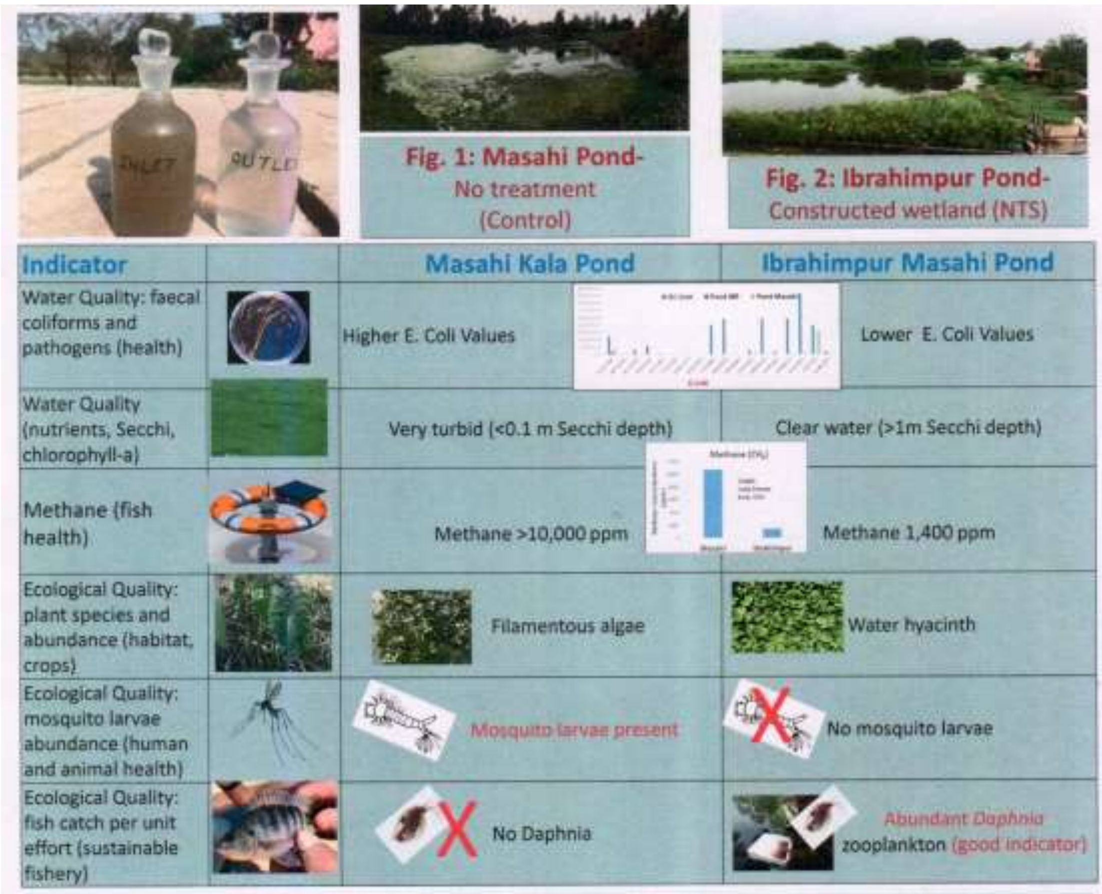


Fig. 9: Impact of pond rejuvenation on various indicator parameters (CW-NTS pond and control pond)

The demonstration study has shown that the treatment of wastewater entering the pond through the constructed wetland has greatly improved water quality (reduced organic loads, coliform bacteria and nutrients and increased dissolved oxygen levels) compared with the control pond. The ecological quality of the pond with constructed wetland treatment is also much higher, with associated enhanced ambience for villagers. The improved pond water quality will also result in improvements in the groundwater quality of the area which will also have positive impacts on human and animal health. The local villager/ stakeholders are utilizing pond water for agriculture and happy with the improvement in the status of the pond and its surroundings.

15. End Users / Beneficiaries of the Study: Villagers & Stakeholders

16. Deliverables: Performance Evaluation Report of CW-NTS, Societal impact of rejuvenated water body.

17. Major items of equipment procured: Nil

18. Lab facilities used during the study: WQL, GWHD (NIH)/ IIC (IITR)

19. Data procured or generated during the study: Pond and groundwater quality and groundwater level data.

20. Study Benefits / Impacts:

- Improved water quality of CW-NTS pond (reduced organic loads, coliform bacteria and nutrients and increased dissolved oxygen levels) compared with the control pond.
- The ecological quality of pond with constructed wetland treatment is also much higher.
- The local villagers/ stakeholders are utilizing pond water for agriculture and happy with the improvement in the status of the pond and its surroundings.
- The outcomes from the study will be utilized to frame a policy document on domestic wastewater treatment through constructed wetlands.

21. Involvement of end users/beneficiaries: Villagers and Gram panchayats

22. Specific linkage with Institution and /or end users / beneficiaries: Gram Panchayats & local District Administration.

23. Shortcoming/Difficulties: Maintenance of CW-NTS related issues

24. Future Plan (upto Sept. 2021): Vide email dated 9/12/2020, UK-CEH has requested to extend the study upto Sept., 2021 to carry out following tasks:

- Dissemination of findings through training/workshop/Webinar for replication of the NTS based technology for domestic wastewater treatment.
- To carry out limited WQ monitoring from CW-NTS after increasing density of plants.
- Mass awareness activities/outdoor activity with stakeholders/HH support to GP for maintenance of pond and utilization of rejuvenated pond water.

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

      Dr. V. C. Goyal

3. **Type of Study:** Internal; **Budget**: 40.0 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 2). The area of Upper Dhasan Basin is 3565 sq. km.

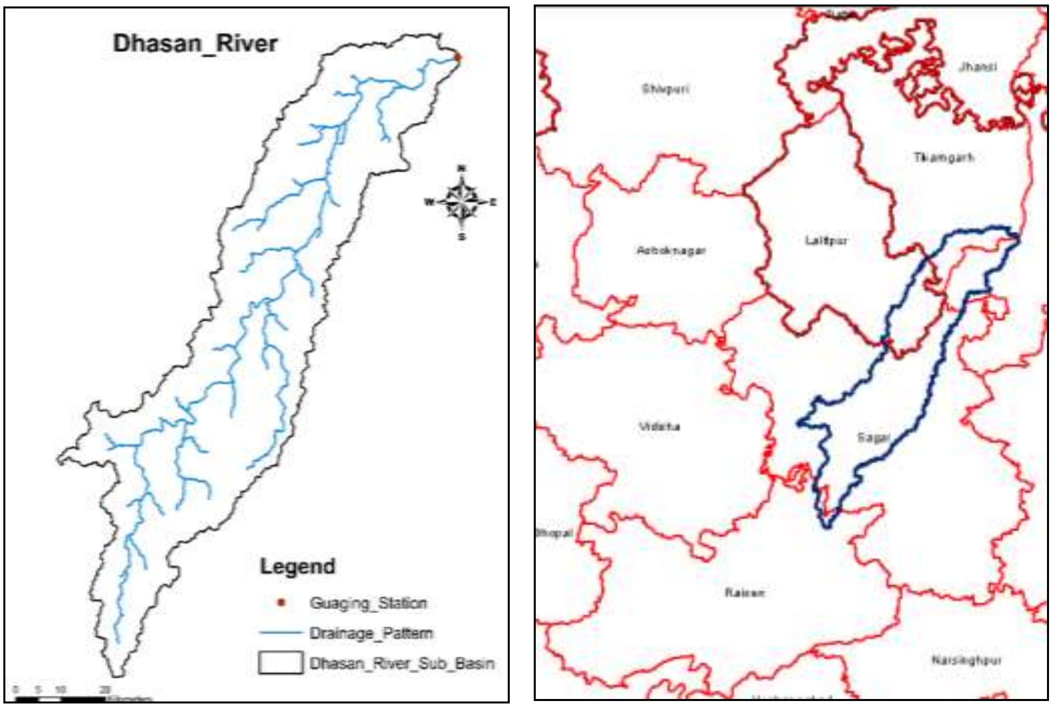


Figure 2: Location of study area (Upper Dhasan basin)

10. **<u>Detailed Methodology:</u>**

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.

11. **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										

12. Objective and achievement during last seven months (Sept 2020-Mar.2021):

<u>1. Data Inventory</u>

(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

2. 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.

