AGENDA AND AGENDA NOTES

71st MEETING OF THE TECHNICAL ADVISORY COMMITTEE (TAC) OF NIH

APPENDICES

(Vol.-II)

April 23, 2018
AT 1100 HRS
COMMITTEE ROOM
3RD FLOOR, CWC, NEW DELHI

NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

APPENDIX – 71.2.1

MINUTES OF THE 70th MEETING OF TAC OF NIH

APPROVED MINUTES OF 70th MEETING OF TECHNICAL ADVISORY COMMITTEE OF NATIONAL INSTITUTE OF HYDROLOGY HELD ON 1 SEP 2017 AT NEW DELHI

The 70th meeting of the Technical Advisory Committee (TAC) of the National Institute of Hydrology, Roorkee was held in the Central Water Commission, New Delhi on 1 Sep 2017. The meeting was chaired by Er Narendra Kumar, Chairman, CWC. The list of the participants is given in Appendix -I.

The Chairman in his opening remarks welcomed the members and the invitees. He appreciated the works being carried out by NIH, and urged that the Institute should accord priority to conducting applied research, with a focus on the latest development taking place in the water sector. After a round of introduction, the TAC members were requested to offer their general comments and suggestions on the working of NIH.

Er. N K Mathur, Member (D&R),CWC	• NIH may focus on applied hydrologic research which leads to solution of problems being faced by practitioners • Work related to surface water hydrology dealing with development of Unit Hydrograph, rainfall runoff modeling, design flood estimation, impact of climate change on hydrologic extremes, etc. Need to focus on a particular basin or sub-basin, which could provide a better alternative to current practices
Dr. Ravinder Kaur, Director, WTC, Delhi	• Offered to partner with NIH to develop cross-collaborative programmes
Sh K B Biswas, Chairman, CGWB	• Appreciated the RBF study and the study on MAR for groundwater augmentation in NCT Delhi
Prof. N K Goel, IIT Roorkee	• There is need for enhanced interactions between NIH scientists and TAC members
Prof. K P Sudheer, IIT Madras	• NIH may take up Awareness on Water Issues in pro-active mode • NIH may initiate studies on urban flooding
Prof. KV Jayakumar, NIT, Warangal	• Enhance interactions with academic institutions • Enhance visibility of NIH's work and output • Quality of publications needs to improve - avoid publishing papers in paid journals • TAC meetings may be held at NIH, Roorkee
Sh Sanjay Kundu, JS(PP)	• NIH may develop content of the modules on 'Awareness on Water Issues' to be prepared for inclusion in the text books. MoWR will write to MHRD for curriculum revision • Consider holding TAC meetings on Saturdays

Dr V C Goyal, Member-Secretary, also welcomed the Chairman, members and invitees. He then took up the agenda items.

ITEM NO. 70.2: Confirmation of the Minutes of 69th Meeting of TAC

The Member-Secretary informed that minutes of the 69th meeting of TAC, held on July 21, 2016, were circulated to all the members and invitees vide letter No. NIH/RCMU/TAC/34/11 dated September 6, 2016. Since no comments were received from the members, the Minutes were confirmed by the TAC.

ITEM NO. 70.3: Action Taken on the Decisions/Recommendations in the Previous Meeting

The Member-Secretary informed that the suggestions offered during the previous meeting have been noted for compliance.

ITEM NO. 70.4: Status of the Work Programme for the Year 2016-2017

The Member-Secretary briefed about the studies carried out by the Institute during the year 2016-2017. Members appreciated the number of publications brought out by the Institute and number of training/workshop/symposium organized by the Institute.

The following studies completed during 2016-2017 were presented during the meeting:

1. Ionic Enrichment Dynamics of Glacial Sediment and Melt Water of Gangotri Glacier (EH Division)
2. Feasibility and Scope of MAR for Groundwater Augmentation in NCT, Delhi (GWH Division)
3. Hydrological modelling of Brahmani Baitarani river basin using eWater Source platform (SWH Division)

TAC noted the status of work programme for the year 2016-17.

ITEM NO. 70.5: Report the Proceedings of the Working Group and RCC Meetings

The Member-Secretary briefed about the 45th meeting of the Working Group of NIH, which was held at NIH, Roorkee, during 11-12 May 2017, and the RCC meetings held at the different Regional Centres. During these meetings, the Working Group/RCC members reviewed the progress of studies for the year 2016-2017 and also discussed the proposed work programme for the year 2017-2018.

TAC noted the proceedings of the Working Group and RCC meetings.

ITEM NO. 70.6: Work Programme for the Year 2017-2018

The Member-Secretary briefed about the proposed work programme of the Institute for the year 2017-2018, which was discussed during the 45th Working Group meeting of NIH. The proposed work programme of the Regional Centres, as recommended by the respective RCCs, was also placed before the TAC.

The TAC approved the proposed work programme of the Institute for the year 2017-2018 (Appendix-II).

ITEM NO. 70.7: Thrust areas of research proposed in EFC for 2017-20

The thrust areas of research areas as proposed in the EFC Memo of NIH for the period 2017-2020 were noted by the TAC.

- JS(PP) opined that the list of thrust areas could be broadened as per requirements of the Ministry of Water Resources, RD & GR.
- Dr Ravinder Kaur mentioned that SPI drought indices are outdated and RS-based indices should be used.
- Member (D&R), CWC advised to focus on (i) issues of climate change impact on hydrological extremes, (ii) Project Hydrology, and (iii) studies on uncertainties and risks.

ITEM NO. 70.8: Major projects and activities of national importance

The TAC noted with satisfaction the NIH's involvement in the following projects and activities of national importance:

1. Integrated Hydrological Studies for Upper Ganga Basin up to Rishikesh (NMSHE)

2. National Hydrology Project (NHP)
   - Prof N K Goel wanted to know how educational institutions can be involved in the PDS.
   - For the 'Training and Capacity Building' component of NHP, the Chairman advised NIH to work in close collaboration with the National Water Academy, Pune. He also advised to consider modalities so that academic institutions may be closely associated with NHP works.

3. Neeranchal National Watershed Project (NNWP)
   - Dr Ravinder Kaur wanted to know the details of DSS-H.

4. Strategic Planning for Ganga River Basin
   - The Chairman advised to apprise the Secretary (WR) with the difficulties being faced while working with the Deltares model.

5. Research Collaboration with Centre for Ecology and Hydrology (CEH)
   - The Chairman enquired about the cost of establishing the proposed Indo-UK hydrological modeling centre at NIH. It was informed that broadly both partners will bear their own costs and NIH is not asking for additional staff.
   - Prof N K Goel informed that IIT Roorkee has also signed a MoU with CEH. The Chairman then advised that NIH and IITR may discuss further to avoid any duplicity.
6. WaterRain-Him: Changes in Water Resources and Adaptation options in the Indian-Himalayan basins.

7. State Specific Action Plan (SSAP) for Water Sector
   - Prof Jayakumar enquired if any template has been developed for preparing the reports by the states.

8. Water accounting exercise by MoWR, RD & GR

9. International Groundwater Conference-2017 (IGWC-2017) on "Groundwater Vision 2030: Water Security, Challenges and Climate Change Adaptation (New Delhi, December 2017)

ITEM NO. 70.9: Establishing a Category-II UNESCO Centre at NIH

The TAC appreciated the proposal of establishing a UNESCO Category-2 Centre at NIH in view of the felt need in the South Asian region, and gave in-principle recommendation to proceed further for establishing the Centre at NIH. He advised that NIH may also consult IIT Roorkee in this matter. The Centre's title as Regional Centre on "Water and Environment" for South Asia was considered apt by the TAC to promote regional research, skill and capacity development, and outreach activities in the identified fields of hydrology, water resources and environment. The proposed UNESCO Centre will strengthen the activities of UNESCO-IHP in India, with its Secretariat already established at NIH.

ITEM NO. 70.10: Road map to organize certificate courses at NIH

The proposal of NIH to **organize few** short training courses on identified topics of hydrology and water resources was appreciated by the TAC. In view of the ongoing National Hydrology Project, and few other major water-related projects, a need exists for training and capacity building of the field engineers and practitioners on the modern techniques of investigations and on analysis and modeling. Moreover, the Government of India's emphasis on the skill development also necessitates premier institutes like NIH to impart training to the young and mid-level practitioners to enable them taking up the flagship schemes and programmes of the government. The Member (D&R), CWC, suggested that in the proposed courses NIH could also focus on modern software tools. A combination of online, offline and virtual mode training courses could be planned. Chairman suggested that NIH may also consult with IIT Roorkee before taking up such training courses to avoid any duplicity.

ITEM NO. 70.11: Reporting Items

Details of the consultancy projects carried out by NIH during the year 2016-2017 were noted by the TAC.

The meeting ended with a vote of thanks to the Chair.

****

Appendix– I: List of Participants
Appendix– II: Approved Work Programme for the Year 2017-2018

Appendix-I

LIST OF PARTICIPANTS OF THE 70th TAC MEETING OF NIH

1. Er Narendra Kumar, Chairman, CWC, New Delhi
2. Er N K Mathur, Member (D&R), CWC
3. Er S K Sinha, Rep. Chief Engineer (HSO), CWC, New Delhi
4. Sh Sanjay Kundu, JS(PP), MoWR, RD & GR
5. Dr Sharad K Jain, Director, NIH, Roorkee
6. Sh K. B. Biswas, Chairman, CGWB, New Delhi
7. Prof N K Goel, IIT Roorkee
8. Prof K V Jayakumar, NIT Warangal
9. Prof K P Sudheer, IIT Madras
10. Dr Ravinder Kaur, Principal Scientist, WTC, ICAR-IARI, New Delhi
11. Dr V C Goyal, Sc. G & Member-Secretary, NIH, Roorkee

INVITEES

1. Dr N C Ghosh, Sc. G & Head, GWH Division, NIH, Roorkee
2. Dr Rakesh Kumar, Sc. G & Head, SWH Division, NIH, Roorkee
3. Dr C K Jain, Sc. G & Head, EH Division, NIH, Roorkee
4. Dr J V Tyagi, Sc. G, NIH, Roorkee
5. Er C P Kumar, Sc. G, NIH, Roorkee
6. Dr Sanjay Jain, Sc. G, NIH, Roorkee
7. Dr M K Goel, Sc. G, NIH, Roorkee
8. Dr Suhas Khobragade, Sc. F, NIH, Roorkee
9. Dr Sanjay Kumar, Sc. E, NIH, Roorkee
10. Dr M K Sharma, Sc. D, NIH, Roorkee
11. Dr J P Patra, Sc. C, NIH, Roorkee
12. Dr Jyoti Patil, Sc. C, NIH, Roorkee

Appendix-II

APPROVED WORK PROGRAMME FOR THE YEAR 2017-2018

ENVIRONMENTAL HYDROLOGY DIVISION
Work Programme 2017-18

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams	Pradeep Kumar (PI) C. K. Jain	2 Years (04/16-03/18)	NIH
II.	**Sponsored Projects (Ongoing)**			
1.	Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier	M. K. Sharma (PI) C. K. Jain Renoj Thayyan Manohar Arora Naresh Saini Jatin Malhotra Rakesh Goyal Shyam Lal	3 Years (05/14-05/17)	DST (Rs 32.8 lakh)
2.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI) Manohar Arora M. K. Sharma Pradeep Kumar D. S. Malik (GKU)	5 Years (04/16-03/21)	DST (Under NMSHE) (Rs 2.25 crore)

GROUND WATER HYDROLOGY DIVISION
Work Programme 2017-18

S. N.	Title of the project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin	Anupma Sharma (PI), N.C. Ghosh (Coordinator), Deepak Kashyap, IITR (Technical Consultant) M K Sharma, R.P. Singh, Sumant Kumar, Shashi P. Indwar	3 years (12/14–11/17)	NIH
2.	Groundwater fluctuations and conductivity monitoring in Punjab.	Gopal Krishan (PI), N.C. Ghosh, Surjeet Singh, C.P. Kumar Dan Lapworth (PI from UK) Alan MacDonald (Proj. Coord.)	2 year (01/16–12/17)	NIH
3.	Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR".	Suman Gurjar (PI), N.C. Ghosh, Sumant Kumar, Surjeet Singh, Anupma Sharma	1.5 Years (04/16–09/17)	NIH

II.	**Internal Studies (New)**			
1.	Feasibility of Managed Aquifer Recharge in NCT, Delhi	NIH-Roorkee (Lead) CGWB, New Delhi	6 months (2/17-7/17)	MoWR, RD & GR (under Plan Fund)
III.	**Sponsored Projects (Ongoing)**			
1.	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.	N.C. Ghosh (Project Coord. & Leader) C.P. Kumar, B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, S.P. Indwar, R.P. Singh, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff SW Lab	3 year (11/15 – 4/18)	MoWR, RD & GR (under Plan Fund) (Rs. 375 lakh)
2.	Study of river - aquifer interactions and groundwater potential in the upper Ganga basin up to Dabrani.	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, S. P. Rai, Manohar Arora, Gopal Krishan,	5 year (03/16–02/21)	DST (under NMSHE) (Rs. 125 lakh)
3.	*Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply"	N. C. Ghosh, Lead Other Scientists of the division	2 years (02/16–03/18)	DST (Rs. 38.4 lakh)
IV.	**Sponsored Projects (New)**			
1.	Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water	N.C. Ghosh (Project Leader), Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff SW Lab - IIT Bombay (Partner) -UJS (Partner)	3 years (11/16-10/19)	MoWR, RD & GR (under NWM) (Rs. 160. 785 lakh)

HYDROLOGICAL INVESTIGATIONS DIVISION
Work Programme 2017-2018

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	Interaction between groundwater and seawater along the northern part of east coast of India	M. S. Rao (PI), Sudhir Kumar Pankaj Garg	2 years (08/15 - 03/18)	NIH
2	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	S.D Khobragade (PI); Sudhir Kumar; S. P. Rai, Senthil Kumar; Pankaj Garg	3 years (04/15 – 03/18)	NIH
3	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	M. S. Rao (PI) Sudhir Kumar	3 years (04/16 – 03/19	NIH
4	Isotopic Investigations in parts of Upper Yamuna River Basin	S. K. Verma (PI), Sudhir Kumar, S P Rai, Mohar Singh, Vishal Gupta	2 years (04/16 – 03/18)	NIH
II.	**Sponsored Projects (Ongoing)**			
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	S. P. Rai (PI); Sudhir Kumar; Rajesh Singh; M. Arora; Dr. R. J. Thayyen; Er. S. K. Verma	*5 Years 04/16-03/21*	DST (Subproject No. 9 under NMSHE, 191.08 lakh)
2.	Dating vary old groundwaters of deeper aquifers in Ganga Plains, India	MS Rao, Sudhir Kumar S. P. Rai Suhas Khobragade	*3 years 10/16 to 09/20*	IAEA Vienna (€ 18,000/-)
3	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar SP Rai	3 Years (04/16 -03/19)	Project with GBPIHE (15 lakhs)

SURFACE WATER HYDROLOGY DIVISION
Work Programme 2017-2018

S. N.	Title of The Project	Team	Duration	Funding
I. Internal studies (Ongoing)				
1.	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh (PI)	1 year (04/16 - 09/17)	NIH
2.	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Sushil K. Singh (PI)	3 years (04/16 - 03/19)	NIH
3.	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar (PI) Vaibhav Garg (IITR) Rakesh Kumar N.K. Bhatnagar	3 years (04/14 - 09/17)	NIH
4.	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Achana Sarkar (PI) T. Thomas Vaibhav Garg (IITR)	3 years (04/15 - 03/18)	NIH
5.	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora (PI) Rakesh Kumar	4years (05/14 - 03/18)	NIH
6.	Study on effect of climate change on sediment yield to Pong reservoir	A. R. Senthil Kumar (PI) J. V. Tyagi Avinash Agarwal Suhas Khobragade Manohar Arora	3 years (04/15 - 03/18)	NIH
7.	Effect of climate change on evaporation at point scale	Digambar Singh (PI) A. R. Senthil kumar Manohar Arora	3years (06/14 - 10/17)	NIH
8.	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani (PI)	3 years (04/15 - 03/18)	NIH
9.	Snow cover variability in the Upper Yamnotri Basin	Naresh Kumar (PI) Manohar Arora Rakesh Kumar	2 years (04/16 - 06/18)	NIH
II. Internal studies (New)				
1.	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments.	S.K. Singh (PI)	1 year (04/17 - 03/18)	NIH
2.	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f).	Sanjay Kumar (PI) Rakesh Kumar J. P Patra Pankaj Mani	4 years (04/17 - 03/21)	NIH
3.	An integrated assessment of a middle Himalayan watershed for sustainability of its water resources.	A. R. Senthil Kumar (PI) Manohar Arora, Digambar Singh, M S Rao, R K Nema, Pradeep Kumar, S K Mishra (IITR)	3 years (04/17 - 03/20)	NIH

4.	Development of regional methods for design flood estimation in Uttarakhand.	J.P.Patra (PI) Rakesh Kumar Pankaj Mani Sanjay Kumar	3 years (04/17 - 03/20)	NIH
III. Sponsored Projects (Ongoing)				
1.	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact.	A. R. Senthil kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora, Digambar Singh.	5 Years 03/16 - 03/21	DST (under NMSHE) 58.256 Lakh
2.	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India.	Ashwini Ranade (PI)	3 years (04/14 - 11/17)	DST 12.6 Lakh
3.	WaterRain-Him: Change in water fluxes and adaptation options in the Indian-Himalayan fed basins.	<u>NIH Team:</u> Archana Sarkar (PI) Director, NIH Sanjay K. Jain <u>Other Collaborators:</u> 1. SMHI, Sweden (Lead) 2. SEI, Sweden 3. IIT Delhi, India	3 years (2015-17)	Swedish Research Council (VR), Sweden NIH budget: SEK 188,000
4.	Modeling of Gangotri Glacier Melt Runoff and Simulation of Streamflow Variation under different Climatic Scenarios.	Manohar Arora (PI)	4 years (04/14- 03/18)	DST 47 Lakh
5.	Hydrological modeling in Alaknanda basin and assessment of climate change impact.	A. K. Lohani (PI) S. K. Jain V. S. Jaikanthan L. N. Thakral	5 Years 03/16 - 03/21	DST (under NMSHE) 42.296 Lakh
IV. Sponsored Projects (New)				
1.	GLORIOUS Copernicus Climate Change Service (C3S). ITT Ref.: C3S_422, Lot 1	<u>NIH Team:</u> Archana Sarkar (PI) Surjeet Singh, T. Thomas <u>Other Collaborators:</u> (i) SMHI, Sweden (Lead) (ii) WU, The Netherlands (iii) CAS, The Netherlands (iv) HZG-GERICS, Germany (v) isardSAT Group, Spain (vi) AGRHYMET, Niger (vii) Australian Bureau of Meteorology (BOM) (viii) Meteodat, Switzerland (ix) MPI, Russia (x) NAWAPI, Vietnam (xi) NCWQR, USA	18 months 09/17 –02/18	European Centre for Medium Range Weather Forecast (ECMWF), UK NIH budget: Euros 24,920

WATER RESOURCES SYSTEM DIVISION
Work Programme 2017-18

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel (PI) Sharad K. Jain Deepa Chalisgaonkar P. K. Mishra	3 years (04/13-12/17)	NIH (16 lakh)
2.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Thayyen (PI) S. P. Rai, Sanjay K Jain, Sudhir Kumar	3 years (04/14-03/18)	NIH (48 lakh)
3.	Hydrologic Modelling of a part of Satluj Basin using SWAT Model	P. K. Agarwal(PI) Sharad K. Jain, M. K. Goel, Sanjay K. Jain, M. K. Nema	4 years (06/14-03/18)	NIH (23 lakh)
4.	Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra	D. S. Rathore (PI) M. K. Goel, R.P. Pandey, Sanjay Kumar, Surjeet Singh	2 years (07/14-12/17)	NIH (34 lakh)
5.	Modeling of Narmada basin by using the GWAVA model	T. Thomas (RC-Bhopal)(PI) P. K. Mishra, M. K. Nema, Sanjay K. Jain, Sharad K. Jain, P. K. Agarwal	2.25 years (12/14-03/18)	NIH
6.	Runoff modeling of Shyok River, Karakorum Range	Renoj J.Thayyen(PI) Sanjay K.Jain	3 years (12/14-12/17)	NIH (38 lakh)
7.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema (PI) Sharad K. Jain, Sanjay K. Jain, Renoj J.Thayyen, P. K. Mishra, P. K. Agarwal	5 Years (12/14-12/19)	NIH (90.55)
8.	Development of Ganga Information Portal	Deepa Chalisgaonkar (PI) Sharad K. Jain, D. S. Rathore, Sanjay K. Jain, Sudhir Kumar, P. K. Mishra, P. K. Agarwal, M. K. Nema	3 years (04/15-03/18)	MoWR (under NIH Plan funds) (65.55 lakh)
9.	Study of hydrological changes in selected watersheds in view of climate change in India.	L. N. Thakural(PI) D. S. Rathore, Surjeet Singh, Sanjay K. Jain, Sharad K. Jain	3 years (04/15-03/18)	MoWR (under NIH Plan funds) (44.30 lakh)
II.	**Sponsored Projects (Ongoing)**			
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen(PI) Farooq Azam P.G. Jose A.P. Dimri (JNU)	3 years (03/16-02/19)	SERB (65.14 lakh)

2.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel (PI) M. Arora, A. K. Lohani, D. S. Rathore, Mrs. D. Chalisgaonkar, A. R. S. Kumar, Surjeet Singh, P. Mani, A. Sarkar, M. K. Nema, P. K. Mishra	5 years (01/16-12/20)	DST (under NMSHE) (52.15 lakh)
3.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore (PI) Mrs. D. Chalisgaonkar V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (under NMSHE) (48.83 lakh)
4.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain (PI) A. K. Lohani Sudhir Kumar P. Thakur (IIRS)	5 years (01/16-12/20)	DST (under NMSHE) (36.79 lakh)
5.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	R. J.Thayyen (PI) Sanjay K. Jain, Sharad K. Jain, S. P. Rai, P. K. Mishra, M. Arora, AP Dimri(JNU)	5 years (01/16-12/20)	DST (under NMSHE) 51.43 (NIH) + 28.29 (JNU)
6.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	Sharad K. Jain (PI) Renoj J.Thayyen, Sanjay K. Jain, S. P. Rai, Surjeet Singh, M. K. Nema,P. K. Mishra, P. K. Agarwal, AP Dimri (JNU)	5 years (01/16-12/20)	DST (under NMSHE) (54.07 lakh)
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra(PI) M. K. Nema, R. J. Thayyen, P. K. Sachan	5 years (01/16-12/20)	DST (under NMSHE) (90.99 lakh)
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen(PI) Farooq Azam, P.G. Jose, A.P. Dimri (JNU)	3 years (03/16-02/19)	SERB (65.14 lakh)
III.	**Sponsored Projects (New)**			
1.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya	R. J.Thayyen (PI) P. K. Mishra	3 years (03/17-03/20)	MoEF (58.76 lakh)
2.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)”	Sanjay K Jain (PI) Sharad K Jain Jointly with IITR	3 Years (01/17-01/20)	MoES (21.202 Lakhs)
3.	Design and development of generic Decision Support System-Hydrology platform for Neeranchal Project	D. S. Rathore (PI) Deepa Chalisgaonkar Jyoti Patil	1 year (04/17-03/18)	DoLR (under NNWP)

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)
Work Programme 2017-18

SN	Title of Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1	Development of IWRM Plan for Ibrahim-Masahi village (Haridwar district) **(Ongoing)**	Omkar Singh (PI), V C Goyal, Dinesh Kumar	04/13-09/17	NIH
II.	**Sponsored Projects (Ongoing)**			
2	Development of IWRM Plan for identified watersheds in Jhansi, Lalitpur and Chhatarpur districts **(Ongoing)**	**NIH:** V C Goyal (PI), Jyoti Patil **MPCST:** Sandeep Goyal, Rajesh Saxena **UP-RSAC:** Rajiva Mohan, Sudhakar Shukla	04/16- 03/18	MoWR, RD & GR (under NIH Plan funds)
III.	**Sponsored Projects (New)**			
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts	V C Goyal (PI), Dinesh Kumar, Omkar Singh, Digamber Singh	04/17- 03/20	MoWR, RD & GR (Rs 830 lakh)
4	Vulnerability assessment of identified watersheds in Neeranchal Project States	Jyoti P Patil + RCs	07/17- 06/19	DoLR (under NNWP)

REGIONAL CENTRE, BELGAUM
Work Programme 2017-2018

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (New)**			
1	Climate Change Adaptation Framework for Water Resources Management for Malaprabha River Basin inKarnataka	B Venkatesh, (PI) MK Jose, PC Nayak, T Thomas & Sc. HRRC B Venkatesh, (PI) PC Nayat, T Thomas, & Sc. of HRRC (In association with WRDO, Govt. Karnataka)	3 years (4/17-3/20)	NHP
2	Sustainability of Spring flows in parts of Western Ghats, India	BK Purandara (PI) & Sc. HRRC, (In association with WRDO, Govt. Karnataka)	3 years (4/17-3/20)	NHP
3	Water balance estimation in selected watersheds of Amaravati and Ahmednagar districts of Maharashtra	Chandramohan T (PI) M.K. Jose Venkatesh.B	One year (2017-18)	DoLR (NNWP)

4	Water balance estimation in selected watersheds of Nalgonda and Mehboob nagar districts of Telangana	M.K. Jose (PI) Chandramohan T Venkatesh.B	One year (2017-18)	DoLR (NNWP)
II.	**Sponsored Projects (Ongoing)**			
1.	Clean and safe drinking water supply to rural community using river bank filtration techniques in hard rock regions of Krishna basin, Karnataka, India.	BK Purandara (PI), Sudhir Kumar, Sc G	3 years (4/16-3/19)	DST (95 lakhs)

REGIONAL CENTRE, JAMMU
Work Programme 2017-18

S. N.	Title of Study	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	PBS: Integrated Water Resources Management (IWRM) Study in Tawi River Basin, JK	P Kumar (PI) S S Rawat	05 years (04/12-8/17)	NIH
2.	Hydrological Investigation of Natural Water Springs of Baan Ganga watershed in Jammu & Kashmir State	S S Rawat (PI) P Kumar S P Rai R V Kale	03 years (05/15-03/18)	NIH
II.	**Internal Studies (New)**			
1.	Performance evaluation of 2D-VPMM and 2D-explicit schemes for two-dimensional overland flow simulation.	R V Kale (PI) M K Goel	1.5 years (04/17 - 08/18)	NIH

REGIONAL CENTRE, BHOPAL
Work Programme 2017-18

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	Development of DSS for Bina river basin in Bundelkand region in M.P. using WEAP Model (under PBS)	T.R. Nayak (PI) R.V. Galkate T.Thomas R.K. Jaiswal Shashi P. Indwar	2 ¼ Years (04/15-07/17)	NIH
2.	Surface and ground water modeling for conjunctive use (under Pilot Basin Studies)	T.R. Nayak (PI) R.V. Galkate T.Thomas R.K. Jaiswal Shashi P. Indwar	2 ¼ Years (04/14-07/17)	NIH
3	Estimation of revised capacities of reservoirs in Chhattisgarh state using Digital Image Processing	R.K. Jaiswal (PI) R.V. Galkate T.Thomas R.K. Jaiswal	2 ¼ Years 04/15-09/17	NIH

	technique	Shashi P. Indwar		
4	Groundwater flow modeling in upper Bina river watershed in Bina block	S.P. Indwar (PI) R.V. Galkate T.Thomas R.K. Jaiswal Shashi P. Indwar	1 ½ Years 10/16-09/17	NIH
II.	**Sponsored Projects (Ongoing)**			
1	IWRM based Development Plan for Water Security in the Four Districts of Bundelkhand Region in India	V. C. Goyal (PI) Omkar Singh T. R. Nayak T. Thomas R. V. Galkate R. K. Jaswal Jyoti Patil	1¼ Years 07/16 – 09/17	MoWR, RD, GR (under NIH Plan funds) Rs. 300 lakhs
III.	**Sponsored Projects (New)**			
1	Water balance estimation in identified watersheds of Jashpur and Kanker districts of Chhattisgarh	T.R. Nayak (PI)	3 Years (04/17-03/20)	DoLR (under NNWP)
2	Water balance estimation in identified watersheds of Dewas and Jabalpur districts of Madhya Pradesh	R.V. Galkate (PI)	3 Years (04/17-03/20)	DoLR (under NNWP)
3	Water balance estimation in identified watersheds of Kuchch and Surendra Nagar districts of Gujarat	T.Thomas (PI)	3 Years (04/17-03/20)	DoLR (under NNWP)
4	Water balance estimation in identified watersheds of Jodhpur and Udaipur districts of Rajasthan	R.K. Jaiswal (PI)	3 Years (04/17-03/20)	DoLR (under NNWP)
5	Revival of Village Ponds through Scientific Interventions in Sagar District	T. Thomas (PI) Jyoti Patil Sandeep Goyal (MPCST) V. K. Bhatt (WALMI)	2 Years (07/17-06/19)	DST Rs. 28.82 lakhs
6	Evaluation of impacts of Rabi irrigation in Ganga river sub basin of Madhya Pradesh	R.V. Galkate, (PI) R.K. Jaiswal, T.R. Nayak, T. Thomas, Shashi P. Indwar,	3 years	PDS (under NHP) (Rs. 41.5 Lakh)

REGIONAL CENTRE, KAKINADA
Work Programme 2017 – 2018

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (New)**			
1	Hydrological Evaluation and Modeling for Water Resources Management in Lower Mahanadi basin in Odisha State	P. C. Nayak (PI) Sharad Jain, N.C. Ghosh, J. V. Tyagi, Y. R. Satyaji Rao, S. V. Vijayakumar B. Venkatesh V. S. Jeyakanthan T. Thomas R. Venkatramana, Prabhash Mishra	5 years (08/17-07/22)	NHP PDS (Rs.2.44 crore)
II.	**Sponsored Projects (Ongoing)**			
1.	Water balance estimation in identified watersheds of Anantpur and Chittoor districts of Andhra Pradesh	Y. R. Satyaji Rao V.S.Jeyakanthan R. Venkata Ramana	18 months (03/17-08/18)	DoLR (under NNWP)
2.	Water balance estimation in identified watersheds of Mayurbhanj and Kandhmal districts of Odisha	Y. R. Satyaji Rao V.S.Jeyakanthan R. Venkata Ramana	18 months (03/17-08/18)	DoLR (under NNWP)
3.	Real-time snow cover information system	V. S. Jeyakanthan	05 Years (2016-2021)	DST (under NMSHE)
4.	Hydrological modeling in Alaknanda basin and assessment of climate change impact	V. S. Jeyakanthan	05 Years (2016-2021)	DST (under NMSHE)

CFMS, GUWAHATI
Work Programme 2017-18

S.N.	Title of the Project	Team	Duration	Funding
I	**Internal Studies (Ongoing)**			
1.	Application of USLE Model for Estimation of Soil Loss in Kulsi River Basin using Remote Sensing and Geographic Information System	Gulshan Tirkey (PI) S. K. Sharma	1 year (04/16-03/17) Extended for 2017-18	NIH
II	**Internal Studies (New)**			
1.	Evaluation of Ground Water Quality with more Emphasis on Arsenic Contamination in Barpeta District of Assam	C. K. Jain (PI) S. K. Sharma Babita Sharma	1 year (04/17-03/18)	NIH
2.	Evaluation of Ground Water Quality in Shillong– the Capital City of Meghalaya	C. K. Jain (PI) M. B. Ritshong (SE, WRD, Meghalaya) S. K. Sharma	1 year (04/17-03/18)	NIH

		Babita Sharma		
3.	Distribution and Risk Assessment of Heavy Metal Pollution in Surface Soils of Guwahati (Assam)	C. K. Jain (PI) S. K. Sharma Upma Vats	1 year (04/17-03/18)	NIH
4.	Estimation of Runoff for Kulsi River Basin using NRCS Curve Number and Geographic Information System	S. K. Sharma (PI) Gulshan Tirkey	2 years (04/17-03/19)	NIH
5.	Morphometric Analysis of Kulsi Basin using different Digital Elevation Models (DEMs)	Gulshan Tirkey (PI) S. K. Sharma	1 year (04/17-03/18)	NIH

CFMS, PATNA
Work Programme 2017-18

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	Development of Relationships between Reference Evapotranspiration (ETo) of Penman-Monteith and other Climatological methods	S.R. Kumar (PI)	3 years (04/16-03/19)	NIH
II.	**Sponsored Projects (Ongoing)**			
1.	Demonstration scheme on Riverbank Filtration in Gangetic plain of Bihar	B. Chakravorty (PI) N. G. Pandey	2 years (02/16-02/18)	MoWR (under NIH Plan funds),
2.	River shifting analysis and flow modelling study of Ganga river from Rishikesh to Anupshahar	Pankaj Mani (PI) Rakesh Kumar, J. P. Patra	3 years (04/16-03/19)	MoWR (under NIH Plan funds),
III.	**Sponsored Projects (New)**			
1.	Water balance estimation in identified watersheds of Ranchi and Dhanbad districts of Jharkhand	B. Chakravorty (PI) N. G. Pandey	2 Years (04/17-03/19)	DoLR (under NNWP)

APPENDIX-71.4.1

WORK PROGRAMME OF THE DIVISIONS AT THE H.Q. AND RC/CFMS OF THE INSTITUTE FOR THE YEAR 2017–18 & 2018-19

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

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

Work Programme 2017-18

S.No.	Study	Study Team	Duration / Status
Internal Studies (ongoing)			
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams	Pradeep Kumar (PI) C. K. Jain	2 Years (04/16-03/18) Status: In-progress
Sponsored Projects (ongoing)			
2.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI) Manohar Arora M. K. Sharma Pradeep Kumar D. S. Malik (GKU)	5 Years (04/16-03/21) Sponsored by: DST Project Cost: 2.25 Crore Status: In-progress
Sponsored Projects (New)			
3.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) C. K. Jain Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur A. K. Shukla Ashok Verma P. C. Das	3 Years (09/17-08/20) Sponsored by World Bank under NHP-PDS Project Cost: 25.4 Lacs Status: In-progress
4.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) S. P. Rai M. K. Sharma Sumant Kumar Pradeep Kumar S. K. Malyan, RA Rakesh Goyal, Meenakshi Rawat, JRF	3 Years (09/17-08/20) Sponsored by World Bank under NHP-PDS Project Cost: 65.6 Lacs Status: In-progress
Consultancy Projects (ongoing)			
5.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines	C. K. Jain (PI) Sudhir Kumar Y. R. S. Rao Anupma Sharma S. D. Khobragade M. K. Sharma Pradeep Kumar	15 Months (04/16 – 06/17) Sponsored by: NTPC Amount Rs. 54.96 Lacs Status: Draft Final Report submitted and comments awaited.

Progress of Studies 2017-18

Study – 1 (Internal Study)

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

1. **Title of the Study:** Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams

2. **Study Group:**

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

3. **Type of Study:** Internal

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

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

6. **Scheduled date of completion:** March 2018

7. **Duration of the Study:** 2 Years

8. **Study Objectives:**

a) To compile the data/information on biotic parameters (abundance of aquatic species) and influencing abiotic parameters (water depth & velocity and water quality parameters: water temperature, pH, DO, BOD, turbidity etc.)
b) To identify the significant relationships between biotic and abiotic parameter and among the biotic parameters at selected locations
c) To establish the habitat suitability curves for aquatic species and habitat parameters

9. **Statement of the Problem:**

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

10. Approved Action Plan / Methodology:

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

11. Objectives and achievement during last one year:

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

12. Recommendation / Suggestion: Nil

Recommendation / Suggestion	Action Taken

13. Analysis & Results:

The graphs between biotic and abiotic parameters and also among biotic parameters have been developed to find out the significant relationships. The fish species richness has been found significant with altitude, air temperature, water temperature, conductivity and alkalinity. No significant relationship has been found between fish species richness and water velocity, DO, turbidity, chlorides and phosphates. The fish species richness is found to be significantly correlated with the density of vertebrates, zooplanktons and Phytoplanktons in the decreasing order. No significant relationship has been found between fish species richness and macroinvertebrates density.

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

15. **Deliverables:** Technical Report & Research Papers

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

17. **Lab facilities used during the study:** None

18. **Data procured or generated during the study:**

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

19. **Study Benefits / Impacts:**

Measurable indicators	Achievements

20. **Involvement of end users/beneficiaries:** Nil

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

22. **Shortcoming/Difficulties:** No

23. **Future Plan:**

Work Element	3rd year (2018-19)			
	I	II	III	IV
Assessment of environmental flows for eight selected tributaries of Satluj, Beas and Ravi through habitat simulation modeling using the developed habitat suitability curves				
Synthesis and report writing				

Study - 2 (Sponsored Project)

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

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

2. Study Group:

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

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

4. Nature of Study: Applied Research

5. Date of start: April 2016

6. Scheduled date of completion: March 2021

7. Duration of the Study: 5 Years

8. Study Objectives:

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

9. Approved Action Plan/Methodology:

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

10. Timeline:

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

11. Progress:

i) Fifteen sampling sites have been selected for water quality assessment in Upper Ganga Basin and monitoring is being carried out on monthly basis from September 2016.

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

iii) Eight sampling zones are being monitored for temporal abundance of different aquatic species (Phytoplanktons, Zooplanktons, Macro-Benthos) on monthly basis.

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

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

12. Research Outcome from the Project:

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

Study - 3 (Sponsored Project)

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

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

2. **Study Group:**

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

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

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

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

6. **Scheduled date of completion:** August 2020

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

8. **Study Objectives:**

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

9. **Statement of the Problem:**

Groundwater is one of the vital resources, which meets the requirements of daily livelihood especially in rural areas of India. Growing demand of water in various sectors viz; agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the groundwater resource, continuously declining groundwater levels, sea water ingress in coastal areas, and groundwater pollution in different parts of the country. Geo-environmental conditions have a marked influence on the groundwater quality. Hydrogeochemical studies relevant to the water quality explain the relationship of water chemistry to aquifer lithology. Such relationship would help not only to explain the origin and distribution of dissolved constituents but also to elucidate the factors controlling the groundwater chemistry. In the District Bemetara, Chhattisgarh, the Precambrian sedimentary province includes Chhattisgarh Super group of rocks of upper proterozoic age of marine origin. It mainly consists of arenaceous-argillaceous-calcareous rocks and dominated by Limestone, dolomite and calcareous shale. The weathered, cavernous and fractured part of the formation constitutes the aquifers in the area. The groundwater of Bemetara district is affected by sulphate contamination reported by Public Health Engineering Department, Durg. Berla block of the district has also the possibility of such type of sulphate contamination in ground water. Therefore, Bemetara district is selected for purpose driven study for sulphate contamination in ground water. The high concentration of sulphate in ground water is due to the dissolution of gypsum veins present within maniyari shale formation. Higher concentration of sulphate in ground water causes gastrointestinal irritation. A cost effective, economic viable and environmental friendly measure will be suggested for remediation of groundwater with special reference to sulphate contamination considering hydrogeology of the area.

10. Approved Action Plan/Methodology:

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

11. Timeline:

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

12. Objectives and achievement during last six months:

Objectives	**Achievements**
Literature Survey	• Literature Survey is in progress.
Field visit and Data Collection, Interim Report	• A field visit is made during 1-5 January, 2018 and explored the availability of ground water data.

13. Recommendation / Suggestion:

Recommendation / Suggestion	**Action Taken**

14. Analysis & Results:

i) Carried out the extensive literature survey related to assessment of groundwater quality and issues

ii) Visited Water Resources Department, Raipur and discussed about the availability of ground water level data. Contacted CGWB, Raipur regarding aquifer property data. Visited Bemetara district and discussed with PHED department regarding the problem.

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

16. Deliverables: Technical report and research papers

17. Major items of equipment procured:

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

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

20. **Study Benefits / Impacts:**

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

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

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

23. **Shortcoming/Difficulties:** No

24. **Future Plan:** Extensive pre-monsoon ground water quality sampling.

Study - 4 (Sponsored Project)

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

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

2. **Study Group:**

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

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

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

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

6. **Scheduled date of completion:** September 2020

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

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

9. **Statement of the Problem:**

Punjab has been the subject of much skepticism in the last decade. It has previously been called the "grain bowl of the country", but has recently adopted a new nickname, "the cancer bowl of the country". The pride of holding the title "a state with maximum per capita income" came with the price of cancer due to unrestricted use of chemicals (pesticides, fertilizers, metals, polycyclic aromatic hydrocarbons, pharmaceutically active hydrocarbons, etc.) in the agricultural fields and industries. A train which connects the affected region with the nearby Bikaner city, which contains a cancer hospital, has been nicknamed Cancer Express. Thakur et al. (2015) analyzed trace metals, pesticides, and other relevant parameters in some major drains, water samples (surface as well as groundwater), fodder, vegetable, and blood samples, and concluded that these samples contained harmful contaminants in excess of desired levels. Intake of these contaminants through the water as well as food is leading to deleterious health effects such as gastrointestinal disorders, reproductive toxicity, neurotoxicity, renal toxicity, and carcinogenic manifestations (WHO, 2011). Another study conducted by Thakur et al. (2008) observed a higher prevalence of cancer cases and cancer-related deaths in the area. A year-long study entitled "An epidemiological study of cancer cases reported from villages of Talwandi Sabo block, district Bathinda, Punjab", conducted by School of Public Health (SPH) at the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, compared cancer incidents in the villages producing cotton with those producing rice and wheat, and found high cancer rates in the villages where pesticide usage was high. A recent hospital-based study for Punjab shows that out of the 1328 cancer cases in the state, 1230 cases were from the seven districts of Southern Punjab comprising Muktsar, Firozpur, Bathinda, Faridkot, Fazilka, Moga& Mansa districts (Aggarwal et al., 2015). Considering the high cancer numbers and poor water quality described above, a comprehensive study of groundwater contaminants, especially carcinogens, is urgently required for the state of Punjab. The objectives of this study is to analyze the water quality of the area with an emphasis on carcinogenic chemicals, identifying their sources, and suggesting appropriate remedial measures.

10. Approved Action Plan/Methodology:

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

11. Timeline:

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

14	Scientific publications												
15	Final technical report												

12. Objectives and achievement during last twelve months:

Objectives	Achievements
Hiring of manpower & training	• Hired
Purchase of equipment & consumables	• Purchase for multiparameter & laptop is in advanced phase. • Purchase of syringe pump and geochemistry software is in initial stage
Upgrading literature and data collection	• Data is being collected from various resources
Delineation of villages and finalization of sampling location	• Will be processed after cancer related data is acquired

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
NA	

14. Analysis & Results: Nil

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

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

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

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

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

20. Study Benefits / Impacts:

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

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

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

23. **Shortcoming/Difficulties:** NA

24. **Future Plan:**
    i) Delineation of villages and finalization of sampling location
    ii) Collection and analysis of samples
    iii) Statistical analysis of data and carcinogenicity test

Proposed Work Programme 2018-19

S.No.	Study	Study Team	Duration / Status
Internal Studies (Cont.)			
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows	Pradeep Kumar (PI) C. K. Jain	3 Years (04/16-03/19) Status: In-progress One year extension requested.
Internal Studies (New)			
2.	Environmental Assessment of Village Ponds in Uttarakhand and Western UP	Rajesh Singh (PI) Suhas Khobragade Pradeep Kumar Digamber Singh	3 Years (04/18-03/21) Status: New
Sponsored Projects (Cont.)			
3.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI), NIH Manohar Arora, NIH M. K. Sharma, NIH Pradeep Kumar, NIH D. S. Malik, GKU	5 Years (04/16-03/21) Sponsored by: DST Project Cost: 2.25 Crore Status: In-progress
4.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) C. K. Jain Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur A. K. Shukla Ashok Verma P. C. Das	2 Years (09/17-08/19) Sponsored by World Bank under NHP-PDS Project Cost: 25.4 Lacs Status: In-progress
5.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) S. P. Rai M. K. Sharma Sumant Kumar Pradeep Kumar S. K. Malyan, RA Rakesh Goyal, Meenakshi Rawat, JRF	3 Years (09/17-08/20) Sponsored by World Bank under NHP-PDS Project Cost: 65.6 Lacs Status: In-progress
Consultancy Projects (ongoing)			
6.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines	C. K. Jain (PI) Sudhir Kumar Y. R. S. Rao Anupma Sharma S. D. Khobragade M. K. Sharma Pradeep Kumar	15 Months (04/16 – 06/17) Sponsored by: NTPC Amount Rs. 54.96 Lacs Status: Final Draft Report submitted and comments awaited.
7.	Downstream Impacts of Water Withdrawal by TTPS from Brahmani River	C. K. Jain M. K. Sharma Pradeep kumar	6 Months (02/18 – 07/18) Sponsored by NTPC Amount: 20 Lacs. Status: In-progress

Study - 1 (New Proposed Internal Study)

1.	**Sustainable Development Goals**	**:**	SDG Target 6.6: Protect and Restore Water-related Ecosystems
2.	**Project Team**		
a.	**Project Investigator**	**:**	Dr. Rajesh Singh, Sc. C, EHD
b.	**Project Co-investigator**	**:**	Dr. Suhas Khobragade, Sc. 'F' Dr. Pradeep Kumar, Sc. 'C' Sh. Digamber Singh, Sc. 'C'
c.	**Scientific/Technical Staff**	**:**	Sh. Rakesh Goyal, Tech. Gr. I
3.	**Title of the Project**	**:**	Environmental Assessment of Village Ponds in Uttarakhand and Western UP

4. Objectives

i) Assessment of water quality status of selected village ponds in Uttarakhand and Western UP
ii) Source identification of major contaminants in the village ponds and impact assessment
iii) Suggestions for possible remedial measures to reduce the impact of contaminants.
iv) Dissemination of knowledge and findings to common people through the preparation of manual, leaflets, booklets and by organizing workshops/training

5. Statement of the Problem

Ponds have played a crucial role in the water sustainability of the villages. Their water was utilized for domestic purposes and, to a limited extent, for irrigation purposes. These ponds also helped in improving the ground water regime in the region. Almost all villages have one big pond to meet the domestic needs throughout the year. However, by the middle of the 20th century, water supply provided through various other means led to the neglect of these ponds most of which are today in a state of utter neglect. A long-term solution to the water scarcity problem in the villages lies in the rejuvenation of these ponds.