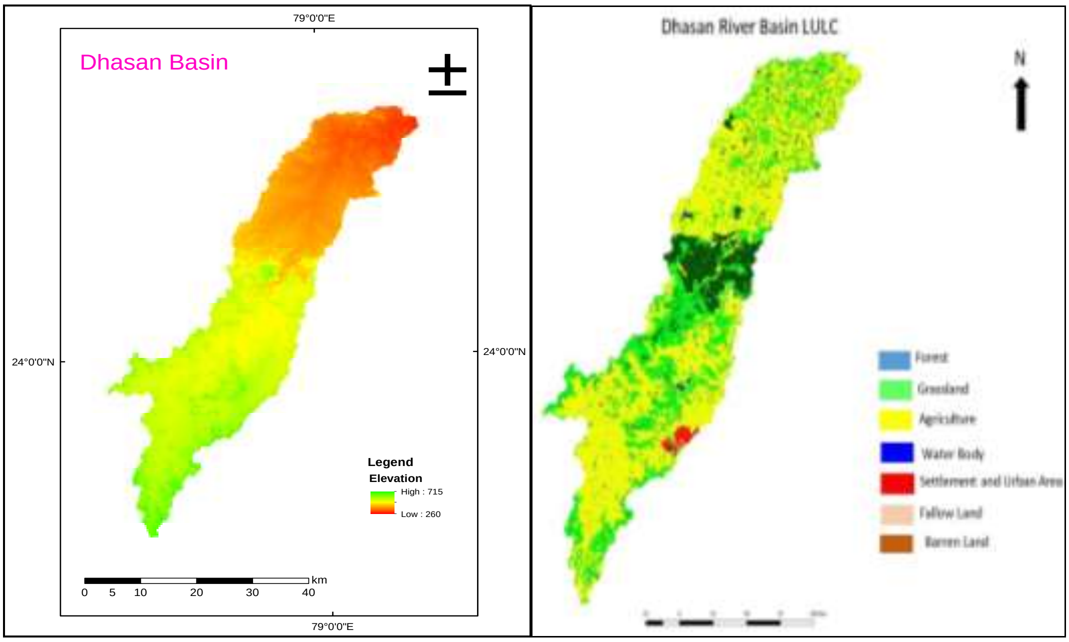


Figure 3 DEM and LULC maps

Table 2 Land use/land cover statistics of Dhasan river basi**n**

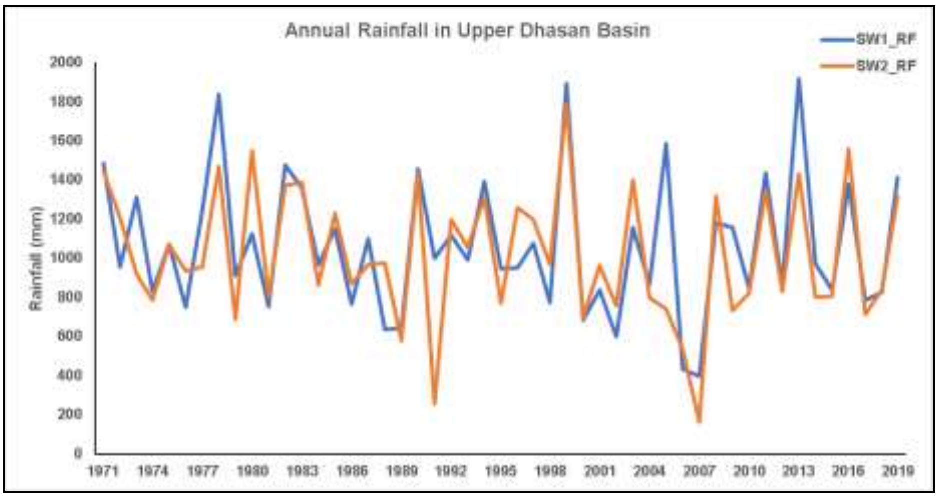
Land use/cover categories	**Area (km^2)**	**Percentage (%)**
Agriculture Area	1982.23	58
Grassland	959.58	28
Forest Area	304.91	9
Barren land	74.02	2
Fallow land	58.20	2
Urban area	29.41	1
Water bodies	18.04	1

3. 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



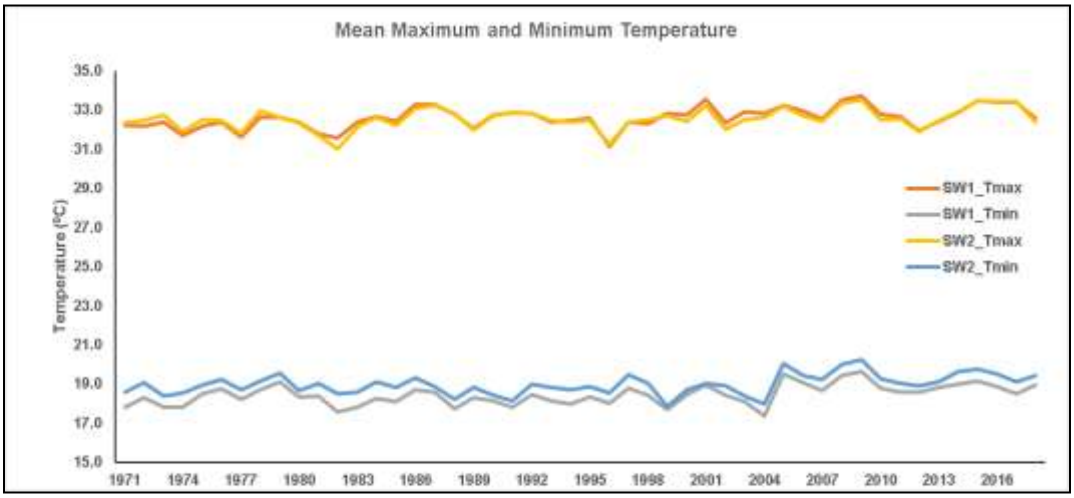


Figure 4 Annual rainfall and mean temperature variation in basin

4. 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.

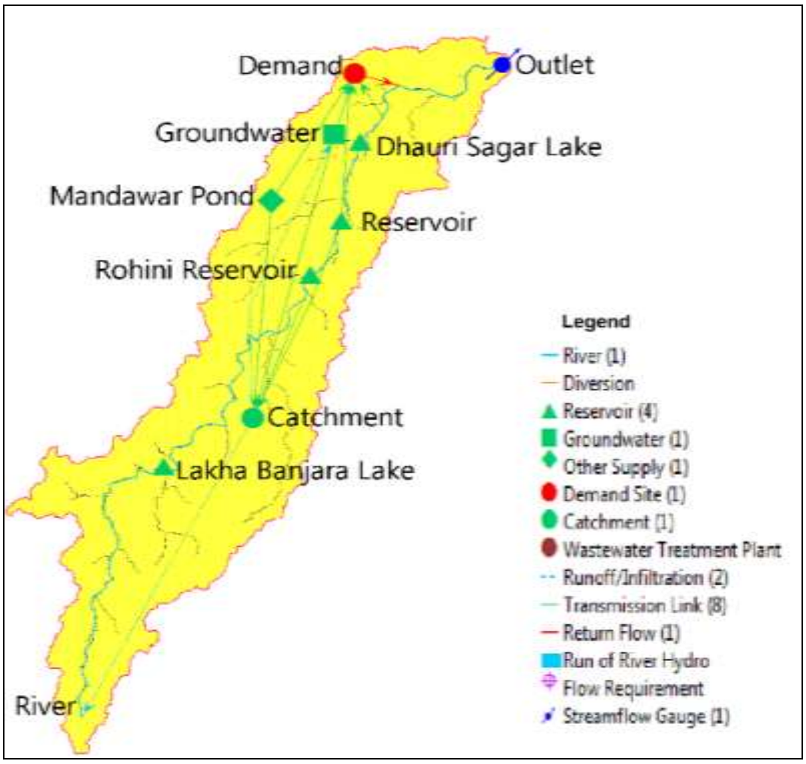


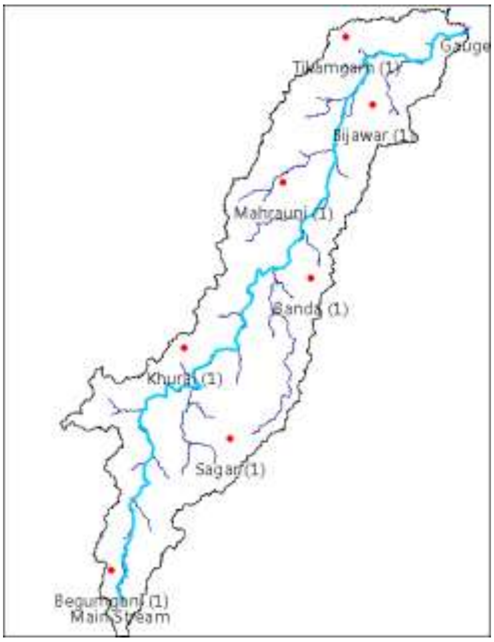
Figure 5 WEAP model formulation for Dhasan Basin

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. The basin is spread over 7 administrative blocks of five different districts of Bundelkhand region (Table 4)

The model setup is under progress.

Table 4 Administrative coverage of the basin

State	District	Blocks
Madhya Pradesh	Raisen (1) Sagar (3) Tikamgarh (1) Chhatarpur (1)	Begamganj Sagar, Khurai, Banda Tikamgarh Bijawar
Uttar Pradesh	Lalitpur (1)	Mehraunipur



5. WA+ Framework- The spatial database is created for WA+ framework analysis. The analysis will be completed as per scheduled activity.

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 F, NIH, Roorkee
Dr. Gajendra Singh, Scientist, USAC, Dehradun
Scientist from Wetlands International South Asia, New Delhi
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.

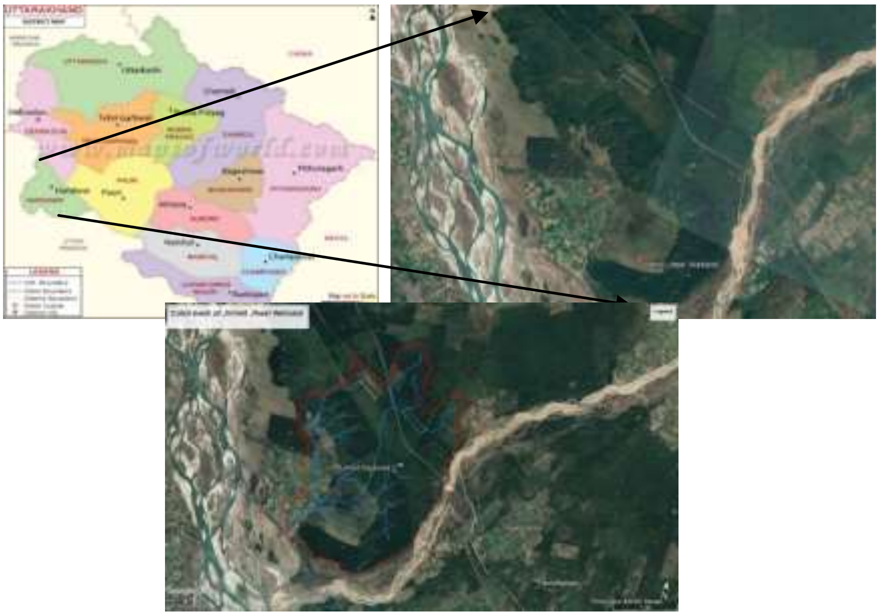


Figure 1: Catchment of Jhilmil Jheel Wetland (Catchment derived from NRSC's high resolution CARTODEM)

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.

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												

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

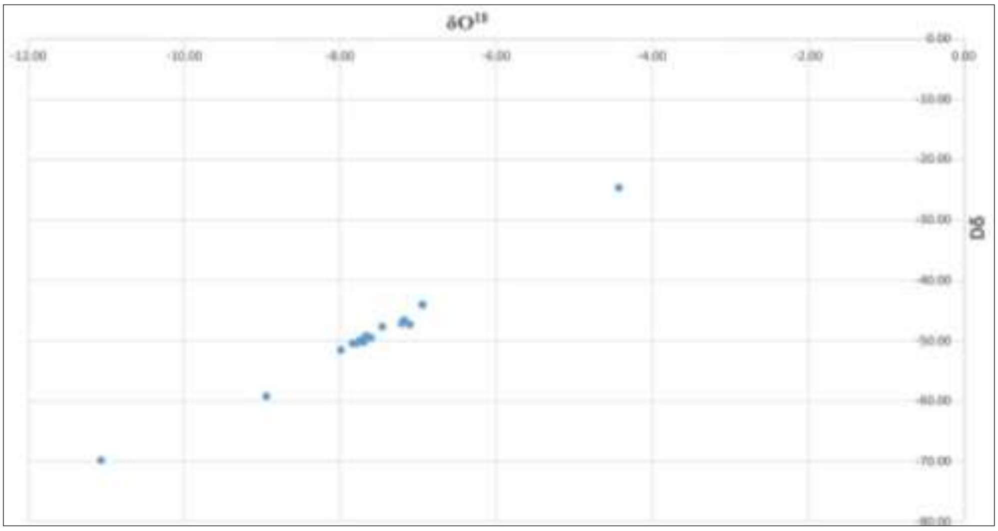


Figure 2: Isotopic composition of collected water samples from different sources (Oct 2020)

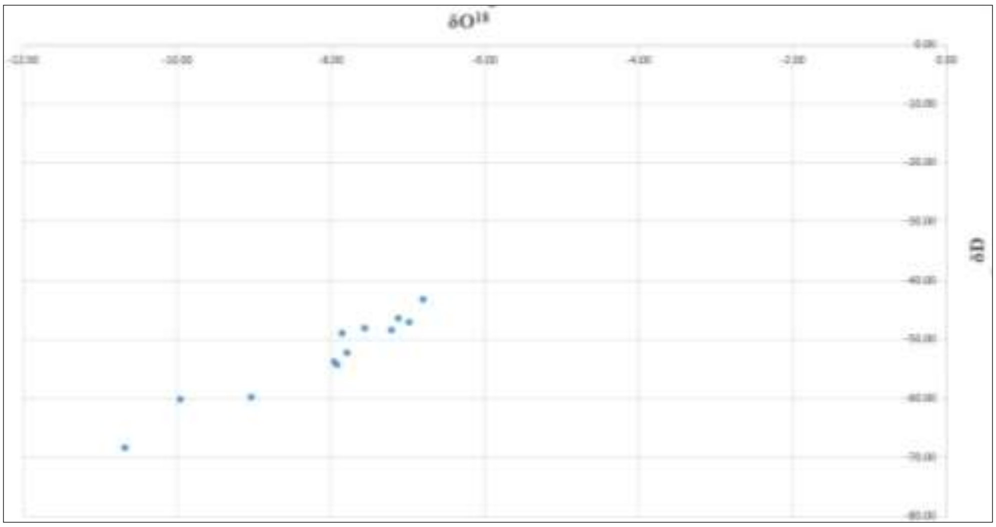


Figure 3: Isotopic composition of collected water samples from different sources (Jan 2021)

- Collection of water quality samples for post monsoon period has been done. Cation and anion analysis has been performed.
- High resolution Carto DEM has been procured from NRSC Hyderabad. The approval for procurement of the high resolution Cartosat 3 multispectral image has been done for generating latest high resolution Land Use Land Cover (LULC) map.
- 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.

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:

Mewat district consists of five blocks such as Nuh, Taoru, Punhana, Nagina and Firozpur Jhirka. Three blocks, Nuh, Nagina and Punhana, are considered for setting up of WEAP model. The drainage network for these blocks has been created by digitizing the topo sheets (53D/15, 53D/16, 53H/3, 53H/4, 54A/13, 54A/14, 54E/1, 54E/2) of 1: 50000 scale downloaded from Survey of India website. The drainage and block boundaries are given in Fig 1. The initial setting up of WEAP model and schematic diagram is given in Fig 2. The area of three blocks lies in between 27° 45´ N to 28° 15´ N and 76° 45´ E to 77° 15´ E. The data required for setting up of the WEAP model are catchment details, water demand from various sectors such as domestic,live stock, irrigation and industrial uses, catchment hydrology such as river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc, meteorological data such as rainfall, minimum and maximum temperature, solar radiation, priority of demand. The area of Nuh, Punhana and Nagina are 459.16, 282.46 and 216.16 sqkm respectively. The population of Nuh, Punhana and Nagina are 2,70,841, 2,62,809 and 1,47, 426 respectively based on the 2011 census. The population projection of Haryana state based on the report of the technical group on population projections constituted by National Commission on Population, May 2006 for the period from 2001-2026 is given as follows:

Population growth rate of Haryana

2001-05	2006-10	2011-15	2016-20	2021-25
2.0	1.7	1.5	1.3	1.1

The population of Nuh, Punhana and Nagina are 306634, 2,97,544, and 1,66,911 respectively by the end of 2020 based on the population project rate as mentioned above. The gridded rainfall, maximum and minimum temperature have been obtained from IMD website for girds lies between 27° 45´ N to 28° 15´ N and 76° 45´ E to 77° 15´ E and the average values are given in the figures 3, 4 and 5. The computation of evapotranspiration requires the data of extra terrestrial radiation for the latitudes 27° 45´ N, 28 N, 28° 15´ N and have been obtained from https://www.engr.scu.edu/~emaurer/tools/calc_solar_cgi.pl. The extra terrestrial radiation values are given in Fig 6.

Fig 1 Drainage network of Mewat (Nuh, Punhana, Nagina)

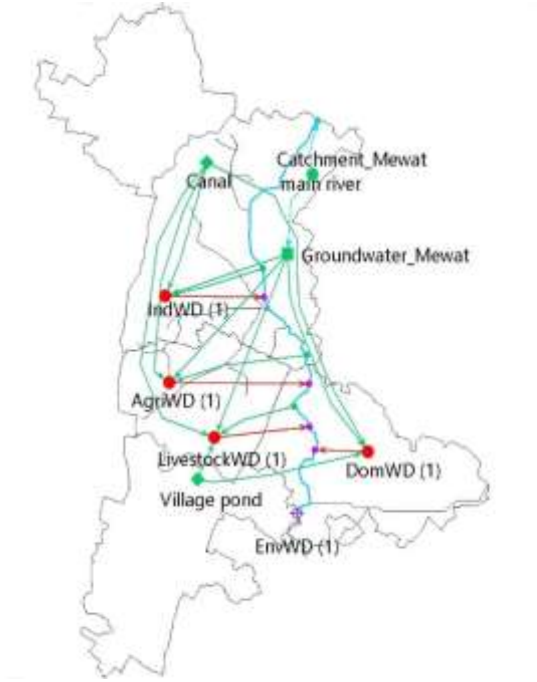


Fig 2 Schematic diagram of WEAP model for Mewat (Nuh, Punhana, Nagina)