To revive, restore and rehabilitate the traditional water bodies, The Government of India has launched a Scheme for Repair, Renovation and Restoration (RRR) of water bodies which has multiple objectives leading to water sustainability of the villages by providing Central Grant to State Governments through various schemes. It was visualized that this programme will go in a long way in enhancing water availability in different parts of the country. Although, this programme is a praiseworthy initiative yet neglect of quality of source water coming to the pond will be a major obstacle in achieving this target. Poor water quality will result in eutrophied ponds leading to imbalanced ecological status and reduction in pond capacity. In this connection, this study is envisaged to assess the water quality status of selected ponds and to suggest holistic rejuvenation plan.

6. Methodology

i) Literature review and data collection
ii) Delineation of villages and finalization of sampling locations
iii) Sampling & analysis of water samples
iv) Rejuvenation plan

7. Research Outcome from the Project

i) First-hand information on water quality of the village ponds

ii) Rejuvenation plan
iii) Technical report and papers

8. Cost Estimate

a. Total cost of the project : Rs. 32.71 Lacs
b. Source of funding : NIH (Internal)
c. Sub headwise abstract of the cost :

S.No.	Sub-Head	I Year	II Year	III Year	Total
1	Salary for JRF/SRF (1 no.)	3 24 000	3 24 000	3 62 880	**10 10 880**
2	Travelling expenditure	50 000	4 00 000	50 000	**5 00 000**
3	Infrastructure / Equipment / Consumable	7 00 000	2 00 000	2 00 000	**11 00 000**
4	Experimental charges	10 000	4 00 000	1 00 000	**5 10 000**
5	Misc. Expenditure	50 000	50 000	50 000	**1 50 000**
	Grand Total	11 07 600	6 07 600	6 34 000	**32 70 880**

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

- Salary: One JRF is required for sample collection, data collection, analysis etc.
- Travelling expenditure: For visit to study area, attending conferences, data collection, surveys etc.
- Equipment: Ion selective meter along with electrodes (DO, NH_3, NO_3, etc.) for field analysis.
- Consumables: Purchase of chemicals, glasswares, plastics, etc.
- Experimental charges: Towards analysis of samples in outside laboratories

9. Work Schedule

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

Sr. No.	Activities	YEAR 1				YEAR 2				YEAR 3			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
1	Literature review & data compilation												
2	Delineation of villages and finalization of sampling location												
3	Collection and analysis of samples												
4	Analysis & synthesis of results												
5	Preparation of rejuvenation plan												
6	Scientific publications												
7	Final technical report												

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

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

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

WORK PROGRAMME 2017-18

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/ NIH/15-18	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.	N.C. Ghosh (Project Coord. & Lead), C.P. Kumar, B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff of SW Lab	2-1/2 year (11/15 – 4/18) **Status: In progress**. Project cost : **Rs. 375 lakh**	Sponsored by MoWR, RD & GR under Plan Fund.
2. NIH/GWD/ NIH/14-17	Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin	Anupma Sharma (PI), N.C. Ghosh, Coordinator Scientists from GWHD and EHD in association with Prof. Deepak Kashyap, IIT Ropar, as Technical Consultant	3 years (12/14 – 11/17) **Status: To be Completed by March 2018**.	Internal Funding.
3. NIH/GWD/ BGS/16-20	Ground water fluctuation and conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements	**From : NIH, Roorkee** Gopal Krishna, (PI) Surjeet Singh, C. P. Kumar, N.C Ghosh **From : BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator	03 Years (01/16-11/20) **Status: In progress**.	**Sponsored,** BGS, UK
4.NIH/GWD/NMSHE/ 16-20	Study of river - aquifer interactions and groundwater potential at selected sites in the upper Ganga basin up to Dabrani.	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, S. P. Rai, Manohar Arora, Gopal Krishan,	1 year (01/16 – 12/20) **Status: In progress. Project cost : Rs. 125 lakh**	Sponsored by DST under NMSHE SP-8.
5. NIH/GWD/ NIH/16-16	Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR".	Suman Gurjar (PI), N.C. Ghosh, Sumant Kumar, Surjeet Singh, Anupma Sharma	08 Months (04/16 – 11/16) **Status: Completed.**	Internal Funding.
6. NIH/GWD/ 16-17	*Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply"	N. C. Ghosh(Lead) Other Scientists of the division **Collaborators:** IIT Roorkee UCOST, Dehradun UJS, Dehradun HTWD, Germany	2 years (02/16 – 03/18) 4 training courses in two years. (3-completed) **Project cost : Rs. 38.4 lakh**	Sponsored by DST

7. NIH/GWD/ NIH/16-19	Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water	N.C. Ghosh (Project Leader), Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Chaudhury, Sanjy Mittal, Ram Chandar, Staff SW Lab - IIT Bombay (Partner) -UJS (Partner)	3 years (11/16-10/19) **Status: In progress.** **Ppartners:** IIT Bombay UJS, Dehradun **Project cost : Rs. 160. 785 lakh** + service tax.	Sponsored by NWM, MoWR, RD & GR
8.NIH/GWD/NIH/17-17	Feasibility of Managed Aquifer Recharge in NCT, Delhi	NIH-Roorkee (Lead) CGWB, New Delhi	6 months (2/17-7/17) **Status : Completed.**	Desired by Secretary, WR, RD & GR
Consultancy Projects				
9.CS/104/ 2016-16/NIH(GWHD)	Hydrological and Water Quality Study of the Project sites of Rays Power Infra Pvt. Ltd. in Roorkee	N.C. Ghosh (PI), Anupma Sharma, Sumant Kumar, Anju Chaudhary, S.L. Srivastava, Mansi Tripathi, Roque Khokar, N.K. Lakhera, C.S. Chowhan, Dinesh Kumar	**06** Months (**03/16-08/16**) **Status: Completed**. **Project cost: Rs. 3 lakh**	Sponsored by Rays Power Infra Pvt. Ltd.
10.CS-108/2016-16/NIH(GWHD)	Evaluation of Water Level Networks to identify Suitable Piezometers for Installation of Digital Water Level Recorders in Districts of North UP	N.C. Ghosh (PI), Sudhir Kumar, Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, R.P. Singh, Anju Choudhary, Sanjay Mittal, S.L. Srivastava	08 Months (11/**16-05/17**) **Status: Completed**. **Project cost : Rs. 17.7568 lakh** + 15% service tax	Sponsored by Ground Water Deptt., Govt. of UP
11.CS-116/2017-17/NIH(GWD	Groundwater recharge source in deep aquifer using isotopes in Punjab	Gopal Krishan (PI), M.S. Rao, N.C. Ghosh, Sudhir Kumar, Vishal Gupta, Vipin Aggarwal, Mohar Singh	02 Months (05/17-06/17) Project cost : Rs. 2,64,500 **Status: Completed**.	Sponsored by Department of Water Supply and Sanitation, Punjab
12.CS-126/2017-18/NIH(GWH)	Water Availability and Water Budgeting Study of Kalsi Micro-Watershed, Uttarakhand	Surjeet Singh (PI), Sharad Jain, N.C. Ghosh, V.C. Goel, Omkar Singh, P.K. Singh, Sanjay Mittal, S.L. Srivastava	06 Months (10/17-03/18) **Status: In progress.** Rs. 6.0 Lakh + GST	WMD, Dehradun

PROPOSED WORK PROGRAMME FOR THE YEAR 2018-19

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/ NIH/15-18	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.	N.C. Ghosh (Project Coord. & Lead), C.P. Kumar, B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff of SW Lab	21/2 year (11/15 – 4/18) Status : Continuing study. Seek extension for one year	Sponsored by MoWR, RD & GR under Plan Fund.
2. NIH/GWD/ BGS/16-20	Ground water fluctuation and conductivity Monitoring in Punjab-New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements	**From : NIH, Roorkee** Gopal Krishna, (PI) Surjeet Singh, C. P. Kumar, N.C Ghosh **From : BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator	03 Years (01/16-11/20) **Status: Continuing study**.	**Sponsored,** BGS, UK
3.NIH/GW D/NMSHE /16-20	Study of river - aquifer interactions and groundwater potential at selected sites in the upper Ganga basin up to Dabrani.	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, S. P. Rai, Manohar Arora, Gopal Krishan,	1 year (01/16 – 12/20) **Status: Continuing study**	Sponsored by DST under NMSHE SP-8.
4. NIH/GWD/ NIH/16-19	Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water	N.C. Ghosh (Project Leader), Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Chaudhury, Sanjy Mittal, Ram Chandar, Staff SW Lab - IIT Bombay (Partner) -UJS (Partner)	3 years (11/16-10/19) **Status: Continuing study**	Sponsored by NWM, MoWR, RD & GR
New Studies for the Year: 2018-2019				
New Studies				
5.NIH/GW D/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin-**FAR GANGA**	**NIH-Team:** N. C. Ghosh (Indian Lead) Surjeet Singh; Sumant Kumar; Gopal Krishan; Suman Gurjar from NIH	**3 years** (01/18 – 12/20) **Indian budget :** Rs. 370.9	DST-Newton Bhabha-NERC-India-UK Water

		Other Indian partners: IIT Roorkee; IIT Kharagpur; & Mahavir Cancer Sansthan, Patna. **UK- Partners:** Prof. David Polya – UK lead; Univ. of Manchester; BGS; Salford University; Univ. of Birmingham.	lakh **NIH budget :** Rs. 138.67 lakh **Status : New Study.**	Quality Research Programme.
6.NIH/GWD/DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific reference to Fluoride and Micro-pollutants.	**NIH-Team:** Dr. Anupma Sharma (Indian Lead); ; Sumant Kumar; Gopal Krishan; Suman Gurjar and M. K. Sharma from NIH. **Other Indian partners:** IIT Ropar & IIT Jodhpur. **UK Partner: Cranfield University** Dr Alison Parker – UK Lead; Cranfield University Dr Pablo Campo Moreno, School of Water, Energy and Environment; Cranfield University	**3 years** (01/18 – 12/20) **Indian budget :** Rs. 359.64lakh **NIH budget :** Rs. 143.16lakh **Status : New Study.**	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme.
7. NIH/GWHD/PDS/18-21	Ganges Aquifer Management in the context of Monsoon Runoff conservation for sustainable River Ecosystem Services- A Pilot study	Surjeet Singh, (PI), N.C Ghosh, Sudhir Kumar, C. P Kumar, Suman Gujar, Gopal Krishan	04 Years (03/18-02/21) Status: **Project cost: Rs. 57.71 lakh Status : New Study.**	Sponsored by NHP under PDS
8. NIH/GWHD/PDS/18-20	Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures	**NIH, Roorkee, India** Gopal Krishan (PI), N. C. Ghosh, Surjeet Singh, C.P. Kumar Haryana Irrigation Department Consultants IIT-Roorkee Brijesh Yadav (PI) Sehgal Foundation, Gurgaon Lalit Mohan Sharma	03 years 01/18 12/20 **Project cost: Rs. 65 lakh Status : New Study.**	Sponsored by NHP under PDS

9. NIH/GW HD/PDS/ 18-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), N.C. Ghosh, Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary, Ram Chandar	03 years 01/18 12/20 **Project cost: Rs. 70 lakh Status : New Study.**	Sponsored by NHP under PDS
10.NIH/G WD/PDS/ 18-20	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi.	NIH Team: Dr. Anupma Sharma (Lead)	Expected New Study	Special Project under "Centre of Excellence"
11.	Follow-up on **"Strategic Basin Planning for Ganga River Basin".** - Training to State organizations - Application for Conjunctive use management of SW & GW in Saryu Nahar Pariyojana, U.P. - Preparation of User Manual.	Ms. Suman Gurjar (PI), Jyoti Patil	1 year (04/18-03/19) **Status : New Study.**	NHP (Centre of Excellence for Hydrologic Modelling)
12.	Implementation of DSS(P)	Anupma Sharma - Lead		NHP
13.	Centre of Excellence for Hydrologic Modeling	N. C. Ghosh - Lead		NHP

Important Activity

Organized 7th International Ground Water Conference **(IGWC-2017)** on **"Groundwater Vision 2030: Water Security, Challenges and Climate Change Adaptation"** in association with CGWB, AGGS and Texas A&M University, USA during 11th -13th December, 2017 at New Delhi along with an add-on post-Conference workshop on "Groundwater Modelling using iMOD for the Ganga basin" on 14th December, 2017.

Convener:

- N. C. Ghosh

Organizing Secretary from NIH

- Anupma Sharma

Joint-Org. Secretary from NIH

- Surjeet Singh

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

Thrust Area under XII five year Plan: Drinking water supply demonstration scheme.

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

Project duration : 30 months (November, 2015 – April, 2018).
Sponsored by : MoWR, RD & GR, GoI. Under NIH's Plan Fund.

Objectives of the Project:

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

Methodology

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

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

Project deliverables

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

Progress made so far:

(i) Laksar Site, Uttarakhand:

One RBF site was drilled at Kuan Khera village in Laksar UK in year 2016 (Photograph -1) . During heavy flood in year 2016 in Solani river, the exploratory RBF well was damaged by bank erosion and the river bank had been shifted towards other side (Photograph 2). On the other hand, the site featured problem of groundwater quality of geogenic origin. These trobleshoot led to ***abandoning*** the site explored in Kuan Khera village.

Photograph 1: Drilling work for RBF well Development.

Photograph 2 : Dislocated riverbank of the RBF site by erosion during 2016 flood.

(ii) Mathura and Agra Sites

Based on the nearly two years field investigations and data analysis, the sites selected in consultation with U.P. Jal Nigam for RBF well exploration and development in Mathura near Gakul barrage and Agra near Agra Water Works are as shown in Figure 3(a) & (b)..

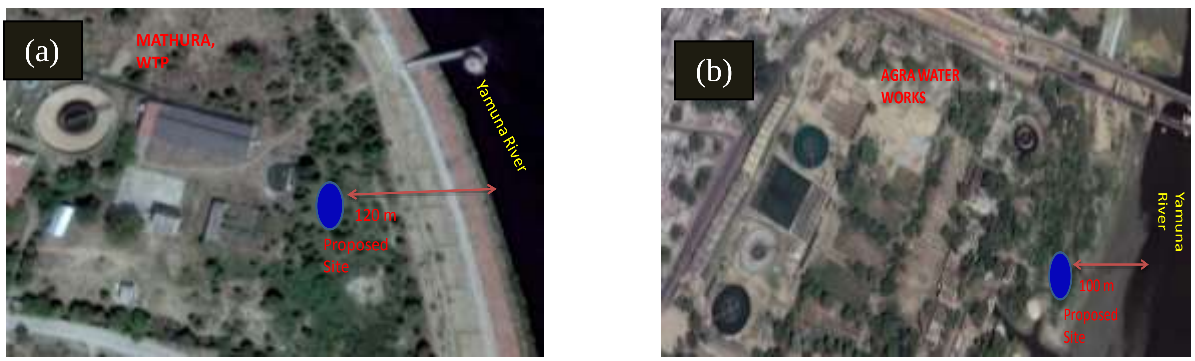


Figure 3: Site selected for exploratory drilling and development of RBF wells; (a) Mathura, and (b) Agra.

For exploratory drillings and installation of tube wells at both the sites, the work is being done through U.P. Jal Nigan as deposit work. A MoU was signed with the U.P. Jal Jigam for carrying out the exploratory boring work and installation of wells. An amount of Rs.4.616 lakh (40% of total work cost of Rs. 11.54 lakh for both the sites) was paid to U.P. Jal Nigam and the work are about to start.

(iii) Arrah site in Bihar

Based on a number of field visits along with Bihar-PHED officials, Berhara village in Arrah district in Bihar has been selected for exploratory drilling & development of RBF scheme. Permission for land and estimate for taking up the work by PHED, Bihar as deposit waork have been obtained. The MOU and deposit of money are yet to take place.

Photographs : Selected site in Behara village of Ara district in Bihar.

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

A site along Varaha River at **Vishakapatnam** has been selected in consultation with A.P. RWS & S, Govt. of Andhra Pradesh. For exploratory drilling and installation of RBF tube well through A.P. RWS & S, Govt. of Andhra Pradesh as deposit work, the estimate (Rs. 3.25 lakh) has been obtained. The MoU for undertaking the task has been executed and 1st installment has been given to A.P. RWS & S. Geophysical survey of the site has been carried out.

Photograph : Selected RBF site along Varaha River at Vishakapatnam.

(v) Sahebganj, Jharkhand

The RBF site in Sahebganj (Jharkhand) is yet to decide..

In view of delay in obtaining permission for land, the whole work got delayed by about a year. It is requested to extend time of the project by one from April, 2018.

2. PROJECT REFERENCE CODE: NIH/GWD/NIH/14-17

Title of the study: **Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin**

Study team:

Type of study (sponsored/consultancy/referred/internal): Internal

Date of start: December 2014

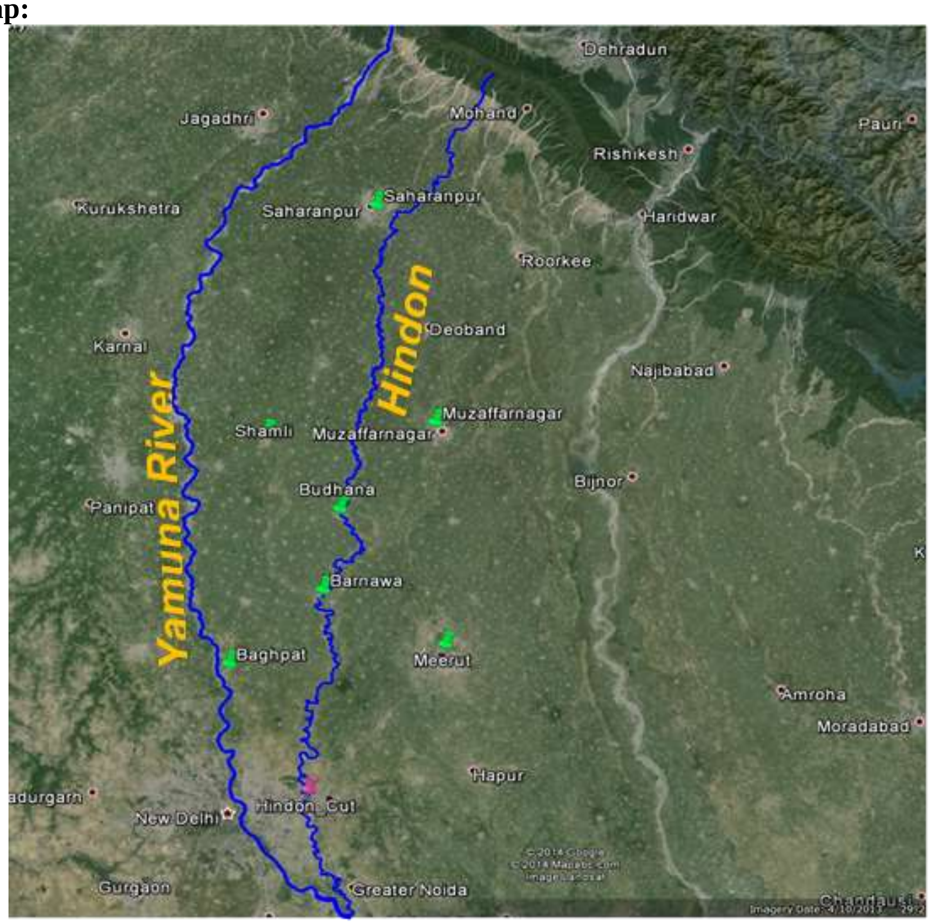
Duration of study: Three years

Study objectives:

1. Numerical modeling for optimal management of surface water and groundwater in Yamuna-Hindon inter-basin.
2. Strategies for groundwater management associated with climate variability events.
3. Assessment of surface water and groundwater quality degradation due to disposal of municipal and industrial effluents and impact on groundwater pumpage.

Need for study and Specific linkages with Institutions and/or end-users/beneficiaries: Severe water quality degradation issues have affected domestic and irrigation water supply in the fertile Yamuna-Hindon inter-basin. Need to develop strategies for conjunctive management of water resources in the region.

Location map:



Objectives vis-à-vis Achèvements:

Objectives	Achievements/ Activities
Data collection	Historical groundwater level data from State and Central Ground Water Depts., crop cultivation, relevant reports and maps, meteorological data, data collection during field visits including soil moisture, depth to water levels, TDS, etc.
Field experiments and Laboratory investigations	- Collection of soil samples and water samples from Hindon river and groundwater (within 500 m). - Soil sample analyses in laboratory for texture analysis, soil moisture characteristics - Chemical analyses of water samples (river water and groundwater) for trace metals during pre- and post-monsoon season
Database preparation	DEM, land use, soil texture, drainage, groundwater levels (pre & post monsoon), water quality
Data analysis and Groundwater modeling	- Analysis of water table and water quality data, satellite data, land use; analysis of soil samples and data for infiltration rates and saturated hydraulic conductivity. The groundwater data reveal that at many locations the groundwater levels have receded compared to 1990s. - Groundwater modeling in Yamuna-Hindon interbasin

Lab facilities used during the study:

- Soil and Water Lab, NIH
- Water Quality Lab, NIH
- Institute Instrumentation Centre, IIT Roorkee

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

Title of the study : **Groundwater fluctuations and Conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements**

Type of study : **Sponsored,** BGS, UK.

Date of start (DOS) : December 2017

Scheduled date of completion : November 2020

Location : Bist- Doab Punjab

Study objectives:

1. To characterise multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers
2. To prepare a status report on groundwater issues in Punjab

Statement of the problem:

The increased use of groundwater to meet out the ever increasing demands of growing population, agricultural and developmental activities leading to groundwater depletion in Punjab. The long term water level fluctuation of the available 414 sites reveals that 317 sites have shown a decline in water level during 1984-2008, these sites are mainly in the major parts of districts Amritsar, Barnala, Fatehgarh Sahib, Faridkot, Tarn-Taran, Ludhiana, Moga, Nawanshahar, Patiala and Sangrur. Apart from these, districts of Kapurthala, Mansa and Mohali mostly show a decline in water level during the period. In the present study, Bist-Doab area was selected based on previous studies which cover Nawanshahr and Kapurthala districts. In Bist-Doab, occurrence of groundwater forms the multi-layered aquifer system. The groundwater fluctuation in the shallow aquifer and deep aquifer show different trends. The large drop in groundwater levels can be due to several reasons like high withdrawals, low-recharge, low-transmissivity, poor conditions of surface water recharge source conditions etc. Characterising and understanding the reasons for this local heterogeneity is fundamental to develop effective water management plans. This requires higher resolution field-based observations.