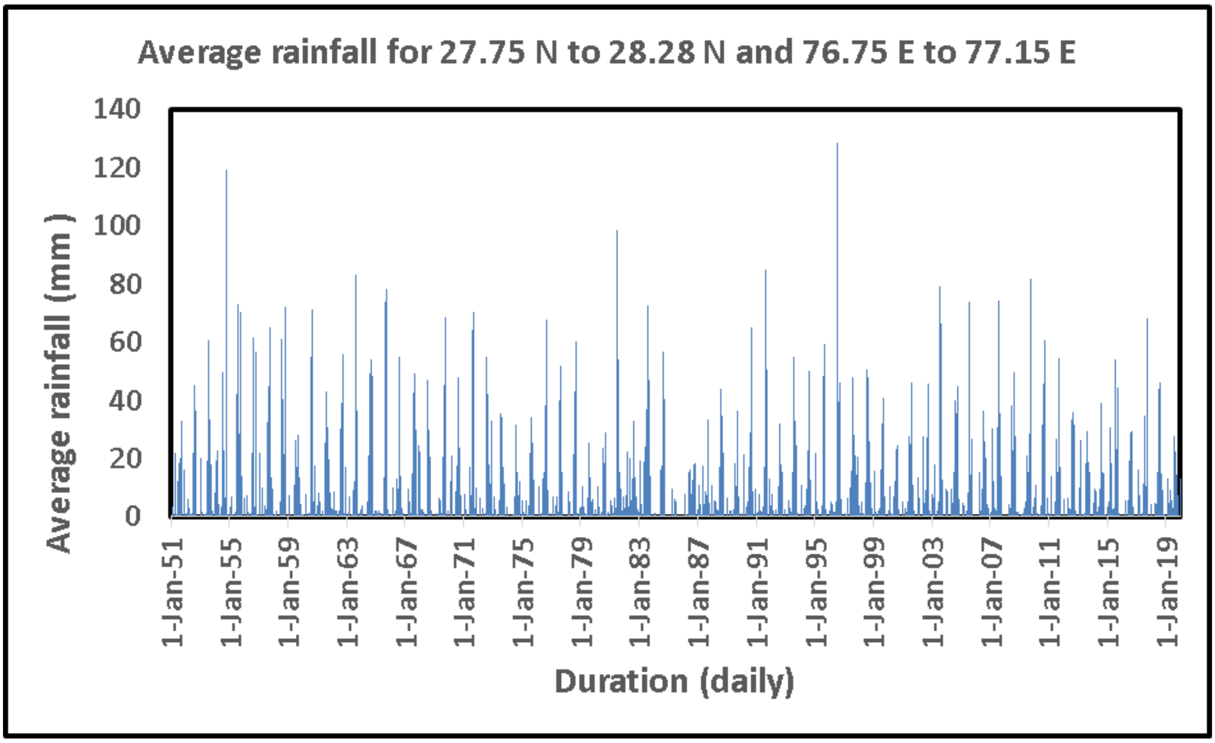


Fig 4. Average rainfall for 27.75 N to 28.28 N and 76.75 E to 77.15 E

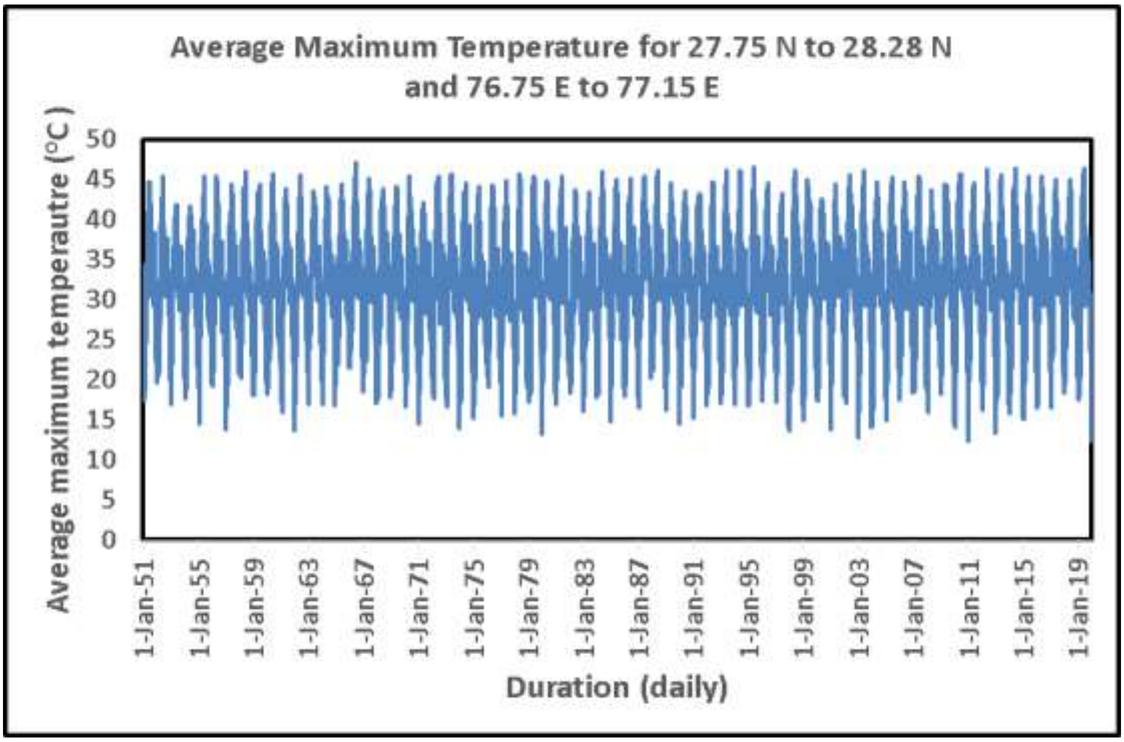


Fig 4. Average maximum temperature for 27.75 N to 28.28 N and 76.75 E to 77.15 E

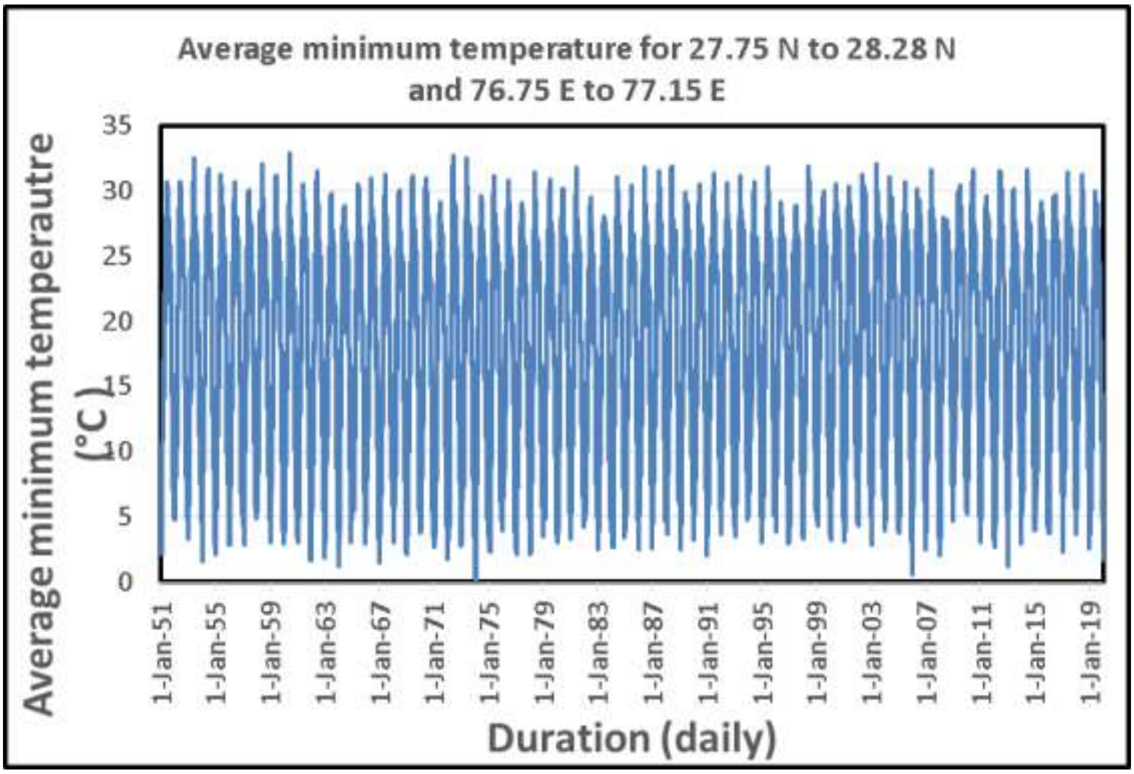


Fig 5. Average minimum temperature for 27.75 N to 28.28 N and 76.75 E to 77.15 E

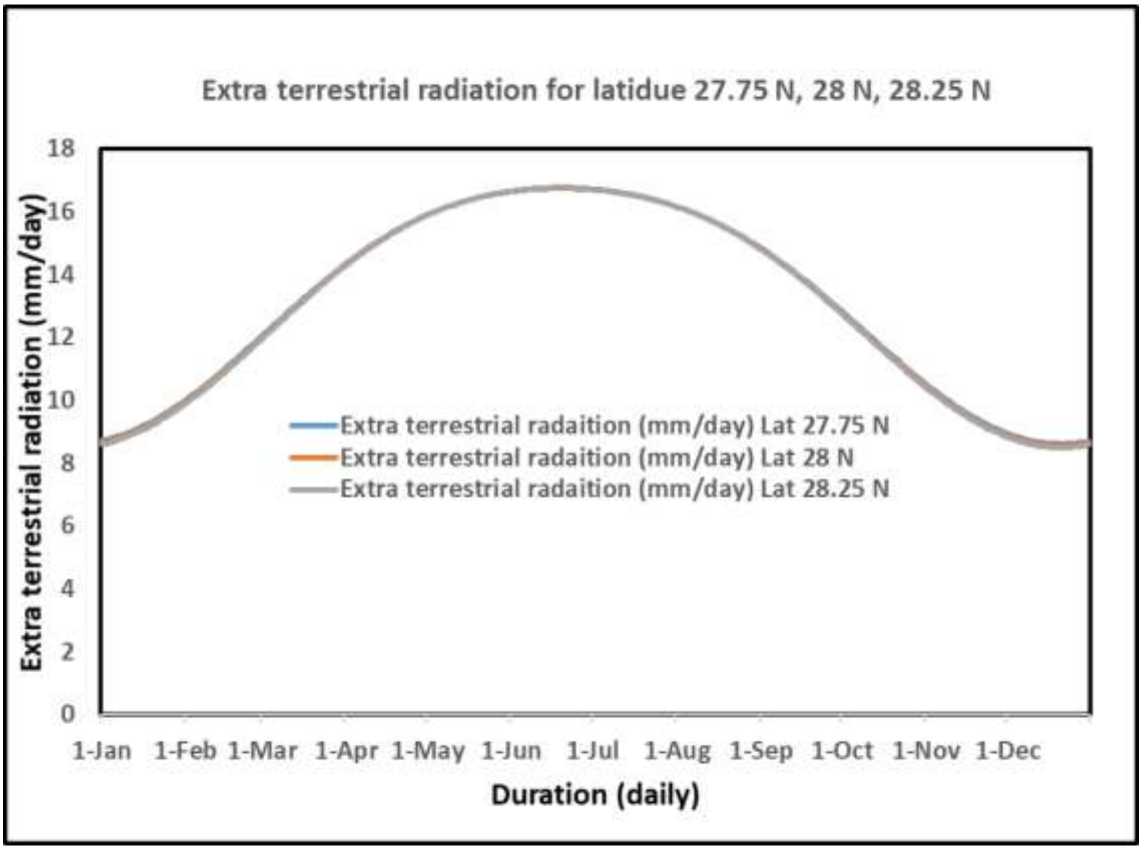


Fig 6 Extra terrestrial radiation for latidue 27.75 N, 28 N, 28.25 N

The values of evapotranspiration by Penman-Monteith and Hargreaves methods are being estimated using average rainfall, maximum and minimum temperature and extra terrestrial radiation. The crop details, cost of cultivation, crop yield for the three blocks are being collected.