Methodology:

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

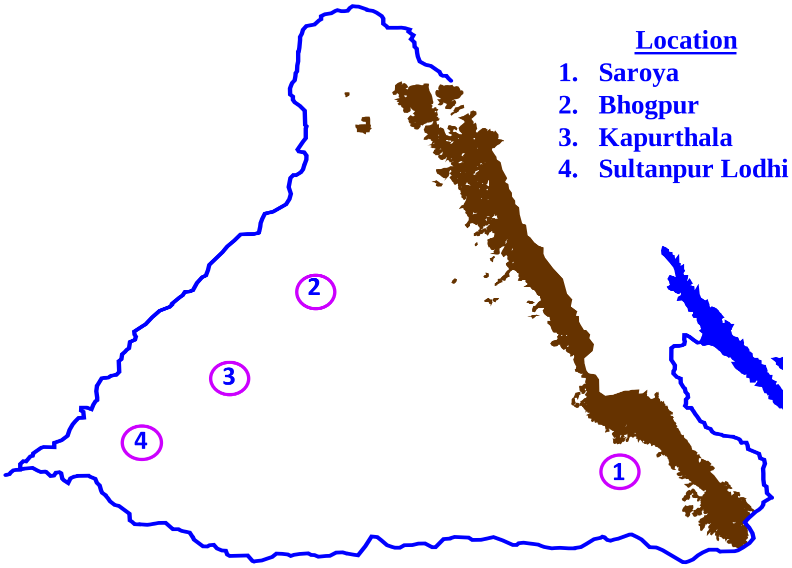


Fig. 1. Study area

From the water level data for the 4 sites: Saroya, Bhogpur, Kapurthala, Sultanpur Lodhi, it has been observed that the groundwater level depth at Saroya, Bhogpur and Kapurthala increased during the Kharif season (June to October) perhaps as a result of excessive abstraction for irrigation during this period while groundwater level at Sultanpur Lodhi was almost constant. The results for conductivity show that there were some irregular trends at all 4 sites.

Action plan:

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

Study Benefits /Impact:

- An overview report on groundwater status in Punjab
- Research publication in high impact journals.
- Upload of results on Websites.

Specific linkages with Institutions: BGS, UK

QUARTER WISE ACTIVITY SCHEDULE FROM DEC. 2017 TO NOV. 2020

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

Progress

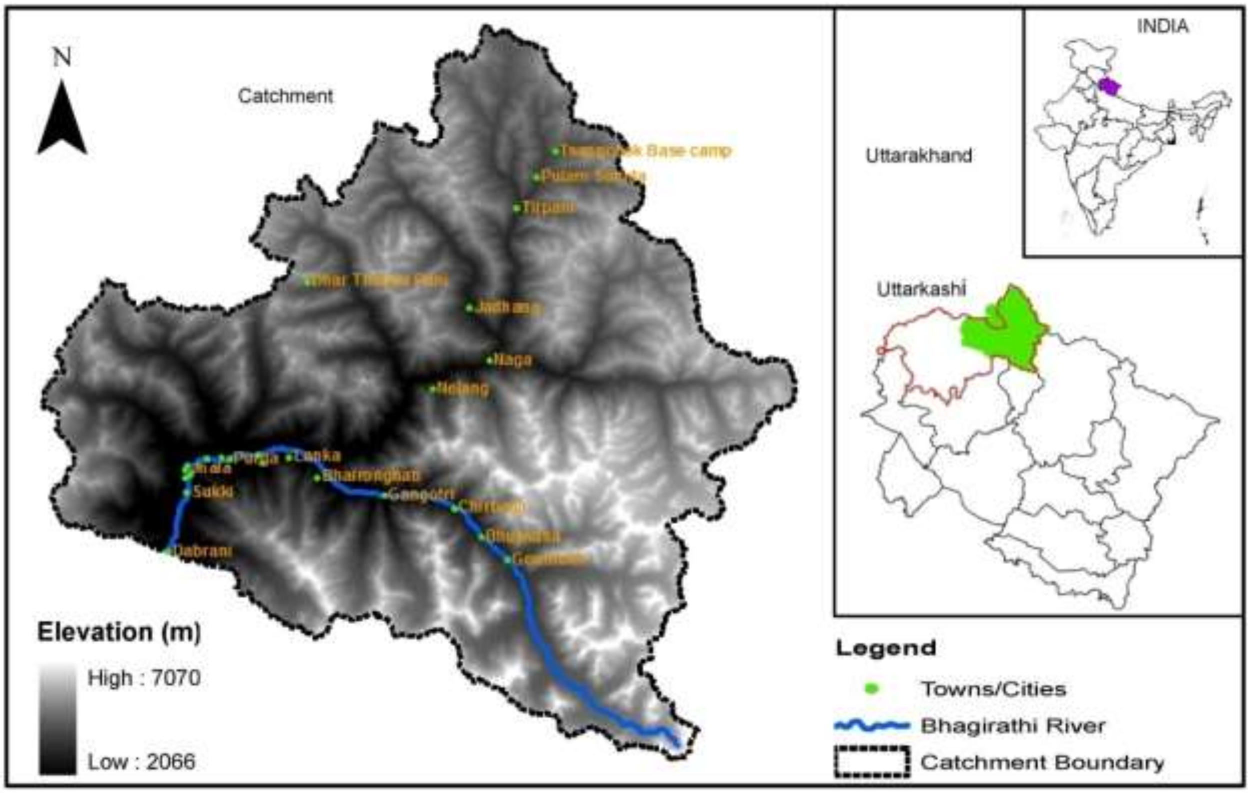
- The approval from Ministry of Water Resources, River Development and Ganga Rejuvenation has been received in the month of December, 2017 on the request sent in March, 2017.
- The water loggers will be installed in the Pz of state department after receiving the permission

Future plan

- Installation of the water level loggers
- Collection of samples
- The hydro-meteorological data will be collected from state departments
- Data analysis work will be carried out with respect to various parameters like rainfall, land use etc. to observe the seasonal and spatial variation

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

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



Study objectives:

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

Approved Action Plan:

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

Timeline and Justification for time over runs:

The work on the development of piezometers in the study is being undertaken with the Uttarakhand Jal Sansthan (UJS), Uttarkashi.

Objectives vis-à-vis Achievements:

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

Recommendations/ Suggestions in previous meetings of Working Group/ TAC/ GB - Nil.

Analysis of Results:

The study is envisaged on the stream/river and groundwater flow interactions and dynamics including potential assessment emerging from snow and glacier melt recharge to answer the question of groundwater development prospects in the hilly areas as well as base flow regimes of the mountainous streams. In order to carry out the study, the existing basin information, geological and geo-hydrological investigations and development of piezometers for groundwater data acquisition are necessary. The study area, lies in the Uttarkashi district of Uttarakhand state, comprises an area of 3,487.06 sq.km. The main river is Bhagirathi river. 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, etc. have been prepared. Geological traversing from Dabrani to Gangotri was also done. Borelog data of five locations were collected and analyzed. The soil map of the basin area has been prepared and given below.

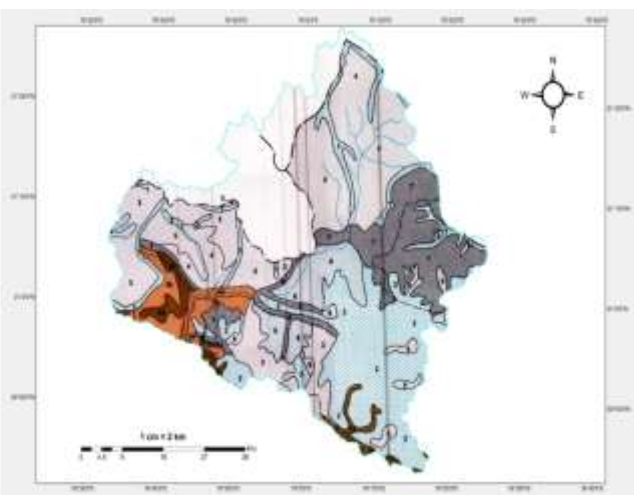


Figure 1: Soil group for the study area prepared from the NBSSLUP map

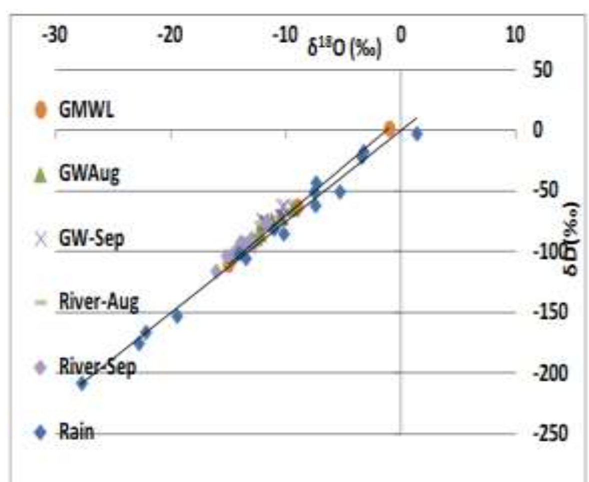


Figure 2: Local Meteoric Water Line for the monsoon season

Water sampling from Bhagirathi river, precipitation and groundwater is being continuously done for the isotopic and water chemistry analysis for studying the interactions. The water samples were collected during the period from Oct. to Dec., 2018 on 10 daily frequency from springs, river, stream and hand-pump and rain on event-basis for the isotopic and water chemistry analysis. A preliminary interpretation based on the limited data collected so far during the monsoon season indicates that most of the river water and groundwater samples fall close to the LMWL (Local Meteoric Water Line) shown above, which indicates mixing of surface water and groundwater. The work on the piezometer development through deposit work is in process with the Uttarakhand Jal Sansthan (UJS).

List of Deliverables:

- Reports; Research papers; Training Workshops.

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

Lab Facility used during the Study:

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

Data Procured/ Generated during the Study:

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

Study Benefits /Impact:

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

Specific linkages with Institutions: DST, UJS.

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

Future Plan:

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

5. PROJECT REFERENCE CODE: NIH/GWHD/NIH/16-16

Title of the Project: Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR"

Type of study : Internal

Nature of study : Outreach Services.

Duration : April 2016 - March 2018

Objectives

- To develop a comprehensive user friendly web-enabled "*Conjunctive Use Model for Management of Surface and Ground Water in a recharge basin using concept of MAR and ASR*".
- To provide a platform to users and professionals for calculating time-varying depth of water in , and groundwater recharge from, a recharge basin consequent to the pumping in the vicinity of the basin for recovery of recharged water .
- To provide a platform to users to simulate the contaminant transport process in the basin and through saturated soil column before mixing with the groundwater.
- To visualize the output in graphical as well as tabular format.
- To host the module in the public domain as an extension of WE-GREM for its large uses by stakeholders and groundwater professionals.

Methodology:

- An analytical model to determine the recharge rate due to interaction of different hydrological components in a recharge basin including pumping in the vicinity of the basin has been developed.

- The model has been developed based on water balance of recharge basin that includes inflow to the basin, outflow from the basin, and rainfall over the basin, evaporation from the basin and groundwater recharge from the basin. For estimation of different hydrological components processed based equation have been used for example SCS-CN method is used for inflow, Standard models like Pan Evaporation, Mass Transfer, combination of Priestley-Taylor and Penman are used for Evaporation, analytical method Hantush (1967) is used for groundwater recharge and for pumping Thesis(1935) well response function is used.

- To simulate the in-basin transport processes and fate of contaminants through saturated soil column before mixing with the groundwater, the conservation equation with decay for the in-basin mass transport, and the analytical solution of 1-Dimensional advection-dispersion equation (ADE) given by Ogata and Banks (1961) together with the decay and Freundlich linear adsorption isotherm equation for contaminant transport through saturated soil column is used.
- The developed model is converted into a web-enabled and user friendly interface.
- The interface is an extension to the WE-GREM.

Progress made so far

- Development of Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR" is completed.
- A comprehensive help module is under development.

Deliverables:

- Web-enabled system for calculating time-varying depth of water in , and groundwater recharge from, a recharge basin consequent to the pumping in the vicinity of the basin for recovery of recharged water. In addition with the module for calculation of the contaminant's transport in the basin and through saturated soil column before mixing with the groundwater.
- Results are shown in the form of charts, tables and graphs.

6. PROJECT REFERENCE CODE: NIH/GWD/NIH/16-17

Title of the Project	**:**	*Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply".
Type of study	**:**	Sponsored by DST, Govt. of India
Nature of study	**:**	Outreach Activity
Duration	**:**	February 2016 - March 2018

Objectives

(i) To develop, strengthen and upscale competence on bank filtration technique and its allied aspects in the Country for attaining drinking water security;

(ii) To create a platform of knowledge repositories on bank filtration in the Country, and develop a network to connect & interact with trained personnel for exchanging knowledge.

Deliverables:

- Upscale Process for competence building on "Bank Filtration"
- Services for knowledge dissemination and up-gradation on "Bank Filtration"
- Compiled report on conducted training courses including feedback analysis.

Progress:

As of now, three training courses, the first one for the states representing Indo-Gangetic and Brahmaputra & Barrack basin covering all eight north-eastern states, West Bengal, Bihar, Jharkhand, Uttar Pradesh, Uttarkhand, Himachal Pradesh, and Delhi was organized at NIH, Roorkee during 12th -16th September, 2016; the second training course for the states of Tamil Nadu, Karnataka, Kerala, Pudicherry, Andhra Pradesh, Telengana, Odisha, Maharastra, Goa, Gujarat, Madha Pradesh, Chhatisgarh, Punjab, Haryana, Rajasthan, Jammu & Kashmir and UTs of Andaman & Nicober was organized at Goa during 6th -10th February, 2017, and the third one again for the states representing Indo-Gangetic and Brahmaputra & Barrack basin covering all eight north-eastern states, West Bengal, Bihar, Jharkhand, Uttar Pradesh, Uttarkhand, Himachal Pradesh, and Delhi at Shillong during 18th -22nd September, 2017 were organized.

The fourth (last) training course again for the states of Tamil Nadu, Karnataka, Kerala, Pudicherry, Andhra Pradesh, Telengana, Odisha, Maharastra, Goa, Gujarat, Madha Pradesh, Chhatisgarh, Punjab, Haryana, Rajasthan, Jammu & Kashmir and UTs of Andaman & Nicoberis is scheduled to be held during 5th -9th March at NIH, Roorkee.

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

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

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

Nature of study: Demonstration

Duration: November 2016 - October 2019

Objectives:

The objectives are to develop a cost effective and non-hazardous wastewaters treatment technique for re-use and recycling of treated water to attain urban and peri-urban water supply security by studying the following aspects:

(i) Potential of natural treatment techniques namely, Constructed Wetlands (CW), Managed Aquifer Recharge (MAR) and Riverbank Filtration (RBF) in treatment of municipal and domestic wastewaters to bring in conformity with the usable water, when applied in series,
(ii) Response and performance evaluation of natural treatment techniques to variable inflows and outflows rate and variable water quality constituents,
(iii) Response of aquifer to variable input loadings, and determination of migration pathways of residual traces in the aquifer under different hydrologic and hydrogeologic conditions,
(iv) Assessment of wastewater and improvisation of water constituents from one treatment unit to another, and
(v) Risk evaluation of hydro-geologic regime due to induced recharge.

Methodology:

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

Deliverables:

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

Progress

Despite all hurdles from Civil Administration, the allotment of a piece of land measuring 45 m x 45 m was given on 2nd May, 2017.

However, the location of land allotted to NIH is very near to the river and it was far away towards the river from the location that we planned in the proposal. The allotted land is close to the river and during monsoon period, it gets submerged. Moreover, it is considerably a depressed land. Our scheme is based on cascade of Constructed Wetland (CW), Managed Aquifer Recharge (MAR) and Bank Filtration (BF). The location where the land has been finally allotted, cannot be used for installation of Bank Filtration well because of scientific, technical and tactical reasons. Keeping all adds aside, even if we implement the scheme at the given location, we shall not be able to demonstrate performance of the technique because of lack of distance required for implementation of BF technology. In one sentence, the given location does not meet the technical requirement of the scheme.

The land allotted to NIH is controversial and villagers from Khanjarpur have objection and showing arrogance not to allow project to implement; in such case, it would be difficult to go ahead with the implementation of the scheme. Further, the present location of land has cremation ghat and dumping place of cattle dead bodies nearby. Even if we succeed to implement the scheme, people from the nearby areas shall not accept use of water because of social reason.

Because of the reasons, the progress of developing & undertaking field experimental work is pending since May, 2017. Uptil now, the Institute has spent some monies on payment of wages to employed project staff only, and we are almost in the initial states in implementation of the project. The view of the Working Group is sought on : (i) what to do for such circumstances (ii) whether to go ahead with the project.

8. ROJECT REFERENCE CODE: NIH/GWD/NIH/17-17

Title of the Project : **Feasibility of Managed Aquifer Recharge in NCT, Delhi.**

Type of study : Assigned by MoWR, RD & GR, GoI.

Nature of study : **Applied research**

Duration : February, 2017 – July, 2017

Executing organizations : NIH & CGWB

Objectives:

The study was assigned by the Ministry of WR, RD & GR, GoI with the following objectives:

(i) To study of aquifer configuration, aquifer-river linkage, aquifer characterization, groundwater resources availability and utilization in NCT, Delhi.
(ii) To investigate feasibility of MAR, in different locations inside NCT Delhi by conservation of monsoon runoffs, and by moderation of monsoon flood water;
(iii) To study the possibility of using treated wastewaters from different STPs by MAR,
(iv) To investigate the scope of Well Fields development at potential sites, on similar lines as that of the Palla area, for drinking water security in NCT, Delhi

Progress:

Report submitted in both MoWR, RD & GR and Delhi Jal Board during September, 2017.
Based on the report and study's outcomes, DJB is preparing DPR for implementation.

NEW STUDIES

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

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

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

Nature of study : Applied Research

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

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

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

Total Project cost : About Rs. 750 Lakh (Indian Budget~ Rs. 370 Lakh; NIH's budget ~ Rs. 138.7 Lakh)

Research challenges:

(i) Role of anthropogenic activities in increasing arsenic groundwater hazard and health risks;

(ii) WQ challenges associated with surface derived labile organic matter ingresses in shallow groundwater systems and contribution to greater mobilization of groundwater arsenic,

(iii) Bio-geochemical magnification due to other 'competing ions and contaminants' and mobilization processes and so on…

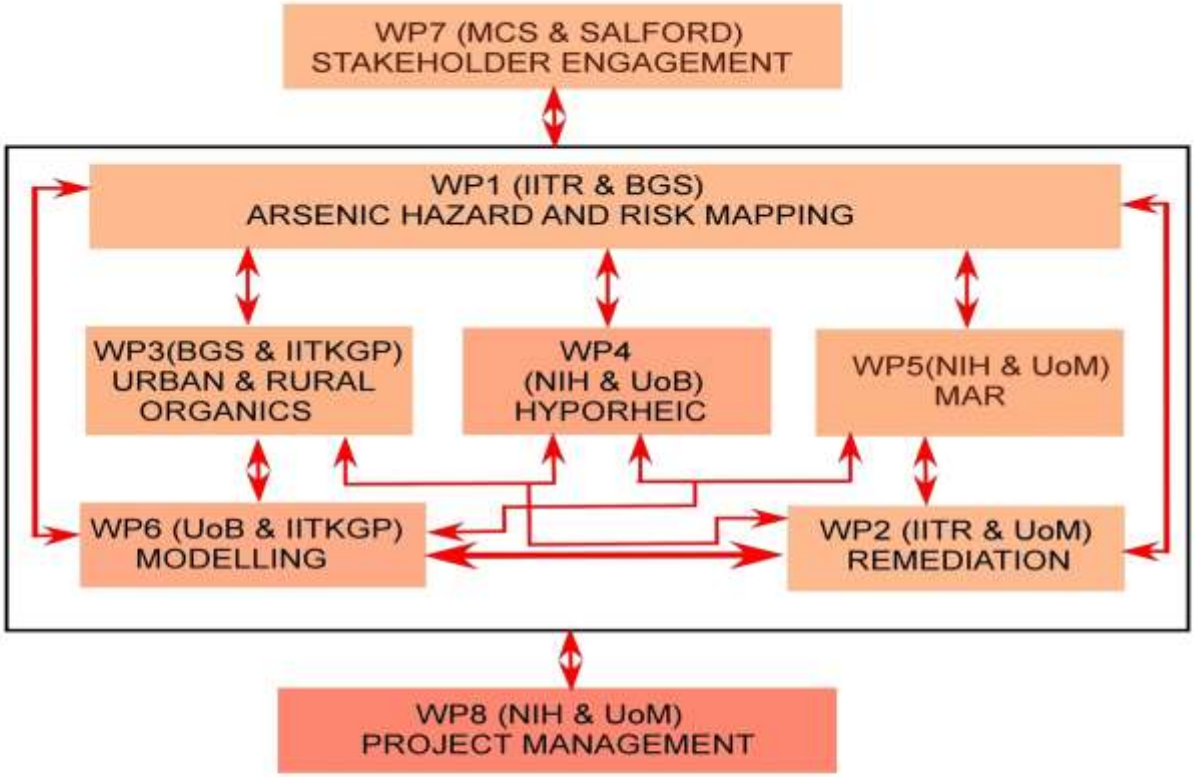
Aims:

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

Objectives:

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

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



Work Packages to achieve our aims.

WP	Key Output	Lead Partner
1	Database of groundwater arsenic hazard	IITR
1	Geostatistical model	BGS
1	Maps of current & future arsenic hazard & associated human health risks	BGS
2	Guidance document for stakeholders	UoM
2	Inputs for modelling WP	IITR
3	Scenario based areal maps & X-sections of expansion of high arsenic)zones with time	BGS/IITkgp
4	Identification of time-variant DOM sources and impacts on aquifer arsenic (re)mobilization	NIH
4	Quantification of hyporheic and river corridor contaminant inputs into shallow aquifers for key monitoring sites	UoB
5	Prediction of the major controls on the vulnerability of MAR systems to arsenic and other contamination	NIH
6	Model-based quantification of river & vertical recharge controls on arsenic remobilisation in aquifers	UoB

6	Scenario-based prediction of arsenic accumulation in shallow aquifers over relevant time scales	UoB
6	Hazard assessment framework for arsenic in groundwater mobilization for different scenario conditions.	IITkgp
7	Summary of stakeholder views	MCS
7	Assessment of the impact of knowledge transfer on stakeholder views	UoS
7	Assessment of the impact of participatory approaches	UoS
7	Stakeholder meeting reports	MCS
8	Consortium Agreement	NIH & UoM
8	Project Implementation Plan	NIH & UoM
8	Project Reports including summary of project publications in leading international peer-reviewed journals	NIH & UoM

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

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

India Lead: NIH Roorkee

PI: Dr Anupma Sharma, Sc. E, GWH Division

Indian Co-Partners (i) IIT Ropar (ii) IIT Jodhpur

UK Partner: Cranfield University

PI: Dr Alison Parker, School of Water, Energy and Environment

Co-Investigator: Dr Pablo Campo Moreno, School of Water, Energy and Environment

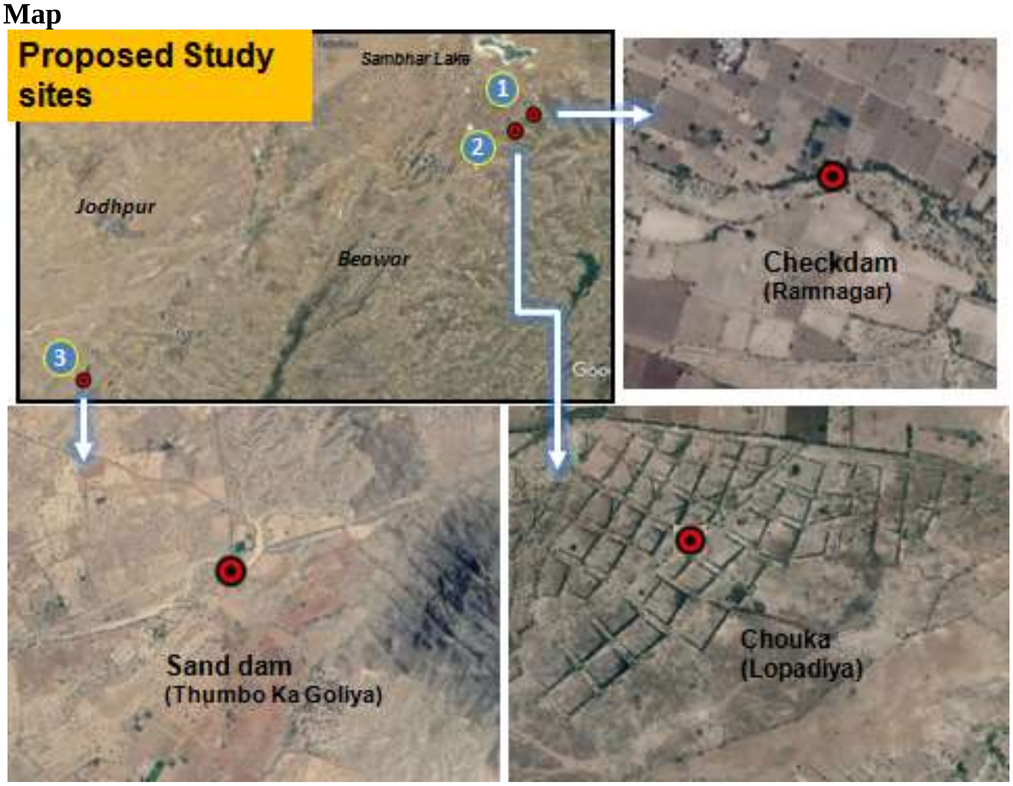
Project Partners: Wells for India and Excellent Development, UK based NGOs together with their Indian offices and local NGO partners in Rajasthan.

Type of study (sponsored/consultancy/referred/internal):

Sponsored Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund
NIH Budget: Rs. 143.16 lakh (incl. 20% overhead)
IIT Ropar Budget: Rs. 108 lakh (lakh (incl. 20% overhead)
IIT Jodhpur Budget: Rs. 108.48 lakh (incl. 20% overhead)

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

Location Map



Project Aim & Objectives

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

1. Evaluate water level and quality at three selected MAR sites in Rajasthan;
2. Assess the proportion of recharged groundwater attributable to MAR systems at selected sites;
3. Investigate the consequences of recharging aquifers with rainwater on the fate and transport of pollutants into aquifers, and understand the role of rainwater DOM levels in remediating fluoride and other groundwater contaminants;
4. Develop analytical protocols to facilitate the detection of micropollutants in water bodies;
5. Understand the interactions of local users with the MAR structure and also their role in water management.

Work Packages

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

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.

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

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

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

Lead Organization: National Institute of Hydrology, Roorkee
PI : Dr. Anupma Sharma, Scientist-E (PI)

Partner Organizations:

a) Irrigation & Water Resources Department, Haryana
b) Ground Water Department, Uttar Pradesh
c) Yamuna Basin Organization, CWC, New Delhi

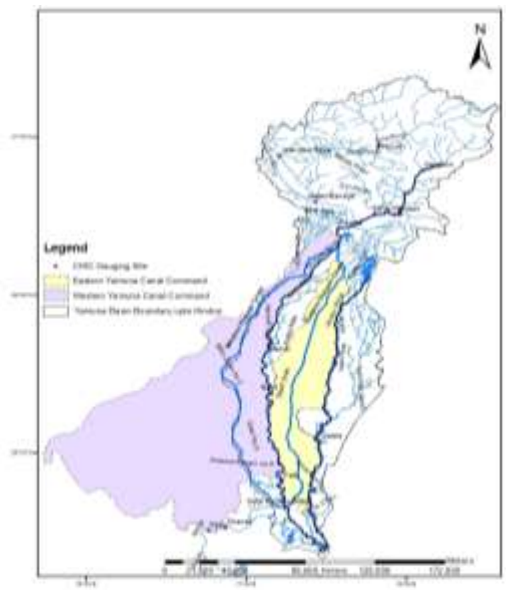


Fig. 1 Study area showing the Upper Yamuna Basin and the command areas of Eastern Yamuna Canal and Western Yamuna Canal

Major objectives

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

- Roll out of technical know-how through training workshops for partner organizations.

Deliverables:

- Application of various models pertaining to surface water hydrology, groundwater hydrology, basin planning, optimal water utilization and their inter-comparison in respect of UYB;
- Evaluation of the impact of climate change, land use change and population growth on the water resources in UYB;
- Assessment of changes in baseflow contribution to River Yamuna and strategies to enhance the contribution;
- Evaluation of impact of climate variability on renewable groundwater resources;
- Training Workshops for State Department officials of UP and Haryana.

12. PROJECT REFERENCE CODE: NIH/GWD/PDS/18-21

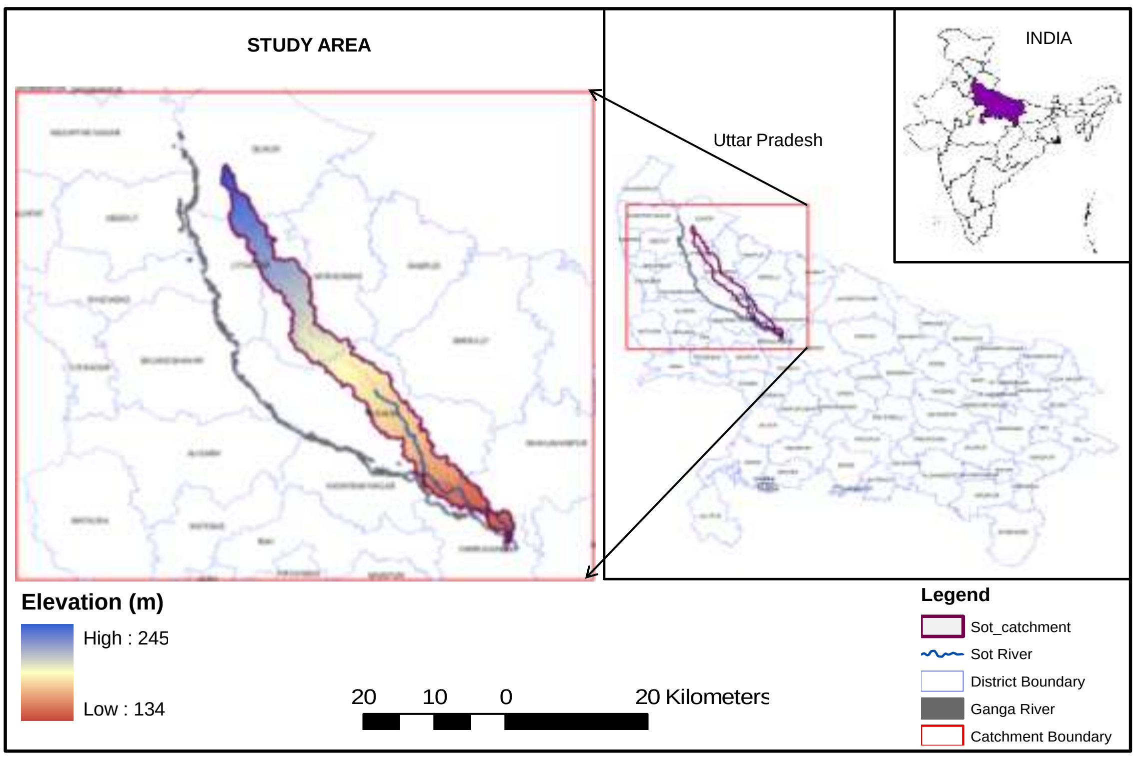
Title of the study : **Ganges Aquifer Management in the context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services – A Pilot Study**

Type of study : Sponsored by NHP under PDS (New)

Date of start (DOS) : March, 2018

Scheduled date of completion: February, 2021 (Four Years)

Location : Sot River Basin (Tributary of the Ganga River)



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 is 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 *Sot River Basin*, a tributary of the Ganga River. The river basin falls between the Ganga River and the Ramganga River. The area 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 basin area falls in the district 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. Under this background, it was felt that investigations leading to the river-aquifer interactions and dynamics are necessary.

End Users/ Beneficiaries: Groundwater Deptt., U.P.; IWRD, U.P.; Local Farmers.

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

Baseline Data/Information on the Study Area & Results of Previous Studies: Existing data and information shall be collected from concerned departments.

Methodology:

- Aquifers will be delineated using borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks Software.
- Time series analysis will be carried out by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river flows during the lean seasons of various years.
- Parametric and non-parametric trend analysis using Mann-Kendall and Sen-Slope Estimator, and change detection using Pettitt technique will be carried out on the hydro-meteorological variables to find the declining trends in river flows, groundwater levels and rainfall during both monsoon and non-monsoon seasons in various years.
- Surface water availability shall be estimated from river flow data using flow-duration curve and groundwater availability using GEC-97 methodology.
- Vulnerability analysis shall be carried out using SAHP/DRASTIC approach.
- Catchment water balance shall be carried out using mass balance approach.
- Integrated surface and ground water modeling shall be used for river-aquifer interactions and future scenarios for river flows during lean seasons.
- Isotopic analysis shall also be carried out to verify the reaches of recharge/discharge zones to/from the river.
- A management plan will be developed for the enhancement of water resources both surface and underground.

Action Plan& Timeline:

S.N.	Items of work	2018	2019	2020	2021
1.	Field visit to the basin and reconnaissance survey for the interaction with the decision makers and the stakeholders.				
2.	Collection of hydro-meteorological data including precipitation and weather datasets from Land Records Office, Agriculture Department and India Meteorological Department.				
3.	Collection of literature pertaining to studies already carried out by the academic and line departments related to river flows, groundwater, land use changes, water demands, supplies, etc.				

4.	Collection of hydrological data viz. the gauge, discharge, silt, water quality at all the gauging sites in the basin from U.P. Irrigation Department and Central Water Commission, New Delhi.				
5.	Collection of groundwater levels, lithologs and aquifer properties from Ground Water Department, Govt. of Uttar Pradesh.				
6.	Collection of data pertaining to population, livestock, agriculture and industry.				
7.	Procurement of high resolution satellite digital datasets pertaining to land use/ land cover, soil, topography and digital elevation model.				
8.	Field experiments for evaluation of hydrologic soil properties including infiltration rates and hydraulic conductivity of soils and collection of soil samples for related laboratory analysis to ascertain other soil properties.				
9.	Preparation of maps on soil type/texture, land use/cover, topography, contour, settlements, roads, geology, hydrogeology, etc. in GIS environment.				
10.	Generation of additional bore logs and pump-tests in the basin.				
11.	Preparation of Status Report.				
12.	First Stakeholders Meeting/Workshop to gather the existing water resources status, issues and expectations of various stakeholders.				
13.	Analysis of variation in river flows and assessment of patterns of river flow cessation.				
14.	Assessment of groundwater level variation and fluctuation in the basin.				
15.	Evaluation of changes in land use, cropping pattern and intensity and meteorological variables during past 20 years.				
16.	Preparation of First Interim Report.				
17.	Development of geological sections, fence and 3D diagrams for the study area.				
18.	Preparation of stratigraphy for the study area.				
19.	Synchronized variation and analysis of various hydro-meteorological variables.				
20.	Evaluation of drought characteristics including the severity, intensity and duration during various time horizons.				
21.	Hydrologic model setup, calibration based on the observed datasets and validation based on the independent datasets.				
22.	Estimation of surface water availability in the basin.				
23.	Estimation of ground water availability in the basin.				
24.	Evaluation of cessation of flows in the river.				
25.	Preparation of Second Interim Report.				
26.	Second Stakeholders Meeting/Workshop.				
27.	Complete water balance of the basin.				
28.	Assessment of vulnerable areas in the basin for water conservation and groundwater recharge.				
29.	Suggestions on various surface water conservation measures including				

	artificial ground water recharge and their suitable locations.				
30.	Suggestions on adaptation measures to cope with the climate change impacts.				
31.	Preparation of Final Report covering all the above aspects.				

Data Requirements:

- Geological maps
- Soil data and information
- Meteorological data
- River flow data
- Groundwater levels, lithologs, etc.

List of Deliverables:

- Reports
- Research papers
- Training Workshops

Specific linkages with Institutions: CGWB; Agric. Deptt., GWD and IWRD, Govt. of U.P.

Major Items of equipment needed: Aquameter, EC and pH meter.

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

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

Type of study : Applied Research

Date of start (DOS) : January, 2018

Scheduled date of completion : December, 2020

Location : Mewat district, Haryana

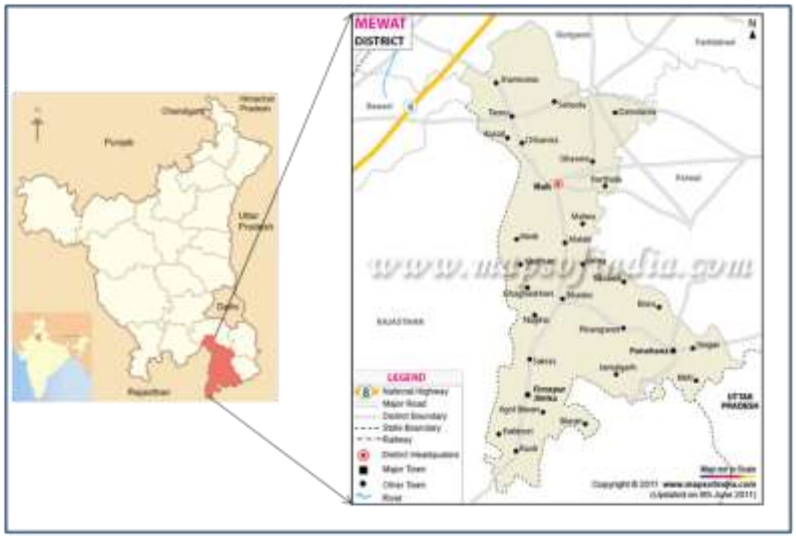
Study objectives:

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

Statement of the problem:

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

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



Map of Mewat district

Whether Study is a New Study/Extension of Previous Studies: New Study under PDS
Methodology:

This work will be accomplished in five phases as identified below:

In Phase 1, socio-economic based survey will be carried out to find out the impact of salinity on the socio-economic condition of the people on the basis of list of indicators is given in the table below. The findings of the study will help in initiating the development activities as coping strategies for the survival of humankind in the presence of salinity in the district of Mewat.

The study proposed to employ both qualitative and quantitative method. Under the quantitative method, a well structured coded interview schedule will be used. Focus Group Discussion (FGD), as a qualitative method, will be administered to collect information on the above socio economic characteristics of the farmers.

Phase 2 of our proposed study will begin with developing of a hydrogeological framework of the aquifer system in Mewat district based on all existing lithologic, stratigraphic and hydrologic information that may be available from various agencies. The saline areas in the district will be mapped.

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

Phase 4 will target the areas surrounding the drinking water wells that showed presence of salinity in Phase 2 using existing and new tube wells. Further, the water extracted from tube wells within and down gradient from the industrial areas will be examined where untreated wastewater may have been disposed on the surface (e.g., in infiltration ponds) or injected into the subsurface. The main purpose of the study in Phase 3 will be to identify cause/source areas using isotopes (release locations).
Phase 5 will include suggestion and development of resilience building measures. Some proposed measures will be construction of hydraulic barrier, solid barriers (clay); high pressure recharge.

Action plan:

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

Study Benefits /Impact:

- Problems to be identified
- Continuing the present work in PDS

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

(QUARTER WISE FROM JAN. 2018 TO DEC. 2020)

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

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

IPR potential and issues **:** NIL

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

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

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

Type of study : Sponsored by NHP (New)

Date of start (DOS) : January, 2018

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

Location : Bhojpur District, Bihar (Figure 1)

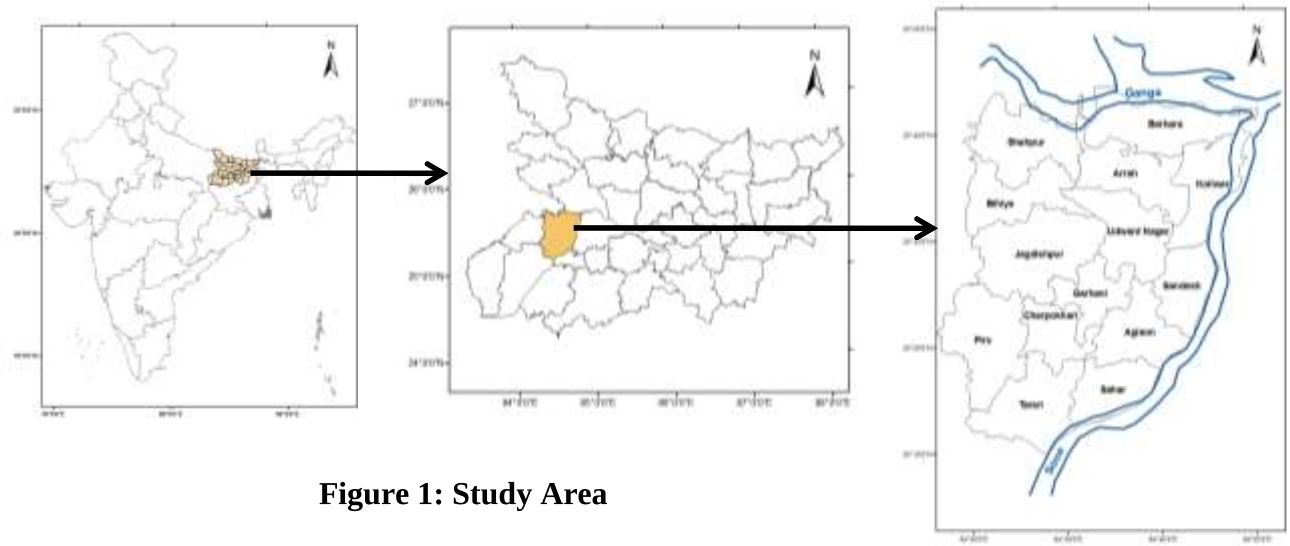


Figure 1: Study Area

Objectives:

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

Statement of the problem:

The central Ganges basin comprises mainly Uttar Pradesh and Bihar is one of the largest fluvio-deltaic systems and most populous regions of the India. In recent few decades, the increasing demand of groundwater for domestic, irrigation (round the year for food production) and industrial with the growing population rate led the extensive exploitations of fresh and potable groundwater. Now a days, there is problem of safe and potable groundwater in this region as most of the areas are contaminated by As.

In last decades few studies are reported the elevated arsenic concentration and the process of the contamination in central Gangetic basin, but none seems to be studied the fate, transport and mobilization of the arsenic although initial estimates indicate that the poisoning might be widespread and several million people may be at risk. The proposed study will be 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, Bihar (Central Ganges Basin). Inferences about the processes controlling the composition of groundwater will be evaluated from field measurements, statistical analyses and geochemical modeling. Column experiment will be performed to define the fate and contaminant transport; and conclusions would be made by combining the above mentioned techniques with geospatial analyses to identify the safe aquifer.

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

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

Baseline Data/Information on the Study Area & Results of Previous Studies: Existing data and information shall be collected from concerned departments.

Methodology:

A) Hydro geochemical sampling of Groundwater and Surface water

Groundwater and surface water samples will be collected during multiple field campaigns (pre-monsoon and post-monsoon season) from both deep and shallow aquifers.

B) Drilling of Boreholes, aquifer parameter estimation and monitoring of Water Table along with chemical parameters

Depending on available resources, drilling would be performed to extract sediment core segments at different depth. The drilling would be done by rotary drill rig or techniques used by local drillers. Total 8 nos. of bore-wells would be drilled in-around the Gangetic and Sone basin at different depth (for the construction of observation well or piezometer). Hydraulic conductivity values would be determined by aquifer tests while sub samples of various sediment types would be used to measure porosity and other aquifer properties.

C) Lab-scale column experiment:

A lab-scale column experiment will be performed to investigate the arsenic release mechanism from the sediment phase to groundwater phase. Separate column experiment will be performed based on the chemical composition of the sediment from highly contaminated and medium contaminated zone to identify the specific processes controlling As release.

Action Plan& Timeline:

Work Element	1st Year	2nd Year	3rd Year
Conceptual model construction			
Drilling of Borehole			
Installation of field equipment			
Water chemistry sampling and analysis			
Development of column experiment set up and analysis			
Understanding Sediment-groundwater interaction processes			

Delineation of Arsenic release mechanism			
Preparation and submission of reports and publications			

Data Requirements:

- Geological maps
- Soil data
- Meteorological data
- Groundwater levels, lithologs
- GW quality data, etc.
-

List of Deliverables:

- Reports
- Research papers
- Training/ Workshops
-

Study Benefits /Impact:

- Delineation of Arsenic safe aquifer will help community to get safe drinking water
- Improved understanding of the hydro-geochemistry of Arsenics in groundwater flow systems in Central Ganges Basin.
- Data base generation for GW quality of the area with special emphasis on Arsenic

Specific linkages with Institutions: Minor Water Resources Department, Govt. of Bihar, PHED, Govt. of Bihar.

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. S P Rai	Scientist F
4	Dr. M S Rao	Scientist E
5	Sri S K Verma	Scientist D
6	Sri Rajeev Gupta	SRA
7	Sri U K Singh	SRA
8	Sri V K Agarwal	SRA
9	Sri. Raju Juyal	RA
10	Sri Vishal Gupta	RA

WORK PROGRAMME FOR 2017-2018

S. N.	Title of the Project	Team	Duration	Funding
III.	**Internal Studies (Ongoing)**			
1.	Interaction between groundwater and seawater along the northern part of east coast of India	M. S. Rao (PI), Sudhir Kumar Pankaj Garg	2 years (08/15 - 03/18)	NIH
2	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	S.D Khobragade (PI); Sudhir Kumar; S. P. Rai, Senthil Kumar; Pankaj Garg	3 years (04/15 – 03/18)	NIH
3	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	M. S. Rao (PI) Sudhir Kumar	3 years (04/16 – 03/19)	NIH
4	Isotopic Investigations in parts of Upper Yamuna River Basin	S. K. Verma (PI), Sudhir Kumar, S P Rai, Mohar Singh, Vishal Gupta	2 years (04/16 – 03/18)	NIH
IV.	**Sponsored Projects (Ongoing)**			
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	S. P. Rai (PI); Sudhir Kumar; Rajesh Singh; S. D. Khobragade; M. Arora; R. J. Thayyen; P. K. Garg	*5 Years* (04/16-03/21)	DST (Sub-project No. 9 under NMSHE)
2.	Dating very old groundwaters of deeper aquifers in Ganga Plains, India	MS Rao (PI) Sudhir Kumar	*3 years* (10/16 - 09/19)	IAEA Vienna (€18,000/-)
3	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar (PI) S. P. Rai	3 Years (04/16-03/19)	Project with GBPIHE (15 lakhs)

ITEM NO. 46.3 PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2017-18

As per the work program approved by Technical Advisory Committee in its 70th meeting held on 1st September 2017, the Hydrological Investigations Division had to carry out 4 R & D studies, 3 sponsored projects (See annexure-I). Status of studies carried out during 2017-18 is given below:

Type of study/Project	*Continuing in Studies*	*New studies proposed*	*Total*
Internal Studies	4	0	4
Sponsored Projects	3	0	3
Total	7	0	7

The progress and the results of the internal studies and the sponsored projects is given below:

R & D STUDIES:

1. PROJECT REFERENCE CODE: NIH/HID/INT/2015-16/1

Title of the Study: Interaction between groundwater and seawater along the northern part of east coast of India

Study Team: Dr M. Someshwar Rao (PI), Dr Sudhir Kumar

Collaborators: Sh. Niladri Naha, Additional Director, SWID, Kolkata

Dr. Abhijit Chakraborty, Asstt. Prof., IIT, Kharagpur

Funding Agency: Internally Funded

Budget: Rs. 26.82 Lakh

Date of Start: November, 2015

Date of Completion: March, 2018

Study Area

The study area covers the Coastal region of West Bengal, Odisha and Andhra Pradesh. Major hydrological problem in the area is seawater intrusion & excess loss of fresh groundwater water to marine environment.