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

1. **Title of the Study: Rejuvenation of Village Ponds in Identified Villages of Baghpat, Ghaziabad and Meerut Districts of Uttar Pradesh**

2. **Study Group:**

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigator Dr. Rajesh Singh, Sc. C, EHD Dr. V. C. Goyal, Sc. G, RMOD Er. Digambar Singh, Sc. C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N. R. Allaka, RA Dr. N. G. Shrivastava, Senior Expert Dr. Nihal Singh, Research Scientist Dr. Kalzang Mathus, Research Associate Sh. Sandeep Yadav, Research Associate Sh. Subhash Vyas, Project Assistant
Civil Work Execution Agency	NPCC Limited (A GoI Enterprise), Noida

3. **Type of Study:** Invited study by MoWR, RD & GR,
4. **Budget:** Rs. 780 Lakh (through Scheme budget)
5. **Nature of Study:** Applied Research
6. **Date of start & duration:** Jan. 2018 (3 Years)
7. **Scheduled date of completion:** Dec. 2020

8. **Study Objectives:**
    - Rejuvenation of identified village ponds by carrying out de-weeding, de-silting and associated civil works for development of Natural Treatment System (NTS) in the ponds for their rejuvenation.
    - Establishment of appropriate phyto-remediation based Natural Treatment System (NTS) at identified pond sites for treatment of wastewater
    - Capacity building/Mass Awareness Activities.

9. **Statement of the Problem:**

With the availability of millions of village ponds and local drains, there exists a vast potential of recycling and reuse of wastewater through simple retrofitting techniques. Such decentralized treatment of these small water bodies is an emerging need for their restoration and preservation, leading to multiple benefits of disaster resiliency, groundwater recharging, environment regeneration and livelihood generation at the local watershed level. The Ministry of WR, RD & GR (GoI) directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Baghpat, Ghaziabad and Meerut (Fig. 1).

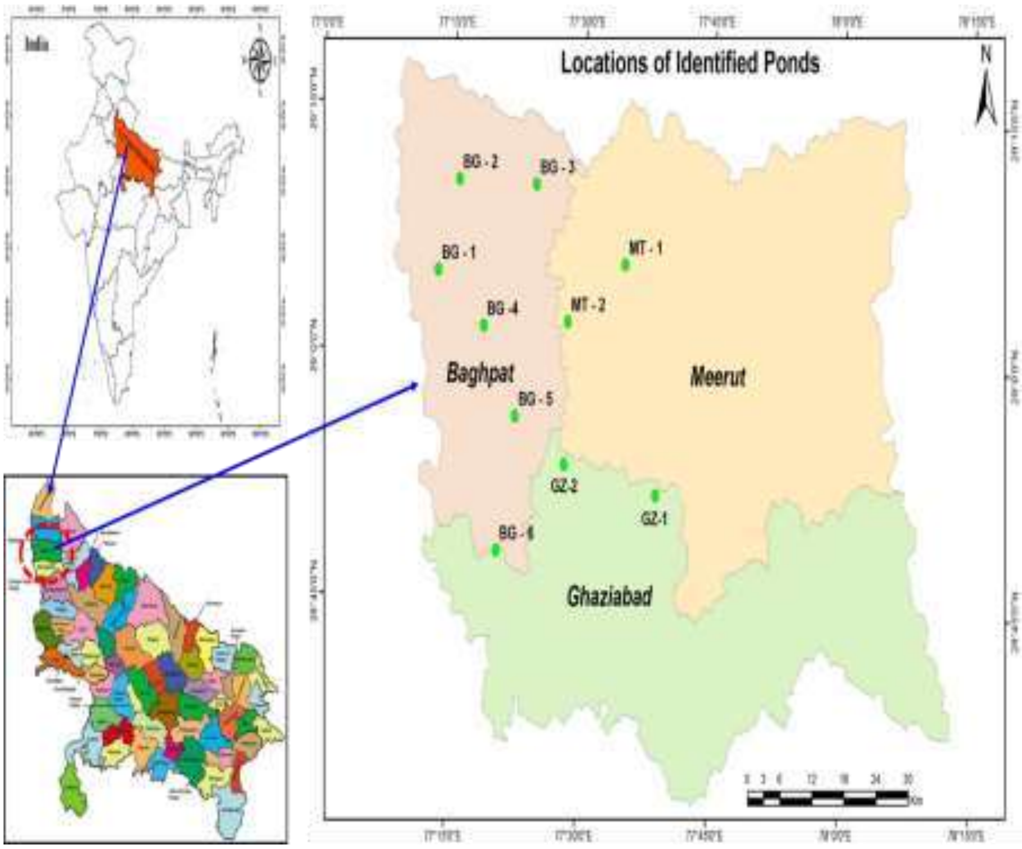


Fig. 1: Location map of identified village ponds in Baghpat, Ghaziabad and Meerut Dist.

At present, the wastewater generated from most of the villages in the country is discharged into the village ponds and leads to eutrophication of these ponds and growth of blue green algae, making the water toxic and unfit for the consumption, even by animals. Moreover, the organic laden water in the pond during recharge to the aquifer transports organics into the aquifer material enhancing the undesirable anaerobic microbial action on the aquifer media resulting in the dissolution of toxic metals like arsenic etc. into the groundwater. The polluted water resources lead to dramatic human cost. Keeping in view of the above issues related to contamination of water resources and wastewater management in the villages, the ministry directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Bagpat, Ghaziabad and Meerut. Accordingly, the research proposal has been formulated which will address the problem related to deteriorating health of village ponds and the declining groundwater levels as well as quality in the villages of western UP on a pilot scale, the results from which can be replicated in other villages of the country.

10. Action Plan/Methodology:

- Reconnaissance survey of identified village ponds for data collection along with sampling and analysis of wastewater input to the pond
- Rejuvenation of identified village ponds & associated civil work (de-weeding, desilting, etc.) including fabrication of suitable natural treatment system (CWT) for nutrients removal (through NPCC).
- Water and wastewater characterization and Health Assessment of Water Body.
- Monitoring of GWQ and GWL around rejuvenated ponds
- Mass Awareness/capacity building

11. Timeline:

S. No.	Activities	w.e.f. Jan. 2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Identification of study site/ponds with GPs												
2	Field investigations (sampling and analysis)												
3	Detailed engineering design/estimates from NPCC for civil works												
4	Execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)												
5	Health Assessment/ Trophic Status of rejuvenated ponds												
6	LU/LC maps for Reuse planning of treated pond water												
7	Mass awareness/capacity building												
8	Technical reports												

12. Objectives and achievements:

Objectives	Achievements
Rejuvenation of identified village ponds by carrying out de-weeding, de-watering, de-silting and associated civil works for development of Natural Treatment System (NTS) in the identified ponds –through NPCC.	• As per letter from the Ministry regarding pond rejuvenation works in the identified villages of Baghpat, Meerut and Ghaziabad Districts, a proposal was prepared and submitted to the Ministry. • In this connection, the Ministry directed Institute to rejuvenate 10 identified village ponds through Scheme budget the Institute in this project. • A revised estimate of civil work was obtained from NPCC and requisite work of pond rejuvenation (9 ponds) was awarded to NPCC as per MOA. • In this connection, a formal consent was also obtained from 9 GPs to rejuvenate their identified ponds. • The civil work component (de-weeding, de-watering, de-silting) of pond's rejuvenation been completed during Nov. 2019 at all 9 identified ponds alongwith development of NTS at two sites by NPCC (Cost: Rs. 502.41 Lakh).
Establishment of appropriate phyto-remediation based Natural Treatment System (NTS) at identified pond sites for treatment of wastewater	• The nursery for developing aquatic plant saplings has been established. • Approx. 5000 Reed Plant and 1000 Canna plant saplings were grown at NIH and requisite nursery plants have been transported at identified two pond sites (Basoli & Ikari). • FW has been established at both identified pond sites (Basoli & Ikari) in this project.