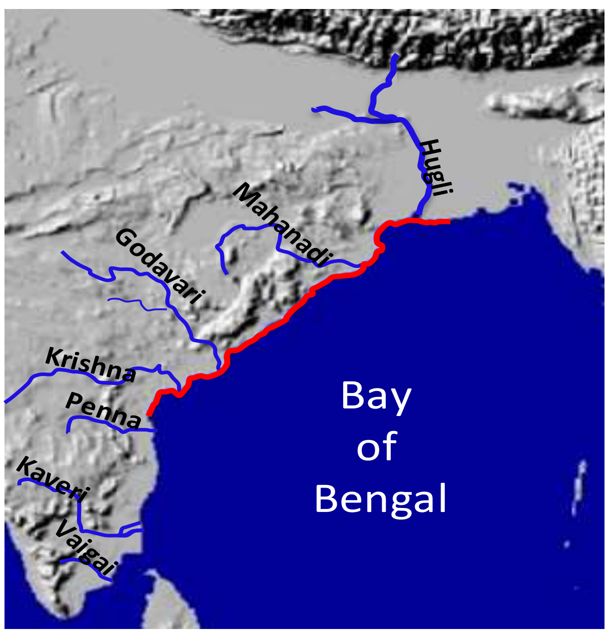


Fig: Topographic features of eastern coastline of India and study area (shown in red-line)

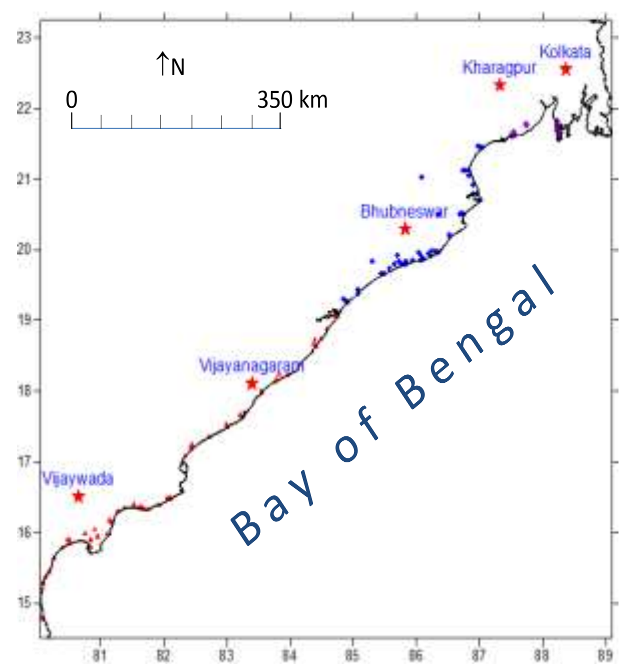


Fig: Water sampling locations in the study area. In the state Andhra Pradesh ( ), Odisha (♦) and in West Bengal (●). Major cities are shown by ( )

Study Objectives:

The objectives of the study are:

i. Mapping the zones of fresh groundwater and saline groundwater zones in the coastal areas of WB, Odisha and AP.

ii. Investigating the groundwater seawater exchange process using water quality and isotope (stable, tritium, dissolved radon) analysis of groundwater

iii. Measures for augmentation and management of coastal groundwater resource

Statement of the Problem

India has over 8000 km length of shoreline with people living over 250 million within 50 km width of the coast and groundwater is an important resource in this region. Increasing population density, industrial growth, irrigation expansion, falling water levels is causing continuous depletion of freshwater resource whereas, factors like monsoon variability, climate change, sea-level change, episodic cyclones etc., are causing short & long term variability in the freshwater availability and thereby variability in the seawater-groundwater interface zone in the coastal zone of India. Mapping of fresh and saline groundwater zones and the operative processes along this zone help to protect the groundwater resource from getting it salinized. The present project is intended to provide a regional map of seawater-groundwater interaction zone of coastal West Bengal and Odisha using salinity and isotopic mapping.

Summary of samples collected (2015-17)

State	Field work Period	No of Samples collected
WB (Total:21 samples collected)	**Nov 2015**	**7 GW**
	Dec 2016	**7 GW+2SW+12 GW from Bakhali on monthly interval**
	May 2017	
	Repeat: Bakhali	
Odisha (15-16: 146 samples)	**Nov 2015**	**37 GW +1 SW**
	May 2016	**3 GW**
	Dec 2016	**33 GW +2 SW+72 GW from 7 locations on monthly intervals**
	Feb 2017	
	Repeat 7 sites	**Chandipur, Sargoni, Tantiapal, Jantilo, Begunia, Kinark, Satpada**
AP (16-17: 53 samples)	**May 2016**	**53 GW**
	March 2017	

Minimum & maximum values of physico-chemical parameters observed in groundwater in coastal Odisha

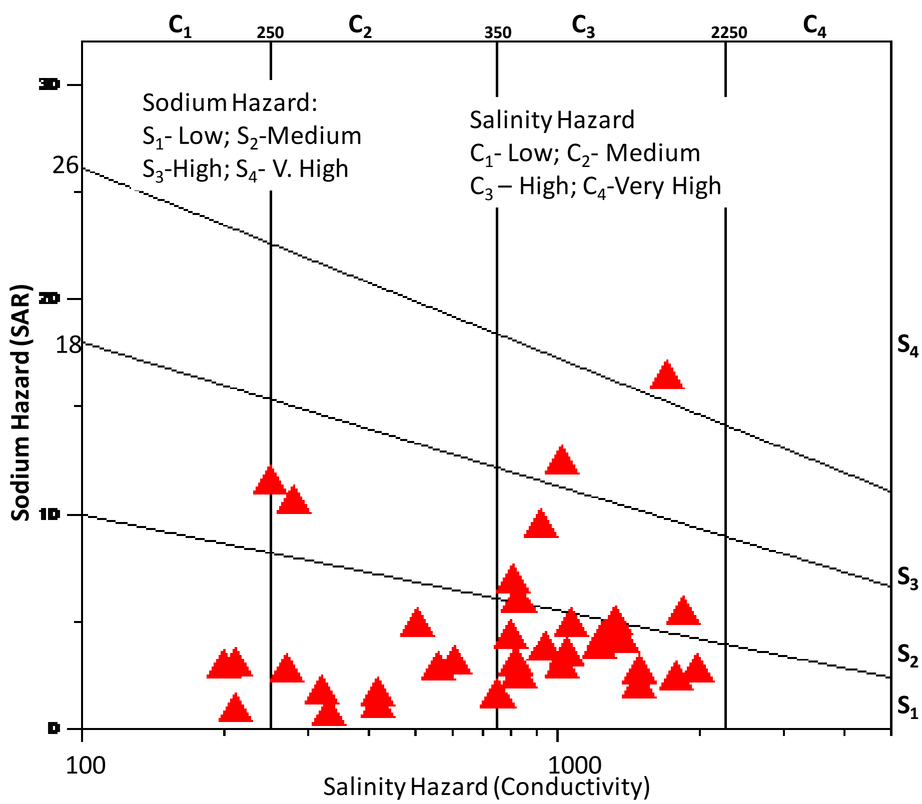
Parameters & permissible limit (BIS)	**Values of the of the observed parameters & the Observed place**	
	Minimum	**Maximum**
EC (μS/cm)	*200 (Kapileshwarpur)*	*13900 (Nuagarh, fishing base)*
Temp(^{o}C)	*26.8 (Satapada Chilka Water)*	*31.8 (Jadupur)*
pH	*6.3 (HP, Satpada, Chilka)*	*8.3 (Ramachandi Temple)*
^{226}Rn;PL:4 nCi/L	*10.16 (H. P., Gopalpur Beach)*	*9611.84 (Bideipur Market)*
δ^{18}O(‰)	-6.03 (H. P. ,Satpada, Chilka)	-2.44 (Rabindranagar, Dosinga)
δD(‰)	-37.86 (H.P., Ramachandi Temple, Konark)	-8.78 (Konark)
F; PL: 1.5 mg/L	0.1(Bhagbatpur,Jantilo)	13.2 (Naya sadak, Chandipur)
Cl; PL: 1000mg/l	14.8(Kapileshwarpur)	3717.9 (Nuagarh, fishing base)

NO_3 PL: 45mg/l	0.4 (Tentulipura, way to Chandipur)	207.9 (Golden Beach, Puri)
NO_2^-(mg/l)	2.3 (Konark fish market)	173.4 (Naya sadak,Sonapur road)
SO_4;PL:400 mg/l	3.9 (Kapileshwarpur)	1123.3 (Nuagarh, fishing base)
Na (mg/l)	21.9 (Konark)	3328.1 (Nuagarh, fishing base)
K(mg/l)	1.9 (Ramachandi Temple)	116.7 (Nuagarh, fishing base)
Mg;PL: 100 mg/l	2.0 (Kapilsehwarpur)	292.2 (Nuagarh, fishing base)
Ca;PL: 200 mg/l	2.9 (Kapileswarpur)	519.1 (Naya sadak,Chandipur)
NH_4; (mg/l)	0.5 (Ramachandi Temple)	123.1 (Nuagarh, fishing base)

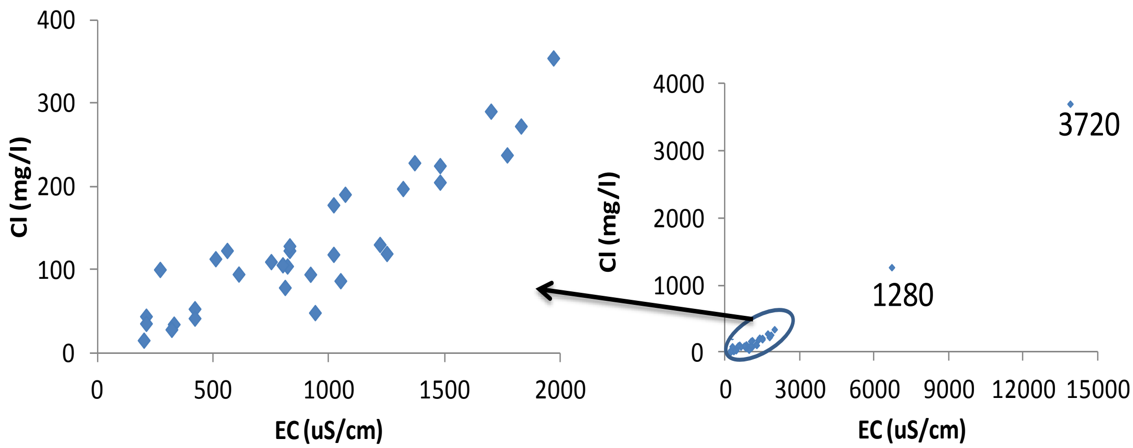
In 50% of the coastal zone of Odisha, high exchangeable sodium content was observed in groundwater. Sites with Sodium Percentage (SP) exceeding 80% (and hence are unsuitable for irrigation use) are seen observed at the locations:

S. No.	Location	Sodium %age	S. No.	Location	Sodium %age
1	Kuruma, Sareda	90.16	5	Kapileshwarpur	82.21
2	Begunia,	89.00	6	Baincha,	81.51
3	Chandipur beach	86.47	7	Jadupur,	80.30
4	Nuagarh (Fishing base)	82.44			

SAR value is also observed very high (36.48 meq/l) at Nuagarh, fishing base.



Sodium-salinity hazard in groundwater of coastal Odisha analyzed using Wilcox Diagram.



Relation between Chloride concentration & EC in coastal groundwater of Odisha

Sites with Cl value exceeding 200 mg/l and EC exceeding 1000 µS/cm are observed at Chudamani, Goplapur, Golden Beach Puri, Kuruma Sareda, Bahadurpetta and at Chulidiha Sasna.

Samples when examined for Na/Cl ratio; it is seen that the molar ratio was observed less than 0.86 (indicating possible seawater intrusion) only at site Chudamani. Similar result is observed when samples were examined for Base Exchange Ratio (BEX = Na + K+ Mg – 1.0716Cl). The negative BEX values indicating possible seawater intrusion is observed only at Konark fish market and at Chudamani.

The ratio of Ca to magnesium concentration was observed >1 indicating possible seawater intrusion in groundwater at sites; Dhamara Port, Baincha, Jetty, Chudamani, Chakulidiha, Sasana, Nuagarh(Fishing base), Damasun, Jharling, Jiunti, Kapileshwarpur, Balighai, Begunia Golden Beach, Puri, Satapada near Chilka Jetty, Baghamunda, Katakpada, Brahmagiri and at Gorul.

The coastal zone groundwater was demarcated as fresh groundwater, saline groundwater without seawater intrusion and groundwater with possible seawater contamination using the following criteria

Water type	Applied criteria
Fresh	$\delta^{18}O$<-3‰ & Cl <500
Evaporation enrichment + Salinity due to leaching of salts	$\delta^{18}O$>-2 to -1 ‰ & Cl 500-1200
Possible intrusion of sea water	$\delta^{18}O$ >-1‰ & Cl >1200

By applying the above criteria the map of coastal groundwater of Odisha is prepared indicating groundwater as fresh, saline (but not due to seawater intrusion) and groundwater with possible seawater intrusion. The map prepared with the above criteria is shown below:

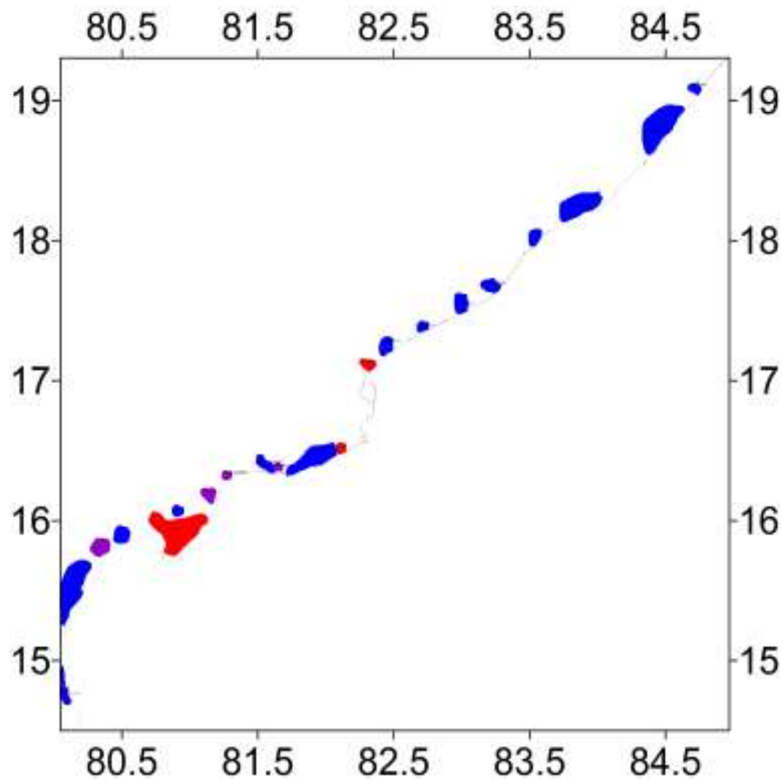


Fig: Groundwater quality in coastal zone of Odisha. Blue: Fresh groundwater; Purple: saline groundwater with no seawater contamination; Red: Groundwater with possible seawater contamination.

Samples collected from West Bengal and analyzed with the above criteria have shown no or negligible seawater contamination.

The results will be confirmed by collecting final set of samples in the month of March, 2018.

The final report will be submitted in April 2018.

2. PROJECT REFERENCE CODE: NIH/HID/INT/2015-18/1

Title of the study: **Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh**

Study Team: **SuhasKhobragade (PI),** Sudhir Kumar, Senthil Kumar, P Garg, Sh. V. K. Agrawal and Satya Prakash

Type of Study: **Internal**

Duration: **3 years**

Date of Start: **April, 2015**

Date of Completion: **March, 2018**

Statement of Problem:

Sukhna Lake in Chandigarh faces water scarcity problems especially during the deficit rainfall years. No studies on the interaction of the lake with surrounding groundwater have been reported so far except for the preliminary investigations carried out by NIH. Preliminary studies on water balance carried out by NIH during 2011-2013 indicated that seepage may be a significant factor determining the water availability in the lake. It was felt that further detailed studies on this aspect are needed to understand and establish the seepage losses from the lake. Hence, the present study has been undertaken.

Study Objectives:

(i) To determine seepage losses from the lake

(ii) To determine the relative significance of seepage losses in overall water balance of the lake

Study Area Map:

Fig 1: Location map of study area

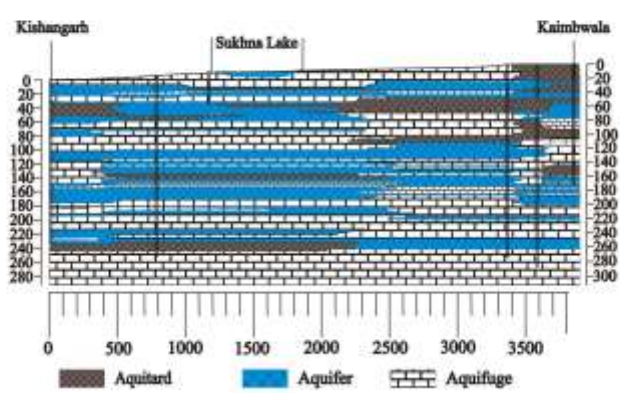


Fig. 2: Conceptual aquifer map of the study area (scale of map is in meters)

Brief Methodology:

i) Isotopic characterization of the different waters of the study area. Water samples from various sources such as the Sukhna lake, shallow groundwater (open wells), medium ground water (piezometrs), deep ground water (tube wells), inflow stream (Sukhna Choe) and surface water bodies in the lake catchment like check dams and ponds have been collected and analysed for stable isotopes of oxygen ($\delta^{18}O$) and hydrogen (δD), at the Nuclear Hydrology Laboratory of the NIH.

ii) Collection, processing and analysis of the lake water level data

iii) Collection, processing and analysis of the water levels of the U/s and D/s piezometer & surrounding groundwater

iv) Analysis of interrelationships of isotopic signatures of different sources, and other parameters such groundwater flow direction, as EC, pH, temperature, etc

v) Water balance of the lake

Objectives vis-à-vis Achievements

Sr. No.	Objective	Achievement
1.	To determine seepage losses from the lake	Achieved
2.	To determine the relative significance of seepage losses in overall water balance of the lake	Achieved
Draft final report is likely to be ready by Feb., 2018		

Results and Analysis:

Variation in isotopic signatures of rainfall of monsoon and winter season indicate different source of moisture for the two. The $\delta^{18}O$ and δD value of rainwater follow altitudinal pattern. The Local Meteoric Water Line (LMWL) developed for the study area for the monsoon season is $\delta D = 5.95\times\delta^{18}O + 7.39$. Local Evaporation Line (LEL) developed for the Sukhna lake is $\delta D = 5.87\times\delta^{18}O - 9.6$ while the LEL for the water bodies in the catchment is $\delta D = 5.15\times\delta^{18}O - 17.8$. The slope and intercept of the LEL suggests a strong evaporation impact on lake and the surface water bodies of the catchment. However, different slopes of the evaporation lines of the two indicate variable rates of evaporation in the two water bodies. The relationship between $\delta^{18}O$ and δD for shallow groundwater is found to be $\delta D = 5.67x\delta^{18}O - 8.80$. Analysis of d-excess indicates that the shallow groundwater in some parts of the catchment is getting a significant amount of its recharge through the surface water bodies of the lake catchment, besides the rainfall. The relationship between $\delta^{18}O$ and δD for upstream deep groundwater is found to be $\delta D = 7.90 \times \delta^{18}O + 7.51$ while that for downstream deep groundwater was $\delta D = 7.73 \times \delta^{18}O + 6.54$. The slope and intercept indicate that the upstream deep groundwater is mainly getting recharged through the rainwater while downstream deep groundwater may be receiving seepage from the lake. The relationship between $\delta^{18}O$ and δD for upstream medium depth groundwater (U/s piezometer) is found to be $\delta D = 7.85 \times \delta^{18}O - 1.33$ while that for the downstream medium depth groundwater (D/s piezometer) is found to be $\delta D = 6.53 \times \delta^{18}O -7.62$. Analysis of the slope and intercept with the LEL of lake and surface water bodies suggests that the recharge for upstream medium depth groundwater has a significant contribution from the surface water bodies in the catchment (possibly the various ponds located in Kaimbwala and Kansal villages) while the recharge for downstream medium depth groundwater has significant impact of the combined effect (mixing of water) of Sukhna lake and those surface water bodies of the lake catchment which are contributing to the recharge of the upstream medium depth groundwater. This indicates seepage losses from the Sukhna lake to the downstream groundwater. It is also confirmed by the analysis of d-excess.

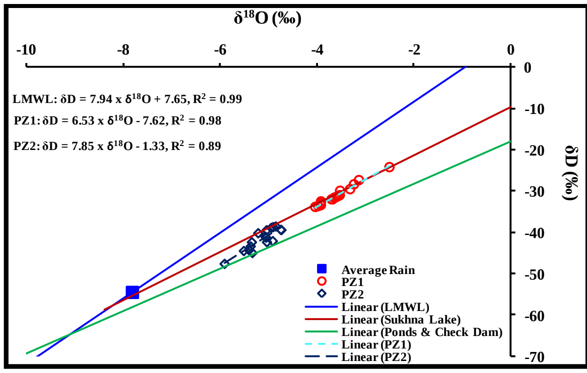


Fig. Relationship between $\delta^{18}O$ & δD for piezometers

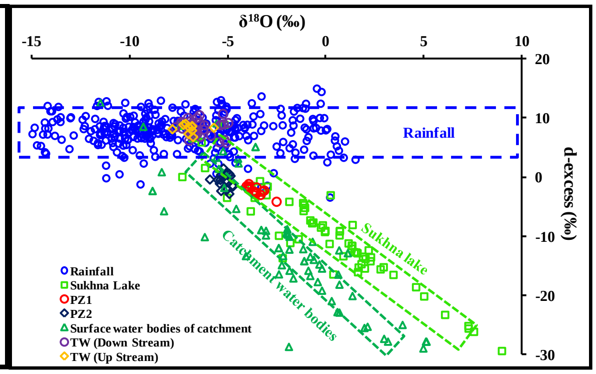


Fig. : Separation of recharge sources of lake water and groundwater on the basis of d-excess

Besides isotopic characterization, groundwater lake interaction has also been analysed and established through analysis of the various other data such as lithologs of surrounding area, lake water levels, groundwater levels, EC, pH and temperature of the lake, the surrounding groundwater, and flow direction of the groundwater etc. Aquifer map of the study area has been developed based on the litholog data of the bore wells. The sub-surface of the lake is observed to have alternate bands of clay, sand and boulders. It has also been observed that in the upstream of the lake a thick layer of clay is present, suggesting that the water cannot infiltrate from upstream site into the lake.