Field investigations for monitoring & analysis of relevant water & wastewater quality parameters, groundwater levels, etc.	**May 2018:** (Base line data for WQ of ponds, hand pumps). **April/May 2019:** Field investigations were carried out to collect GW samples, GWL, soil & sludge samples (for trace metals-As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg), infiltration tests at pond beds, etc. **January 2020:** Field investigations (WQ of ponds & adjacent hand pumps, GWL) were collected at two NTS pond sites (Basoli & Ikari). LU/LC maps (1km radius from ponds) were prepared for reuse of treated wastewater. **Dec. 2020:** WQ of ponds, hand pumps and GWL measurements Visit of pond supervision committee
Capacity building/Mass Awareness Activities	The concerned GPs (Basoli and Ikari) were given necessary input for maintenance of the NTS plants and system

13. Recommendation / Suggestion:

Recommendation / Suggestion	**Action Taken**
There were no specific comments from working group members.	-

14. Analysis & Results:

(A) Civil Work

The civil work related to the rejuvenation of the ponds has been completed by the NPCC. Natural treatment system (Floating wetland) has been established in pond at Basoli and Ikari as per revised scope of work. The status/ progress of the civil works by NPCC is given below in Table 1:

Table 1: Status of rejuvenation of ponds in Baghpat, Ghaziabad and Meerut

Date: 01/10/19

RENOVATION & OTHER CONSTRUCTION WORK OF POND

STATUS OF WORK UPTO SEPTEMBER- 2019

S.No.	Name of Pond and Village		Dewatering	Removal of Sludge	Periphery Drain work	Sedimentation Tank	Screening Chamber at Inlet	Compaction of embankment & periphery	Floating Wetland Work	Depth of Pond (NGL)	(Sludge)
A	Baghpat & Ghaziabad (PACKAGE-1)										
1	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	[illegible]	[illegible]
2	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	[illegible]	[illegible]
3	Basoli	[illegible]	Completed	Completed	Completed	Complete	Not required	Completed	Completed	[illegible]	[illegible]
4	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	[illegible]	[illegible]
5	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	[illegible]	[illegible]
6	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	[illegible]	[illegible]
7	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	[illegible]	[illegible]
8	Ikari	[illegible]	Completed	Completed	Completed	Complete	Complete	Completed		[illegible]	[illegible]
9	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	[illegible]	[illegible]

P.M.
Project Manager
NPCC Ltd
Meerut Unit

(B) R&D Component: Pre- and post-rejuvenation Situations

I. Water Sampling and Analysis

- Groundwater (nearby hand pumps)

- Pond water
- Wastewater (at pond inlets)

Physical: pH, EC, ORP, TDS, TSS, turbidity, alkalinity

Chemical: fluoride, nitrate, nitrite, sulphate, DO, COD, BOD; hardness, calcium, magnesium, sodium, potassium, chloride, ammonium,

Biological: TC, E.coli

Trace metals: aluminum, cadmium, copper, chromium, lead, manganese, zinc
Groundwater level ranged from 9.58m to 33.25 m (2018) and 2.3 to 33.64m (2019). The trend lines of GWL variation of two pond sites (Basoli and Ikari) are given in Fig.3, which clearly shows the improvement of ground water levels after pond rejuvenation.

II. Sludge and Soil Sampling and Analysis

- Sludge at pond bed
- Pond bed soil
- Soil from nearby agricultural fields
- Soil bulk density and texture
- pH, EC, organic carbon, boron, zinc, copper, iron, nickel, lead, arsenic, chromium, Sulphur, manganese, available nitrogen, phosphorus, potassium
-

III. Permeability and Infiltration Rate Analysis

IV. Establishment of Natural Treatment System (NTS)-Floating Wetland (FW) at Basoli & Ikari

V. Reuse planning of treated wastewater

- GIS-based LULC buffer maps

Various field investigations were carried out during April/May 2018, June 2019 and Jan. 2020 and Dec. 2020, respectively. The list of water quality samples collected before and after pond rejuvenation works are given in Table 2.

Table 2: List showing WQ samples collected in the study

S.No	Village Name	Village ID	No. of samples (Apr/May 2018)	No. of samples (Jun 2019)	No. of samples (Jan 2020)	No. of samples (Dec. 2020)
1	Basoli	BL	5	4	3	3
2	Khindora	KD	6	6	-	3
3	Saidpur	SR	5	3	-	3
4	Paldi	PD	6	3	-	3
5	Ikari	IK	6	4	3	3
6	Dhikana	DK	6	4	-	3
7	Dagarpur	DG	6	5	-	3
8	Pilana	PI	6	3	-	3
9	Budhera	BD	6	4	-	3
Total		**10**	**57**	**36**	**6**	**27**

Based on field investigations, the water quality of identified ponds before and after rejuvenation was assessed and results are given below in Table 3. The results indicate that the water quality has been improved after pond rejuvenation.

Table 3: WQ parameters of ponds before and after rejuvenation

		Before Rejuvenation (May 2018)						After Rejuvenation (*Jan 2020)/Dec.2020					
Pond Sample ID	Vilage	pH	EC	TDS	DO	BOD	COD	pH	EC	TDS	DO	BOD	COD
			µs/cm	mg/L	mg/L	mg/L	mg/L		µs/cm	mg/L	mg/L	mg/L	mg/L
BD	Budhera	8.7	1370	877	0	460	800	8.67	1216	778	12.0	21.6	-
KD	Khindora	7.1	2026	1297	0	500	160	8.28	1605	1027	13.6	200	-
DK	Dhikana	6	2100	1344	0	80	56	7.36	1881	1203	4.0	56.4	-
BL*	Basoli	7.8	1561	999	0	410	216	8.74	1437	915	9.5	90	168
IK*	(Ikari)	6.7	1505	963	0	70	136	6.67	1687	1079	3	40	80
SR	Saidpur	6.32	1810	1158	0	130	160	7.56	1726	1105	0	144.8	-
PD	Paldi	7.28	1619	1036	0	80	288	8.64	1432	916	24.2	26.3	-
PI	Pilana	9	2058	1317	0	70	160	8.49	1917	1227	7.1	48.1	-
DG	Dagarpur	8.12	1604	1027	0	80	176	8.48	2727	1745	11.6	-	-

Water quality parameters of before and after rejuvenation of ponds shown in Table 4 indicates that after rejuvenation work water quality of ponds improved significantly. Initially Dissolved oxygen was nil almost in all ponds but after the installation of floating wetland DO improved from 0 to 9.5 mg/l in Basoli pond and 3 mg/l in Ikari pond. Similarly, BOD in pond reduced to 70 mg/l to 40 mg/l and COD of ponds decreased from 136 to 80 mg/l in Ikari pond. COD values also reduced to 216 to 168 mg/l in Basoli pond and 136 to 80 mg/l in Ikari pond after rejuvenation work.

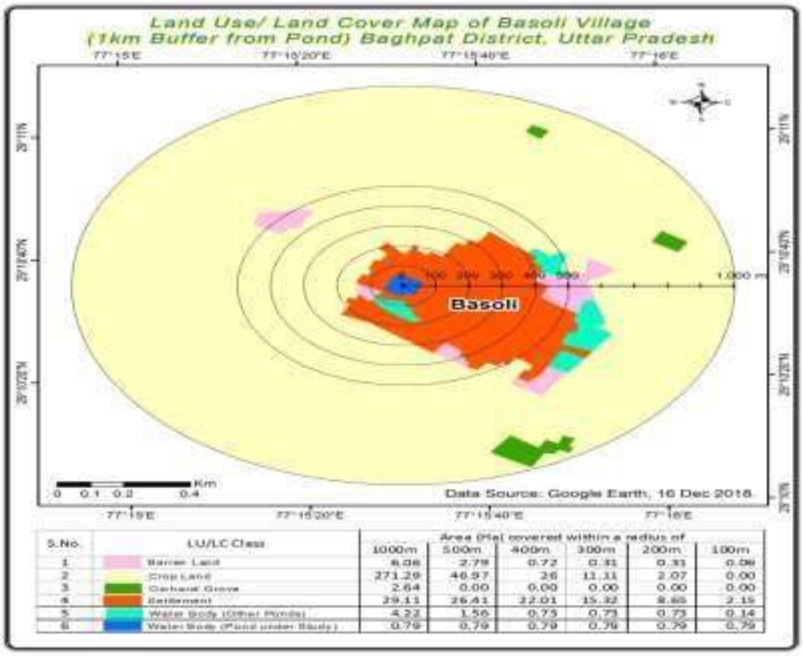
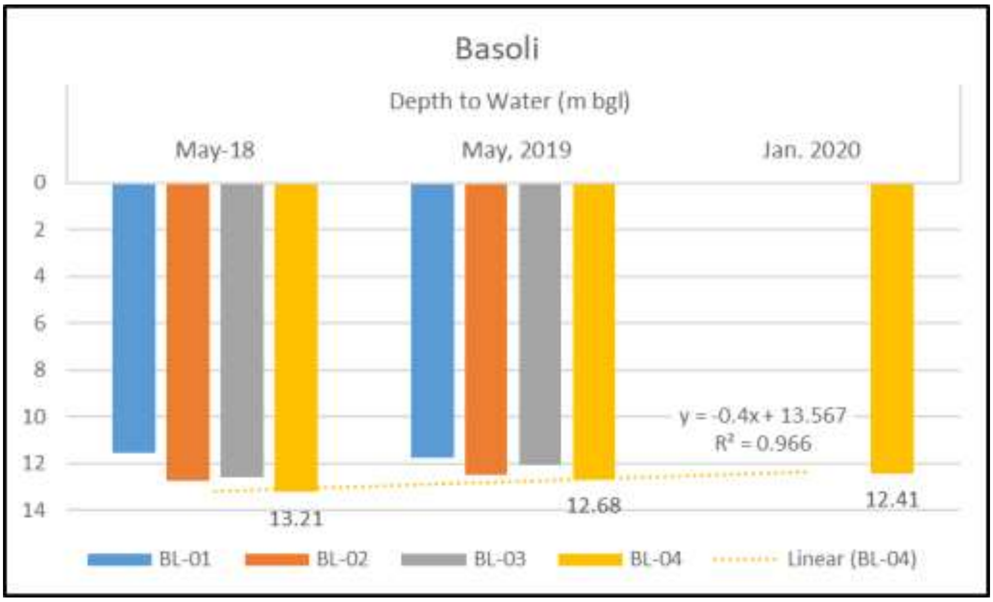


Figure 2: LULC Map of Basoli

The LULC maps of the area around pond surroundings (upto 1 km) were prepared for reuse planning of the treated pond water (Fig.2). The GWL variation in the study area during pre (May 2018) and during rejuvenation (May 2019) stages of ponds is given in Fig. 3.