Groundwater flow direction map for the study area has been prepared using the groundwater level data. It shows that the groundwater flows from the catchment in the direction of the Sukhna lake. However, the groundwater levels are observed to be at lower levels compared to the lake bed elevation, implying that that the lake receives no sub-surface inflow from the catchment upstream. The EC, pH and ^{222}Rn of the waters of the lake and the piezometers (upstream and downstream) indicate that there is a mixing of lake water with the downstream groundwater. This mixing of the lake water with the downstream ground water is also supported by flow direction of the groundwater. Further, the temperature data of lake and piezometers (upstream and downstream) also confirm the mixing of the lake water with the downstream groundwater. Thus, the isotopic signatures of the various water sources as well as various other parameters studied clearly indicate an interaction of the lake with the downstream groundwater.

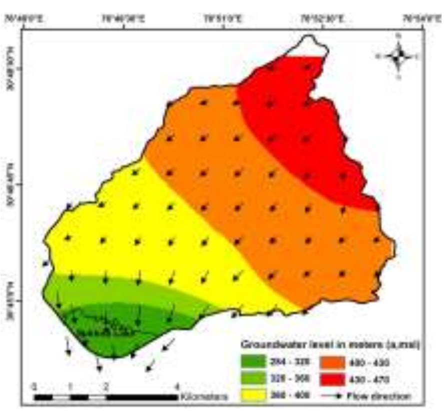


Fig. Groundwater flow direction map

Table: *Electrical Conductivity and pH of Sukhna lake and the surrounding groundwater*

	Upstream groundwater (PZ-2)		Lake		Downstream groundwater (PZ-1)	
	EC (µs/cm)	pH	EC (µs/cm)	pH	EC (µs/cm)	pH
30-Sep-14	460	8.2	260	9.1	390	8.5
30-Oct-14	430	8.7	250	9.2	390	9
13-Dec-14	430	6.6	280	7.3	410	6.9
03-Feb-15	490	7.7	260	8.2	480	7.8
11-Jun-15	480	6.9	280	7.6	380	7.3
24-Jun-15	490	7.7	270	8.1	390	7.1
13-Oct-15	540	7.4	250	7.5	460	7.6
28-Jul-17	540	NA	210	NA	460	NA

After establishing that there is subsurface flow (seepage losses) from the lake to the downstream groundwater, seepage rates from the lake have been quantified. The seepage rates have been obtained based on the water balance of the lake for the non-monsoon period. The seepage rates estimated using the water balance model have been compared with the results obtained through isotope method. The resulting percentage frictional contribution of lake water into groundwater is found to be 33.73% and 28.69% using $\delta^{18}O$ and δD method respectively. The seepage percentage using water balance method is found to be 34.61%.

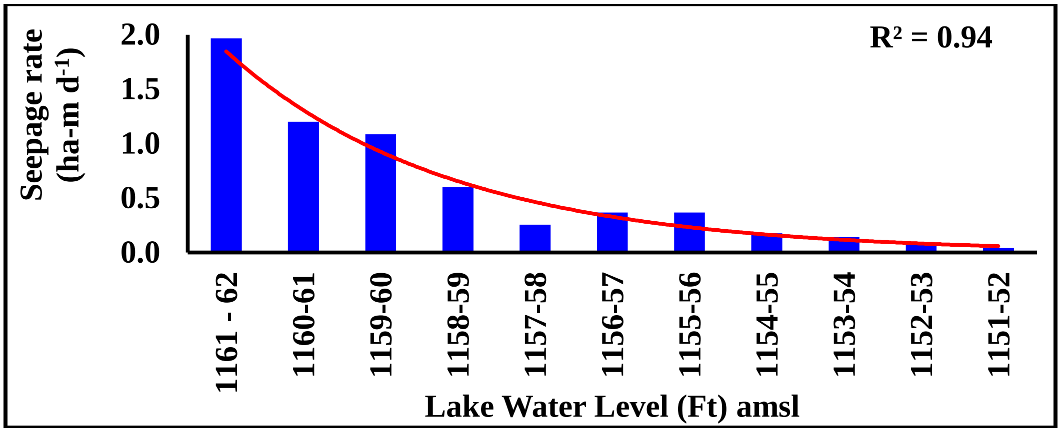
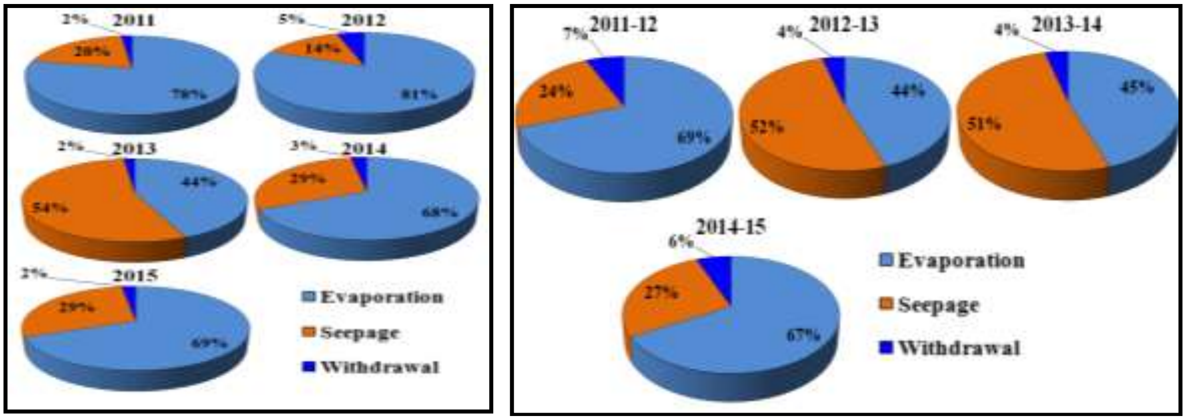


Fig. Seepage rates for Sukhna lake at different water levels

Based on the estimated seepage rates at different water levels, seepage losses from the lake have been estimated for different months of the study period. The seepage losses are found to be highly variable for different months during different years. The amount of seepage losses depends on the water level reached by the lake during the monsoon, which in turn depends upon the rainfall received during the monsoon, as well as the water level of the lake before the onset of the monsoon. During the study period, it varied from low losses of about 1.67 ha-m in June 2012 to high losses of about 51.19 ha-m during September 2013. Most of the seepage losses are observed to occur during the monsoon months of July to September and the immediate post monsoon months of October and November, as the water levels are high during this period.

Analysis of the relative contribution of seepage losses in total losses from the lake indicates that when the lake storage is high, the seepage losses are high and evaporation losses are comparatively low. During monsoon of 2011 to 2015, seepage losses varied in the range of 14% to 54%. The seepage losses were particularly high during the monsoon of 2013, when the average lake water level was high (353.37 m amsl). Similarly, during monsoon of 2012, the average lake water level was low (351.16 m) and consequently the seepage losses were also low.

As far as non-monsoon season is concerned, during 2011-12 and 2014-15, the water level reached by the lake on 1st October was 352.46 m and 352.43 amsl respectively. At this level the seepage rates are lower (about 0.32 ha-m d^{-1}). Therefore, the amount of water lost through seepage is also lower at 24% to 27% respectively. As far as 2012-13 and 2013-14 are concerned, seepage losses are about 50%. This is because the water level reached at the end of the monsoon was much higher at 354.01 m and 353.81 m amsl respectively.



(a) Monsoon (b) Non-Monsoon

Fig. Relative contribution of various losses in total losses from the lake

Based on the results of the various investigations and analysis carried out, the study concludes that there are significant seepage losses from the lake. Since these losses are higher at higher water levels reached by the lake, bringing more water to the lake cannot completely solve the water scarcity issues of the lake. It is for this reason that inspective of the total inflow of water received by the lake during monsoon and post monsoon months, at the end of summer of each year the lake ends up in reaching a water level of about 1154 ft amsl, as evidenced from the long term water level data of 1981 to 2015.

All the analysis work has been completed and report writing has been initiated. The draft final report is likely to be submitted by February, 2018.

Future Plan:

(i) Finalization and submission of the Report
(ii) Publication of research paper related to seepage analysis

3. PROJECT REFERENCE CODE: NIH/HID/INT/2015-18/1

Title of the study:	**Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin**
Study Team:	Dr M. Someshwar Rao Sc. 'E'(PI), Dr Sudhir Kumar, Sc G
Funding Agency	Internally Funded
Budget	Rs. 15.95 Lakh
Duration	$2^1/_2$ years
Date of Start	May, 2016
Date of Completion	Oct, 2018

Study Objectives:

The objectives of the study are:

i) Development of ^{14}C dating system

ii) Preparing manual of 'Procedure of Radiocarbon dating analysis in NIH'

ii) Dating old groundwater as inferred from tritium dating using ^{14}C dating technique and re-interpretation of the data.

Work elements:

- Fabrication of ^{14}C glass line
- Purchase of imported items (reference standards, chemicals and glassware)
- Purchase of items from Delhi/Roorkee and fabrication of items in-house
- System calibration
- Sample collection
- Analysis
- Preparation of Manual & SOP

Work Accomplished:

- Purchased imported glassware
- Identified old groundwater samples from Ganga basin
- Purchase of other items & fabrication work are in process.
- Sampling wells have been identified and are being located in the field

Future Plan:

The project has been merged with the new PDS approved under the National Hydrology Project.

4. PROJECT REFERENCE CODE: NIH/HID/INT/2015-18/1

Title of the Study	:	**Isotopic Investigations in parts of Upper Yamuna River Basin**
Study Team	:	S. K. Verma (PI), Sudhir Kumar, S. P. Rai, Mohar Singh, Vishal Gupta
Type of Study	:	Internal
Duration of study	:	Two years
Date of Start	:	April 2016
Date of Completion	:	March 2018

Study Area : Parts of Upper Yamuna river basin comprising the districts of Saharanpur, Muzaffarnagar, Shamli, Baghpat and Meerut in Uttar Pradesh and Ambala, Karnal, Kurukshetra, Sonipat and Yamunanagar in Haryana.

Study Objectives:

1. To assess radon concentration in groundwater
2. Isotopic ($\delta^{2}H$ & $\delta^{18}O$) characterization of groundwater
3. To identify the geothermal zones and its impact on isotopic composition

Present state-of-art:

During the last 40 years large scale groundwater abstraction, particularly in the north western states of Punjab, Haryana & Uttar Pradesh has taken place due to increase in irrigation requirements. Because of this, groundwater depletion of this region has become under the vulnerable condition and a hot spot for groundwater management. The groundwater depletion rates in the states of northwestern India are reported highest in comparison to other parts of world. There is a major task to replenish the groundwater depletion through rainfall recharge. In this connection, NIH has initiated an isotopic investigation in parts of upper Yamuna river basin through a project entitled “Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains” funded by IAEA. The preliminary investigations carried out under this project indicated that the temperature is more than 30^{0} C in some parts of Upper Yamuna river basin. Therefore, the detailed isotopic investigations are required to investigate the source and cause of this thermal groundwater occurring in parts of Upper Yamuna river basin.

Brief Methodology:

In order to study the radon concentration in the study area at different locations, groundwater samples from shallow as well as deeper aquifers will be collected for in-situ radon measurement. Spatial variation of radon concentration in groundwater will be studied. The groundwater samples from shallow/deeper aquifers for existing hand pumps, open wells and tube wells will also be collected for stable isotopes & strontium analysis to study their variations. 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 groundwater.

Action Plan

Sr. No	Activity	April 2016 to March 2018							
		1st Q	2nd Q	3rd Q	4th Q	1st Q	2nd Q	3rd Q	4th Q
1.	Review of literature, Collection of hydro-geological data/information for the study area etc.	♦	♦						
2.	Preparation of index map of study area, selection of locations/sites for experimental works etc.	♦	♦						
3.	Collection of groundwater samples for radon measurement, stable isotopes analysis & analysis of radon concentration		♦	♦	♦	♦			
4.	Lab. analysis of groundwater samples for stable isotopes and Strontium		♦	♦	♦	♦	♦	♦	
5.	Interpretation of isotopic data						♦	♦	
6.	Preparation of interim report/Part-1				♦				
7.	Final report								♦

Analysis and Results

- The analysis of radon concentration has been carried out for a total of 18 groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the districts of Ambala, Yamunanagar & Saharanpur. The values of radon concentration obtained fall well below the safe limit recommended by the World Health Organization (WHO) for drinking water purpose.
- The electrical conductivity has been measured at 18 locations for the groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the study area. The electrical conductivity varies from 440 µS/cm to 860 µS/cm in the study area.
- The stable isotopes analysis (□^{18}O, □D) has been carried out for all the 18 groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the study area. The variation of stable isotopes (□^{18}O, □D) with radon concentration for groundwater samples as collected above has been studied.
- In addition to above, a total of 18 groundwater samples from intermediate/deep aquifers have been collected for environmental tritium analysis in Nuclear Hydrology laboratory. The analysis of 18 groundwater samples for environmental tritium is in progress in the laboratory.

Future Plan:

- Interpretation of Data
- Finalisation of Report

SPONSORED PROJECTS

1. PROJECT REFERENCE CODE: NIH/HID/SPON/16-21

Title of the Study:	**Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques**
Study Team:	Dr. S. D. Khobragade (P.I.), Sc. 'F', Dr. Sudhir Kumar, Sc. 'G', Rajesh Singh, Sc. 'C', Dr. M. Arora, Sc. 'D', Dr. R. J. Thayyen, Sc. 'D' and Er. S. K. Verma Sc. 'D'
Type of Study	**S**ponsored
Funding Agency	DST, Govt. of India
Budget	Rs.191.08 lakh
Date of Start:	13.01.2016
Date of Completion	12.01.2021

Location Map

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

Study Objectives:

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

Statement of the Problem:

The Himalayan mountain system is the source of one of the world's largest supplies of fresh water which is under threat due to serious environmental degradation and climate change. Continuing climate change is predicted to lead to major changes in the strength and timing of the Asian monsoon, inner Asian high pressure systems, and winter westerlies – the main systems affecting the climate of the Himalayan region. The impacts on river flows, groundwater recharge, natural hazards, and the ecosystem, as well as on people and their livelihoods, could be dramatic affected, although not the same in terms of rate, intensity, or direction in all parts of the region. Therefore, a thorough understanding of hydrological processes operating Ganga River Basin is a fundamental requirement.

Action Plan: (2016-2021)

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

Objectives vis-à-vis Achèvements

Objectives	**Achievements**
Isotopic characterization of precipitation and identification of sources of vapor	Sampling of rainfall from 13 ORGs, installed at different altitude, has been started for isotopic analysis and samples are being analysed
Runoff generation processes in headwater region of Ganga using isotope and modeling	Collection of water samples from river, springs, snow and glacier melt, along with their isotopic analysis are in progress
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	• To cover the spatial and temporal variability, 18 sites from upstream to downstream have been developed for regular sampling from both the rivers i.e. Bhagirathi and Alaknanda. • Input file for SNOWMOD model is under preparation
Contribution of transient groundwater and its role in sustainable flow of Ganga	~ 80 samples of water collected from different sources (GW, river and rainfall) have so far been analyzed for tritium.
Groundwater dynamics in mountainous area including identification of recharge sources and zones of major springs	Few springs near Srinagar have been selected and samples are collected for detailed isotopic investigation in order to determine the recharge zone.

Progress of Work/Results and Analysis

The summary of progress carried out in the project is given below:

a) A field visit was conducted between 30th September 2017 to 10th October 2017 to collect water samples from varied sources (rivers, streams, springs, hand pumps) for isotopic analysis. Apart from this, water samples (river and rainfall) of three months i.e. October, November and December were also collected from the 18 monitoring sites established in the basin (Figure 2).

b) A total number of 6205 water samples collected, 4500 have been analysed for stable isotopes (δ^2H and δ^{18}O), 79 for tritium, and 2500 for EC and 29 for ^{222}Rn. Analysis of the remaining samples in process.

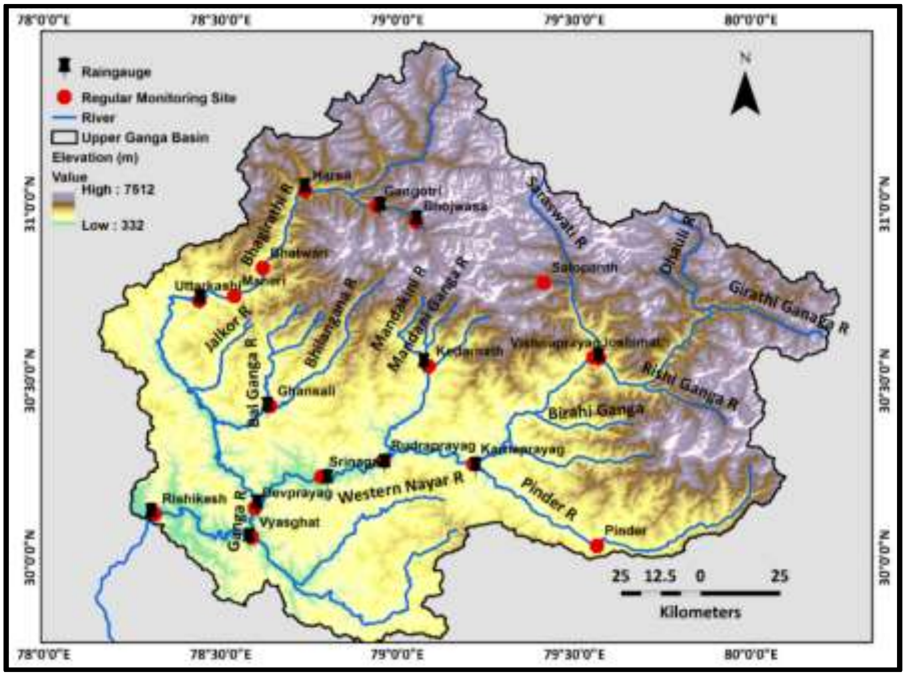


Figure 2: Study area and established monitoring sites

c) δ^2H and δ^{18}O of analysed rain water are varying from -197.6 to 71.0‰ and -26.3 to 9.6‰. A Local Meteoric Water Line (LMWL) is also developed, i.e., $\delta^2H=8.0*\delta^{18}O + 11.13$. The slope and intercept of the LMWL were almost similar to those of the GMWL (slope: 8.17 and intercept: 11.27).

d) δ^2H and δ^{18}O in analysed river water are varying from -155.6 to -6.7‰ and -16.5 to -7.5‰ (Figure 3). A systematic enrichment in isotopic signature of both the tributaries of Ganga River i.e. Bhagirathi and Alaknanda is observed as they flow downstream from their origin. It indicates that the contribution of snow and glacier melt water is decreasing and contribution of runoff and baseflow generated from low altitude are increasing (Figure 3). The best-fit regression line of RWL is found to be $\delta^2H=7.50*\delta^{18}O + 7.30$ which is close to the LMWL in terms of slope but shows a slight variation in the value of intercept.

e) The isotopic characterisation of groundwater is carried out from the catchment to find out source of origin of their water. As a whole, δ^2H and δ^{18}O in groundwater water are found to be varying from -99.2 to -28.2 and -13.7 to -4.3 however, they exhibit significant variation in their isotopic compositions.

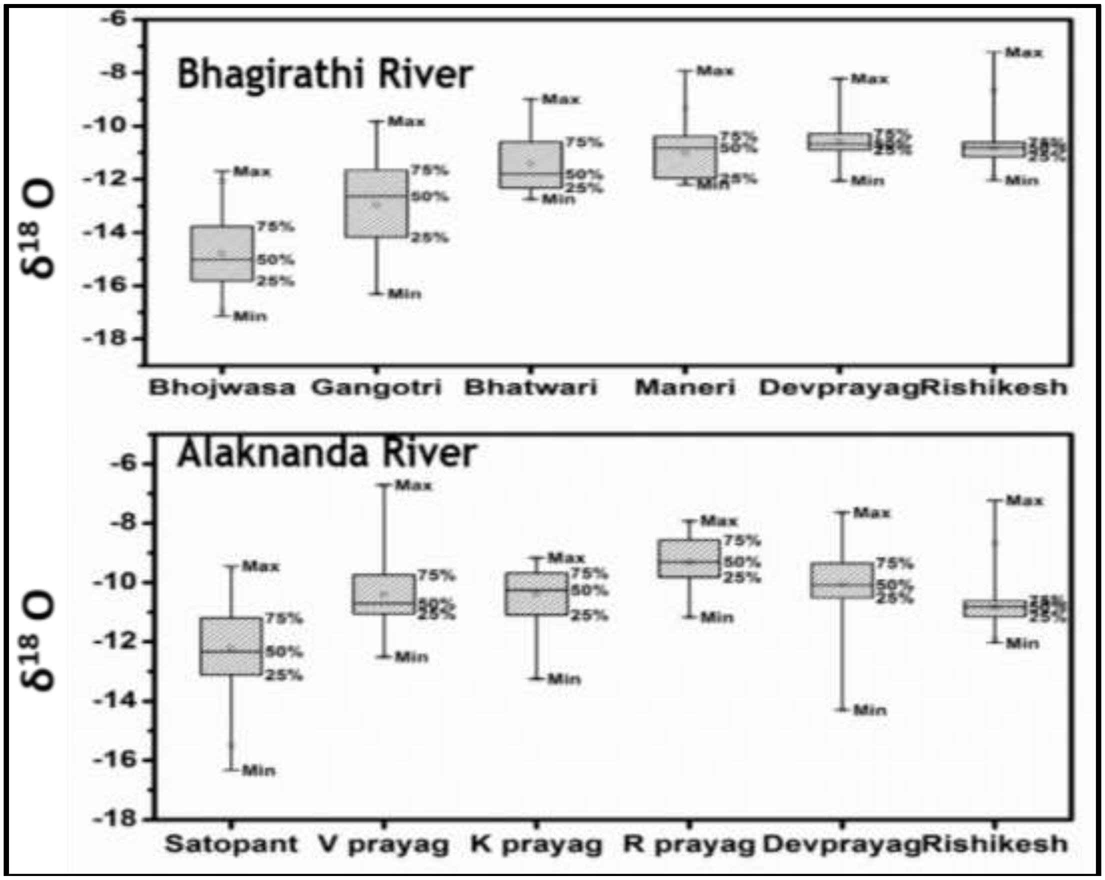


Figure 3: Spatial pattern of variation in isotopic composition of river water

Future Plan:

- Regular sampling of river, groundwater, precipitation for stable and radio isotope
- Estimation of contribution of different tributaries in Alaknanda and Bhagirathi River
- Estimation of snow and glacier melt contribution in Alaknanda and Bhagirathi river
- Estimation of Recharge zones of Springs

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

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

The details are combined with new project “**Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin” (Project No. *NIH/HID/SPON/18-21/PDS-SK).***

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

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

Objectives and Scope of Work:

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

Study Area

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

Analysis and Results

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

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

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

Figure 1: Map of Study Area

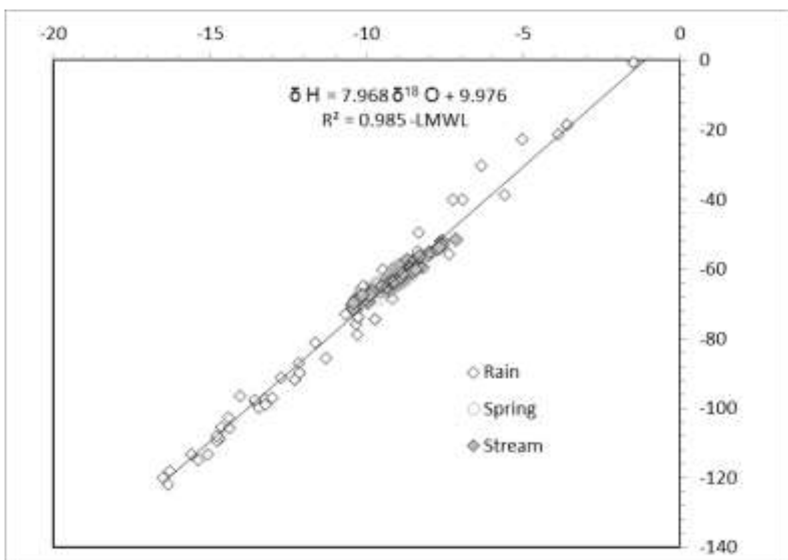


Figure 2: $\delta^{18}O$ – δD diagram for the study area

Future Plan:

- Sample collection from the monsoon of 2018-19
- Analysis for isotopic characteristic
- Interpretation of data.