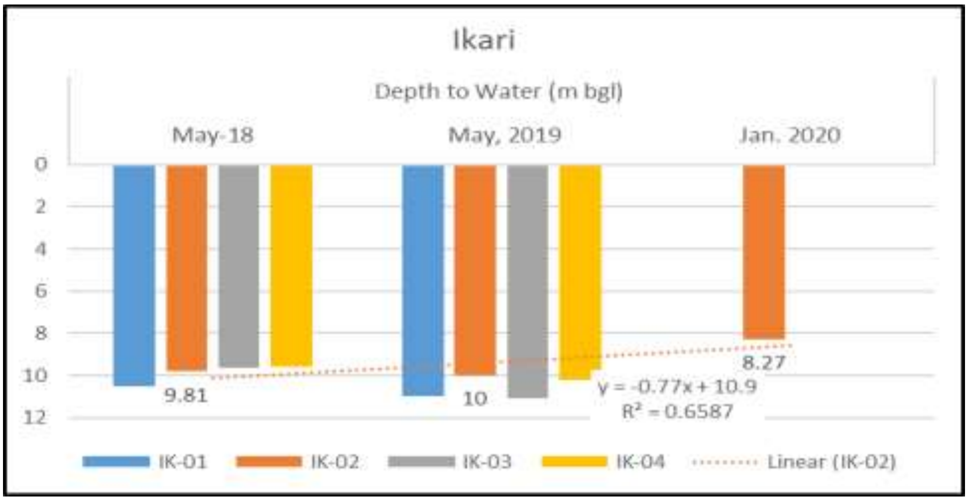


Fig. 3: Variation of ground water levels (DTW, m bgl) in the study area

15. **End Users / Beneficiaries of the Study:** Stakeholders
16. **Deliverables:** Rejuvenated village ponds, Technical report(s) and publications.
17. **Major items of equipment procured:** Nil
18. **Lab facilities used during the study:** WQL, S&W Lab, GWHD (NIH)/ IIC (IITR)
19. **Data procured or generated during the study:** Groundwater quality, Pond water Quality, Village wastewater quality, Trophic Status Index of pond, Groundwater level, Infiltration rate at pond bed, Permeability, Leachability of trace metals and nutrients in the sludge.

20. **Study Benefits/Impacts:** (i) Improvement of groundwater conditions and GWQ around rejuvenated ponds, (ii) Improved water quality of rejuvenated ponds (reduced organic loads, coliform bacteria and nutrients and increased dissolved oxygen levels) compared with the control pond, (iii) The local villagers/ stakeholders are utilizing pond water for agriculture/fishery.

21. **Involvement of end users/beneficiaries:** Villagers & Gram Panchayats

1. **Title of the study:**
Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact

2. **Study Group:**
Dr. A. R. Senthil kumar Sc F, NIH, Roorkee
Dr. J. V. Tyagi, Director, NIH, Roorkee
Dr. M. K. Goel, Scientist 'G', NIH, Roorkee
Dr. S. D. Khobragade, Scientist 'F', NIH, Roorkee
Dr. P. C. Nayak, Scientist 'E', Deltaic Regional Centre, NIH, Kakinada
Dr. Manohar Arora, Scientist 'E', NIH, Roorkee
Project staff: Sh. Sandeep Chourasia, JRF, Sh. Bhajanlal, PA

Date of start: 1 January 2016

3. **Duration of the study: 5 Years**

4. **Whether externally funded or not: DST**

5. **Objectives of the study:**
   a. To model stream flow/snow melt runoff in Bhagirathi Basin up to Tehri dam.
   b. To model sediment yield at Tehri dam.
   c. To investigate the impact of likely future changes in climate on stream flow and sediment yield up to Tehri dam using future climate scenarios.
   d. To assess impact of afforestation/deforestation on sediment yield in the basin.
   e. To assess the operation policy of the Tehri dam in light of the climate change impact.

6. **Statement of the problem**
The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Tehri reservoir. The study on impact of afforestation/deforestation on sediment yield in the basin is also important for effective watershed management.

7. **Brief methodology:**
Sediment yield model
The sediment yield up to Tehri reservoir is modeled by Soil and Water Assessment Tool (SWAT) with the information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed.

Streamflow simulation
The streamflow up to Tehri reservoir is modeled by WinSRM with the input data of elevation, rainfall, aspect, temperature and snow cover area. The performance of SWAT is compared with WinSRM Simulating the discharge.

Climate Scenarios
The different scenarios of climatic conditions for RCP 4.5 is obtained from CMIP5 models available from different institutes.

Computation of streamflow and sediment yield under different scenarios
The parameters of the SWAT are calibrated using the historical hydro-meteorological data. The future streamflow and sediment yield are simulated using SWAT and WinSRM with the data of

different climatic scenarios. The impact of likely future changes in climate on streamflow and sediment yield up to Tehri is analyzed by the output of SWAT and WinSRM for future climate scenarios.

Revision of elevation-area-capacity table
The projected sediment volume for future periods is distributed in the reservoir by empirical-area reduction method to find out the revised elevation-area-capacity table.

The impact of afforestation/deforestation on sediment yield is analyzed by the simulation of sediment yield using SWAT by increasing/decreasing the LULC.

The rule curves for operating the reservoir are modified by considering the revised elevation-area-capacity curve in light of increased/increased sediment yield.

8. **Results achieved with progress/present status:**

The sediment yield at Tehri reservoir is modelled by Soil and Water Assessment Tool (SWAT). The inputs such as DEM, LULC and Soil map for running the ARCSWAT have been generated using different sources available in the web sites of different organizations such as NASA, National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Indian Council of Agricultural Research, Harmonized World Soil Database (HWSD) International Institute for Applied Systems Analysis **(**IIASA) and National Remote Sensing Centre (NRSC). The daily rainfall values at Mukhim, Tehri, Bhatwari, Dunda, Maximum and Minimum temperature at Mukhim, relative humidity and wind speed at Mukhim have been obtained from IMD. The daily discharge (1994 to 2007) and sediment yield (1994 to 2001) have been obtained from THDC, Rishikesh. The parameters of the SWAT are calibrated for discharge and sediment yield by considering the data from IMD and THDC, Rishikesh. The 10 elevation zones for catchment up to Tehri Dam have defined to account the orographic effect of precipitation and temperature. The SWAT-cup has been used to find out the sensitive parameters for streamflow and sediment yield. The streamflow has been calibrated and validated using the data from 1996 to 2005 and 2006 to 2007 respectively with 1994 and 1995 as warmup periods. The data of sediment yield from 1996 to 1999 and 2000-2001 have used for calibration and validation of sediment yield respectively with 1994-1995 as warmup periods. The performance of SWAT model for the streamflow is given as follows:

Statistical parameters	**Calibration (1994-2005)**	**Validation (2006-07)**
R^2	0.78	0.74
NSE	0.74	0.69

The performance of SWAT model for the sediment yield is given as follows:

Statistical parameters	**Calibration (1996-1999)**	**Validation (2000-01)**
R^2	0.60	0.533
NSE	0.46	0.43

WinSRM has been used for the simulation of streamflow up to Tehri with data of daily rainfall, temperature and snow cover area for the years from 2001 to 2003. The 8-day maximum snow cover data from MODIS 8-day snow cover product (MOD10A2) with spatial resolution of 500 m has been used to map and monitor SCA for the period from 2001 to 2007. The snow depletion curves have prepared for years 2001 to 2007 (March to September) using the MODIS images. The parameters such as temperature lapse rate °C per 100 m, critical temperature (°C), Degree day factor (D), Runoff coefficient for rain (C_R) have been taken from literature and data. The results for the simulation of streamflow for years 2001 to 2003 are given as follows:

Period	2001	2002	2003
Measured run-off volume ($10^6 m^3$)	7480	7465	7979
Average measured run- off (m^3/s)	237	236	253
Computed run- off volume ($10^6 m^3$)	7420	7190	7838
Average computed run- off (m^3/s)	235	228	248
Volume difference, D_v (%)	0.79	3.68	1.76
Coefficient of determination, R^2	0.73	0.67	0.68

From simulation results, Snowmelt Runoff (SMR) has started increasing from the (April–May) season, mainly due to increase in air temperature, whereas maximum run-off has been observed in August, mainly due to monsoonal rains. The volume difference is high during the year 2002.

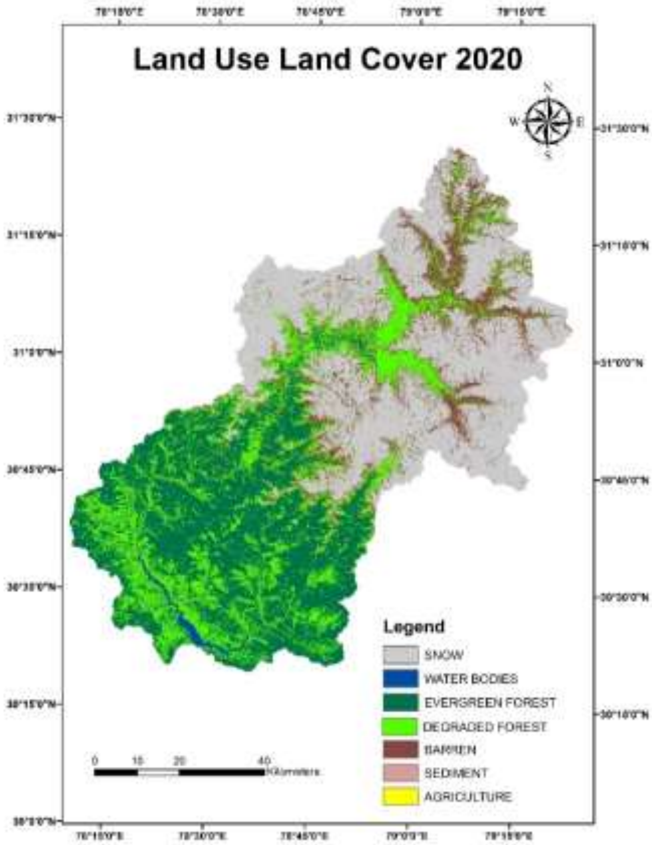
streamflow for years from 2004 to 2007 has been simulated using WinSRM with the same values of parameters and the results are given as follows. The volume difference is high for the year 2005 and is very low for the 2006. The simulation result for the 2007 is better than other years in terms of coefficient of determination.

Period	2004	2005	2006	2007
Measured run-off volume ($10^6 m^3$)	6008	7642	6448	6608
Average measured run- off (m^3/s)	190	242	204	209
Computed run- off volume ($10^6 m^3$)	5831	7194	6468	6733
Average computed run- off (m^3/s)	184	228	205	213
Volume difference, D_v (%)	2.94	5.86	0.31	1.88
Coefficient of determination, R^2	0.65	0.67	0.83	0.78

Sentinel 2 image has been used to study the effect of deforestation/afforestation in the catchment upto Tehri reservoir. SENTINEL-2, launched as part of the European Commission's Copernicus program provides services related to land management, agricultural production and forestry, and monitoring of natural disasters and humanitarian operations. The resolution of imageries vary from 10 to 60 m in the visible, near infrared (VNIR), and short-wave infrared (SWIR) spectral zones, including 13 spectral channels, which ensures the capture of differences in vegetation state, including temporal changes, and also minimizes impact on the quality of atmospheric photography. The cloud free image of May 2020 with 10 m resolution has been used to simulate the streamflow and the sediment load at Tehri dam using calibrated parameters of SWAT and other meteorological data. The change in area for different land uses from Sentinel image 2020 compared to LISS III image 2007 is given as follows

Land use type	**LISS 2007 image**		**Sentinel 2020 image**		**Change in area (km^2)**
	Pixel number	**Total Area (km^2)**	**Pixel number**	**Total Area (km^2)**	
Snow	1366019	692	26517390	2652	1960
Water Body	120361	61	439335	44	-17
Deep Forest	2780521	1408	21896292	2190	782
Degraded Forest	3207266	1624	14828194	1483	-141
Barren	3492070	1768	8650421	865	-903
Sediment	2954615	1496	415662	42	-1454
Agriculture	475197	241	136432	14	-227

The landuse land cover map from SENTINEL image is given as follows:



The average monthly streamflow and sediment yield with landuse prepared from by Sentinel image 2020 is given as follows:

Months	LISS 2007 image		Sentinel 2020 image	
	Average of flow in cumecs	**Average of sediment yield in tons**	**Average of flow in cumecs**	**Average of sediment yield in tons**
1	26.147	7520.576	50.838	23341.394
2	61.084	31254.519	143.553	92826.128
3	93.629	47751.000	214.075	130374.250
4	141.721	57835.583	324.974	172029.917
5	269.780	135103.083	665.417	401439.750
6	491.676	265492.500	1044.459	639391.667
7	551.425	311184.167	1050.617	666603.333
8	446.175	240051.667	827.755	516038.333
9	274.418	132583.583	508.290	316479.167
10	96.920	30767.583	153.084	54962.917
11	91.173	40980.442	173.130	94253.750
12	43.505	14377.658	84.527	38946.892
Grand total	**215.638**	**109575.197**	**436.727**	**262223.958**

It clearly indicates that the average monthly streamflow and sediment yield has been increased for simulation with land use land cover from SENTINEL image 2020.

The effect of climate change on streamflow and sediment yield has been studied from the scenario recommended from study on "Statistical Downscaling for Hydro-climatic projections with CMIP5 simulations to assess Impact of Climate Change" funded by Indian National Committee on Climate Change (INCCC) and Ministry of Water Resources, Government of India. Five GCM models were considered for giving downscaled data for whole India and the models are CCCMA CanESM2, CNRM CM5, MPI ESM MR, MPI ESM LR and BNU ESM. Based on the recommendation of the study, precipitation, minimum and maximum temperature for the scenario RCP4.5 of CNRM CM5 with other meteorological data and calibrated parameters for SWAT, the streamflow and sediment yield has been simulated for period from 2008 to 2100. The average monthly streamflow and sediment yield with landuse prepared from by Sentinel image 2020 and precipitation, minimum and maximum temperature scenario from CNRM CM5 (RCP 4.5) is given as follows:

Months	LISS 2007 image		Sentinel 2020 image with Scenario from CNRM CM5 (RCP 4.5)	
	Average of flow in cumecs	Average of sediment yield in tons	Average of flow in cumecs	Average of sediment yield in tons
1	26.147	7520.576	155.645	75591.688
2	61.084	31254.519	243.504	108988.968
3	93.629	47751.000	201.164	101488.849
4	141.721	57835.583	96.388	34748.355
5	269.780	135103.083	93.295	25812.398
6	491.676	265492.500	473.710	241570.860
7	551.425	311184.167	1088.429	684507.527
8	446.175	240051.667	1250.003	807726.882
9	274.418	132583.583	583.548	281496.129
10	96.920	30767.583	179.368	54550.753
11	91.173	40980.442	128.550	47469.739
12	43.505	14377.658	163.826	78108.880
Grand total	**215.638**	**109575.197**	**388.554**	**212106.012**

It clearly indicates that the average monthly streamflow and sediment yield has been increased for simulation with land use land cover from SENTINEL image 2020 with scenario from CNRM CM5 (RCP 4.5). The reservoir operation considering discharge and sediment yield for LISS 2007 image, Sentinel 2020 image and Sentinel image with scenario from CNRM CM5 (RCP 4.5) is being carried out.

9. **Outcome of the study**

The output of the study will give an idea of increased sediment yield and streamflow from the future climatic scenarios to the state department officials for managing the various demands based on the available the storage in the reservoir on priority basis. The impact of afforestation/deforestation on sediment yield will be used for planning cropping pattern to reduce the sediment yield

10. **Expected date of completion**: 31 March 2021

11. **Timeline**

Activity	2016-17		2017-18		2018-19		2019-20		2020-21	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
Collection and processing of Hydrometeorological data and purchase of satellite imagery										
Data preparation for SNOWMOD and SWAT										
Simulation of streamflow by SNOWMOD										
Simulation of Sediment yield by SWAT										
Downscaling of data from GCM Models										
Simulation of streamflow and sediment yield with the data from future climatic scenarios										
Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield										
Analysis of the reservoir performance with the revised elevation-area-capacity table and projected streamflow										
Writing of the final report										
Training workshop										

1. **Title of the 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, Er. 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 2021)

Milestones	Activities	Target Month	NIH Progress
Hiring of Project Staff	Hiring of project staff at NIH Roorkee	M6	Completed
Development of Centre's Portal	Development of IC-EcoWS Centre's Website and social media pages for information dissemination and communication (Webpage , Facebook page and Gmail Account) ; IC-EcoWS project Flyers/Brochures.	M12	Completed
Organization of Users Interaction Workshops (annual)	IC-EcoWS Project Inception Cum Need Assessment Workshop (8-9 August, 2019)	M12	Completed
	Report on First Annual Workshop- IC-EcoWS Inception Cum Need Assessment Workshop		Completed
Establishment of Live Laboratories	Procurement of several technical and scientific lab equipments for setting up the IC-EcoWS Innovative Centre at NIH Roorkee (Ongoing: Online monitoring system).	M18	Completed
	Establishment of horizontal sub-surface-flow constructed wetland for domestic wastewater treatment (peri-urban residential area in Roorkee)		Completed
	Installation of Online Monitoring System for water quality monitoring		Ongoing
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	Ongoing
	In-situ treatment of domestic wastewater in urban drain using floating constructed wetland and bio-inoculum – Solanipuram Roorkee		Ongoing
	Pilot-scale demonstration unit for wastewater treatment of residential building using floating wetland system at NIH Roorkee		Ongoing

Milestones achieved by IIT, Bombay (March 2021)

Milestone/activities	Target Month	Progress
Report on existing NTS installations and their performance in India	M8	Completed
Report on nutrient and energy flows through the NTSs	M18	In progress
Report on environmental performance of the NTSs and relevant resource recovery technologies	M30	To be started
Report on multi-criteria assessment of the NTSs	M 42	To be started
Decision Support Tool (DST)	M48	To be started

Milestones achieved by MNIT, Jaipur (March 2021)

Milestones	Activities	Target Month	Progress
Hiring of Project Staff	Hiring of project staff at MNIT Jaipur	M6	Completed
Establishment of Live Laboratories	Design of a "pilot CW" finalized (10 KLD_) sewage from RBC of MNIT Jaipur	M18	Ongoing
	Demarcated space for CW for gray water treatment of a Girl's hostel (50 KLD) in MNIT		
	Sample Testing from CW receiving residential and Hospital wastewater		
	Equipment Procurement (Laptop/PC)		Ongoing
Development and application of innovative ideas on NTS	Organization of capacity building, awareness creation, outreach and dissemination activities for promotion and propagation of NTS	M24	Ongoing

Milestones achieved by IRMA, Anand (March 2021)

Milestone/ Activities	Target Month	Progress
Hiring of project staff	M6	Completed
Life Cycle Cost (LCC) estimation of identified NTS technologies	M30	In progress
Business Models for Technology Packages	M42	To be started
To organize capacity building, awareness creation, documentation and dissemination activities, and preparation of a TOT Module	M 48, M50	To be started