ITEM NO. 46.4 PROPOSED WORK PROGRAM OF THE H.I DIVISION FOR THE YEAR 2018-19

As per the approved work program of the Hydrological Investigations Division for the FY 2017-18, 1 R&D study and 3 sponsored projects are to continue during the FY 2018-19. Three new sponsored projects (PDS) under NHP have been approved w.e.f 01.01.2018 under National Hydrology Project to the scientists of the Division. One R&D study continued from previous year has been merged with one of these PDS. The proposed work program of the division for FY 2018-19 is given at Annexure-II.

Type of study/Project	***Continuing Studies***	***New studies***	***Total***
Internal Studies	-	-	-
Sponsored Projects	3	3	6
Total	3	3	6

The details of the proposed new sponsored projects are given below:

1. PROJECT REFERENCE CODE: NIH/HID/SPON/18-21/PDS-MSR

Title of the Study:	**Integrated Study on Groundwater Dynamics in the Coastal Aquifers of West Bengal for Sustainable Groundwater Management**
Study Team:	Dr M. Someshwar Rao Sc. 'E'(PI), Dr Sudhir Kumar, Sc. 'G'
Type of Study	**S**ponsored
Funding Agency	National Hydrology Project
Budget	Rs.51.50 lakh
Duration:	$3^1/_2$ years
Date of Start:	01.01.2018
Date of Completion	30.06.2021
External Institution:	**Er**. Subrata Halder, Exec. Eng., State Water Investigation Directorate (SWID), Government of West Bengal

Statement of the Problem

The structure of the saline–freshwater interface is important in the assessment of (i) diminishing rate of fresh groundwater reserve (ii) fresh groundwater discharge to sea (iii) salt enrichment in the inland aquifers and (iv) pollution discharge into the marine environment. Isotopic & chemical tracer techniques are field based methods extensively used for investigating the dynamic state of the freshwater - saline water interface. In the present study, seasonal variation in the seawater groundwater interface and the responsible factors affecting this dynamic condition in the coastal zone of West Bengal will be assessed using isotopic and chemical techniques. The results from field based data and modeling exercise will be attempted to develop management strategies (protocol for groundwater withdrawal, artificial recharge measures etc) for long term groundwater sustainability.

Study Objectives: The specific objectives of the project are:

i. Assessment of spatio-temporal variables (sea level change, variation in groundwater levels, rainfall trend etc) influencing dynamics between seawater & groundwater interface using archival data
ii. Spatio-temporal variation map of fresh water – saline water interface from the present observations.
iii. Identification of source of salinity in groundwater
iv. 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
v. Management measures for safe & sustainable coastal groundwater use

Methodology

To meet the project objectives the study will be conducted along the following lines:

i) **Literature Survey:** Literature on state of art knowledge on Seawater Intrusion & Submarine Groundwater Discharge will be compiled and, the present state of fresh groundwater availability in the coastal West Bengal will be prepared.

ii) Data collection & Analysis: The archival data on hydrological details of the study area (sea-level change, groundwater level, rainfall data, river stage etc.), will be collected and will be analyzed to get hydro-meteorological trends, groundwater flow pattern, groundwater fluctuation etc.

iii) Field work: Water samples from production wells (hand-pumps, bore wells etc) will be collected in pre & post monsoon seasons and will be analyzed for major ion concentration, EC, $\delta^{18}O$ & δD and radon concentration to investigate seasonal variation in hydrological exchange pattern between land and sea in response. A few samples will also be dated by measuring their environmental tritium activity. The groundwater age can be used to assign the time scales of groundwater-seawater exchange process.

iv) Analysis: EC, $\delta^{18}O$ and δD, dissolved radon, major ion concentration, environmental tritium activity etc measured in the collected samples will be interpreted in integration with the archival data to explain, source of salinity in groundwater, recharge sources to groundwater and coastal contamination process. Various thematic maps will be prepared.

vi) End use: The results will be interpreted in terms of identification of recharge areas, adoptive management strategies to improve the groundwater conditions through suitable artificial recharge measures or by groundwater withdrawal strategies.

vii) Knowledge dissemination: Annual/ interim reports, publications, knowledge dissemination through training programme, mass awareness programme etc.

Work Plan & Activity Chart

(Describe various work elements of study and give a 3-monthly activity chart)

Sl.	Work Element	1st Yr				2nd Yr				3rd Yr				4th Yr	
No.		1	2	3	4	1	2	3	4	1	2	3	4	1	2
1	**Appointment of project staff**	✓													
2	**Procurement of items**	✓			✓										
3	**Preparation of various index maps**		✓	✓											
4	**Field survey for water sampling, sample & data collection and monitoring of hydro-meterological data**		✓		✓	✓		✓	✓		✓	✓	✓		
5	**Literature survey and writing of Status report, review report & interim report**		✓	✓	✓	✓	✓	✓		✓					
7	**Stable isotope, water quality, radon measurement and tritium analysis**				✓	✓	✓	✓	✓	✓	✓	✓	✓		
8	**Preparation of thematic maps, data analysis & modeling, identification of recharge areas, drawing inferences on coastal hydrological processes and suggesting adoptive measures to improve the groundwater conditions**							✓	✓	✓	✓	✓	✓	✓	
9	**publications**									✓	✓	✓	✓		
10	**Trainings and mass awareness programme**					✓			✓		✓		✓	✓	
11	**Final report**													✓	✓

2. PROJECT REFERENCE CODE: NIH/HID/SPON/18-21/PDS-SK

Title of the Study:	**Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin**
Study Team:	Dr Sudhir Kumar, Sc. G (PI), Dr. C. K. Jain, Sc. G, Dr M Someshwar Rao, Sc. E
Type of Study	**S**ponsored
Funding Agency	National Hydrology Project
Budget	Rs.55.40 lakh
Duration:	$3^{1}/_{2}$ years
Date of Start:	01.01.2018
Date of Completion	30.06.2021
External Institution:	RD (NR), CGWB

Statement of the Problem:
Groundwater in India is depleting at shocking rate. About half a century back, the dug wells which were providing sufficient water to serve the country have got replaced by over 50 lakhs tube wells drawing over 245 BCM of groundwater. Growing demand of food grain, speedy economic growth, agricultural drought, climate change etc are accelerating the water demand and, the advancement in technology is providing ease to draw water from deeper and deeper depth. Today, in most part of the country the shallow aquifers are either dried up or nearly became un-usable for economic use. Even the Ganga basin, one of the largest groundwater multi-aquifer systems in the world is witnessing the groundwater problem. The basin is covered by alluvium of varying thickness with a depth ranging up to 8km (Sastri et al., 1971). Recent studies carried out by National Institute of Hydrology in support with IAEA, Vienna has revealed that deep groundwater of Ganga basin are older than 1,00,000 years, meaning that groundwater in deeper aquifer is quasi-static in nature. With the progressive water demand as the wells are getting sunk to deeper depths the deeper aquifers will become active (depletion and contamination). As on date it is not known the depth below which groundwater exist in quasi-static condition, what is the age, quality and source of this groundwater. The objective of the present project is to investigate and answer some of these unknown details.

Study Objectives: The specific objectives of the project are:
i. To identify the various aquifers present in Upper / Middle Ganga Plains.
ii. To identify the source of recharge of deep aquifers
ii) To assess interaction of deep aquifer with overlying aquifers.
iii. Water quality of deep aquifer
iv. Sustainability of deep aquifer for its exploration and future use

Methodology:

Water sampling: In the study region, tube-wells of CGWB/ State owned wells will be examined and the selected deep aquifer groundwater (which tap water form depth more than the wells presently getting tapped for any purpose (irrigation/industrial/domestic). Water samples from surface water sources (rain, river canal etc) will also be sampled to fingerprint the recharging groundwater source.

Measurements: Physico-chemical parameters, major ions & trace metals concentration, bacteriological analysis, stable isotopes ($\delta^{18}O$, δD), tritium (^{3}H) content & ^{222}Rn concentration will be measured using the experimental facility available at NIH, Roorkee. For dating old samples, radiocarbon measurement facility will be developed in NIH.

Support of IAEA, Vienna will be taken for measurement of noble gas and for dating using $^{3}H/^{3}He$ and ^{36}Cl techniques.

Interpretation: Data will be interpreted in terms of formation (leakage from overlying aquifer, distant recharge areas, flow dynamics, turn over time (i.e, how old is the groundwater) etc. Noble gas data will be used to estimate the recharging source water temperature.

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

Work Plan & Activity Chart

Sl. No.	**Work Element**	**1st Yr**				**2nd Yr**				**3rd Yr**				**4th Yr**	
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**
1	Appointment of project staff	✓													
2	Procurement of items	✓			✓										
3	Collection of available literature, data from CGWB and State Groundwater Departments and identification of wells and aquifers to be tapped for groundwater sampling		✓	✓	✓										
4	Water sampling for chemical, stable isotope analysis, ^{222}Rn, radiometric dating (^{3}H, ^{14}C, $^{3}H/^{3}He$) and noble gas analysis					✓	✓	✓	✓						
5	Development of radiocarbon dating line, procurement of standards from IAEA, Vienna, calibration of the system		✓	✓	✓	✓	✓	✓							
7	Chemical, bacteriological and isotopic analysis of water samples at NIH, Roorkee and transport of samples to IAEA, Vienna for analysis at IAEA, Vienna					✓	✓	✓	✓	✓	✓				
8	Noble gas & $^{3}H/^{3}He$ analysis at IAEA, Vienna							✓	✓	✓	✓				
9	Data analysis & interpretation									✓	✓	✓	✓		
10	Trainings and mass awareness programme								✓		✓		✓		✓
11	Interim reports & Final report				✓				✓						✓

3. PROJECT REFERENCE CODE: NIH/HID/SPON/18-21/PDS-SDK

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, Sc.F **(PI),** Sudhir Kumar, Sc. G, C.K. Jain, Sc. G + team from IRI, Roorkee
Type of Study	**S**ponsored
Funding Agency	National Hydrology Project
Budget	Rs.36.0 lakh (NIH)
Duration:	3 years
Date of Start:	01.01.2018
Date of Completion	31.12.2020

Statement of Problem:

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

Objectives:

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

Present state-of-art

A number of studies have been reported on the two lakes. Singh and Das (1996) studied the ion chemistry of the Bhimtal lake water and weathering process in the lake catchment. Bhishm kumar et al. (2007) estimated sedimentation rates of the some north Indian lakes including Bhimtal and Naukuchiatal using sediment dating techniques. Negi et al (2010) have reported the fishery potential and characteristics of some Kumaun lakes including the Bhimtal and Naukichiatal lakes. Purushothaman and Chakrapani (2012) studied the trace metals biogeochemistry of Kumaun Himalayan lakes including Bhimatal and Naukuchiatal lake. Negi and Rajput (2012) have reported the fish diversity in Bhimtal lake. Choudhary and Chakrapani **(**2013) analysed 100- year record of changes in organic matter characteristics and productivity in Bhimtal Lake. Negi and Rajput (2013) studied the diversity of phytoplankton in relation to different environmental variables in Bhimtal lake**.** Bisht et al. (2013) studied the physico-chemical behavior **of** Bhimtal lake. Panwar and Malik (2014) analysed the **v**ertical variations in physico-chemical characteristics of Bhimtal lake. Panwar and Malik (2015) studied the **z**ooplankton diversity, species richness and their distribution pattern in Bhimtal Lake. Panwar and Malik (2014) analysed the **v**ertical variations in physico-chemical characteristics of Bhimtal lake. Kholiya and Roy (2015) have discussed the phyto-remediation techniques for improving Bhimtal and Naukuchital lakes. Khati (2016) carried out the analysis of the physico-chemical characteristics of Bhimtal Lake. Joshi et al. (2016) studied the physico-chemical characteristics of the five lakes of Kumaun Himalaya including Bhimtal and Naukuchital. The review brings out that most of the studies are related to physico-chemical characteristics of the lake and hardly any reference is made to hydrological aspects such as lake evaporation, groundwater-lake interaction, water balance of the lake etc.

Methodology

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

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

Research outcome from the project

i) Comprehensive Project Report including all data, maps, information, analysis and results. The report would also contain specific recommendations/conservation plan for the conservation and management of the lake based on the basis of the analysis carried out.
ii) Research Publications
iii) Training Workshop for Concerned state government officials

Activity Schedule (Combined activity schedule of NIH & IRI)

SN	Activity	Quarter											
		Year- I				Year- II				Year- III			
		1	2	3	4	1	2	3	4	1	2	3	4
1.0	**PREPARATORY WORK**												
1.1	Reconnaissance survey & finalization of various sampling locations	√											

1.2	Recruitment of project staff	√											
1.3	Collection & Review of all available data/information	√	√	√									
1.4	Procurement and installation of instruments	√	√	√									
1.5	Purchase of Data	√	√										
1.6	Preparation of basic maps of lake and catchment		√	√									
1.7	***Installation of piezometers***	√	√										
1.8	***Arrangement for discharge measurement***	√											
2.0	**FIELD WORK**												
2.1	Generation of hydro-meteorological		√	√	√	√	√	√	√	√			
2.2	Collection of water samples for water quality analysis		√	√	√	√	√	√	√	√			
2.3	Collection of water samples for isotope analysis		√	√	√	√	√	√	√	√			
2.4	Collection of sediment samples			√									
2.5	Infiltration tests to determine Infiltration rates			√	√								
2.6	Monitoring of discharge		√	√	√	√	√	√	√	√			
2.7	Bathymetric Survey of lake		√										
2.8	Monitoring of lake water levels		√	√	√	√	√	√	√	√			
2.9	Monitoring of ground water levels		√	√	√	√	√	√	√	√			
3.0	**LABORATORY ANALYSIS**												
3.1	Analysis of samples for Water Quality		√	√	√	√	√	√	√	√			
3.2	Analysis of water samples for isotope characterization		√	√	√	√	√	√	√	√			
3.3	Analysis of sediment samples			√	√								
4.0	**DATA INTERPRETATION & ANALYSIS**												
4.1	Processing of bathymetric data			√	√								
4.2	Development of depth-area-capacity curve for the lake				√								
4.3	Preparation of other maps, morphometric characterization and morphological analysis			√	√								
4.4	Analysis of rainfall and other meteorological data									√			
4.5	Estimation of evaporation losses from the lake										√		
4.6	Assessment of lake-ground water interaction										√		
4.7	Estimation of water balance of the lake										√	√	
4.8	Isotopic characterization of waters of study area									√			
4.9	To develop local meteoric water line										√		
4.10	To estimate sedimentation rate of the lake										√		
4.11	To assess the water quality of the lake			√		√		√		√			
4.12	Assessment of suitability of lake water for various uses											√	
4.13	To develop conservation plan for the lake											√	
5.0	**PREPERATION OF REPORT**												
5.3	Preparation of Interim Project Report				√				√				
5.4	Organization of Training Workshop											√	
5.5	Preparation of Final Project Report												√

PROPOSED WORK PROGRAMME FOR 2018-2019

S. N.	Title of the Project	Team	Duration	Funding	SDG no.
I.	**Internal Studies (Ongoing)**				
1					
II.	**Sponsored Projects (Ongoing)**				
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	S. D. Khobragade (PI); Sudhir Kumar; Rajesh Singh; M. Arora; R. J. Thayyen	*5 Years 04/16-03/21*	DST (Subproject No. 9 under NMSHE)	6.5
2.	Dating very old groundwaters of deeper aquifers in Ganga Plains, India	M. S. Rao (PI) Sudhir Kumar	*3 years 10/16 - 09/19*	IAEA Vienna (€ 18,000/-)	6.5
3	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar (PI) SD Khobragade S. K. Verma	3 years 04/16 – 03/19	Project with GBPIHE (15 lakhs)	6.6
III.	**Sponsored Projects (New)**				
1	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	MS Rao (PI) Sudhir Kumar Sumant Kumar Sh. S Halder (SWID, WB)	*3 ½ Years 01/18 – 06/21*	NHP (PDS)	6.5
2	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) CK Jain SD Khobragade MS Rao CGWB (NR)	*3 ½ Years 01/18 – 06/21*	NHP (PDS)	6.5
3	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal Lakes, Uttarakhand	SD Khobragade (PI) Sudhir Kumar CK Jain AR Senthil Kumar	*3 Years 01/18 – 12/20*	NHP (PDS)	6.6

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

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

Work Program for the Year 2017-18

S.No. & Ref. Code	Title	Study Team	Duration
	ONGOING STUDIES		
1. NIH/SWHD/NIH/14-18	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar Vaibhav Garg Rakesh Kumar N.K. Bhatnagar	3 years (April 2014 to March 2018)
2. NIH/SWHD/NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Achana Sarkar T. Thomas Vaibhav Garg	3 years (April 2015 to March 2018)
3. NIH/SWHD/NIH/14-18	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora Rakesh Kumar	4years (May 2014 to March 2018)
4. NIH/SWD/NIH/14-18	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	3 years (Oct. 2014 to May 2018)
5. NIH/SWHD/NIH/15-18	Study on effect of climate change on sediment yield to Pong reservoir	A. R. Senthil Kumar J. V. Tyagi Avinash Agarwal Suhas Khobragade Manohar Arora	3 years (April 2015 to March 2018)
6. NIH/SWHD/NIH/14-17	Effect of climate change on evaporation at point scale	Digambar Singh A. R. Senthil kumar Manohar Arora	3years (June 2014 to Oct 2017)
7. NIH/SWHD/NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani	3 years (April 2015 to March 2018)
8. NIH/SWD/NIH/16-18	Snow cover variability in the Upper Yamnotri Basin	Naresh Kumar Manohar Arora Rakesh Kumar	2 years (April 2016 to June 2018)
9. NIH/SWHD/NIH/16-17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh	1 year (April 2016 to September 2017)
10. NIH/SWHD/NIH/16-19	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Sushil K. Singh	3 years (April 2016 to March 2019)
	NEW STUDIES		
11. NIH/SWHD/NIH/17-18	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments	S.K. Singh	1 year (April 2017 to March 2018)

12. NIH/SWHD/NIH/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakeh Kumar J. P Patra Pankaj Mani	4 years (April 2017 to March 2021)
13. NIH/SWHD/NIH/17-20	An integrated assessment of a middle Himalayan watershed for sustainability of its water resources	A. R. Senthil Kumar Manohar Arora Digambar Singh M S Rao R K Nema Pradeep Kumar S K Mishra	3 years (April 2017 to March 2020)
14. NIH/SWHD/NIH/17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P.Patra Rakesh Kumar Pankaj Mani Sanjay Kumar	3 years (April 2017 to March 2020)

Work Program for the Year 2018-19

S.No. & Ref. Code	Title	Study Team	Duration
SPONSORED STUDIES			
1.NIH/SWHD/NIH/15-18	WaterRAIN-Him: Changes in water Resources Adaptation options in Indian-Himalayan basins	Archana Sarkar Sanjay K Jain	Ongoing 3 years (1 Jan2015 to 31 Mar. 2018) **Total Cost: 188000 SEK**
2.NIH/SWHD/NIH/14-18	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	Ongoing 3.5 years (Oct. 2014 to May 2018) **Total Cost: 12.6 Lac**
3.NIH/SWHD/NIH/16-20	Hydrological modeling in Alaknanda basin and assessment of climate change impact	A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	Ongoing 5 years (Jan. 2016 to Dec. 2020) **Total Cost: 42.296 Lac**
INTERNAL STUDIES			
4.NIH/SWHD/NIH/14-18	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar N.K. Bhatnagar Vaibhav Garg Rakesh Kumar	Ongoing 3 years (April 2014 to Mar. 2018)
5.NIH/SWHD/NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Archana Sarkar Vaibhav Garg N.K. Bhatnagar	Ongoing 3 years (April 2015 to March 2018)
6.NIH/SWHD/NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani Sanjay K. Jain	Ongoing 3 years (April 2015 to March 2018)
7.NIH/SWHD/NIH/15-19	Study of Hydrological Changes in selected watersheds in view of climate change in India	L.N. Thakural S. Rathore Surjeet Singh Sanjay Kumar Jain Shard Kumar Jain	Ongoing 4 years (April 2015 to March 2019
8.NIH/SWHD/NIH/16-17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh	Completed 1 year (April 2016 to Sep. 2017)

9.NIH/SWHD/NIH/16-19	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Sushil K. Singh	Ongoing 3 years (April 2016 to March 2019)
10.NIH/SWHD/NIH/16-18	Snow cover variability in the Upper Yamuna Basin	Naresh Kumar Manohar Arora Rakesh Kumar	Ongoing 2 years (April 2016 to June 2018)
11.NIH/SWHD/NIH/17-18	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments	Sushil K. Singh	Ongoing 1 years (April 2017 to March 2018)
12.NIH/SWHD/NIH/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J. P. Patra Pankaj Mani	Ongoing 4 years (April 2017 to March 2021)
13.NIH/SWHD/NIH/17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P.Patra Rakesh Kumar Pankaj Mani Sanjay Kumar	Ongoing 3 years (April 2017 to March 2020)

NEW STUDIES (Sponsored)			
14.NIH/SWHD/NIH/17-19	Impact Assessment of Climate Change on Water Resources and Agriculture in Banas basin in Western India using Climate change Indicators(CII’s)	Archana Sarkar Surjeet Singh T. Thomas	3 years (Sep. 2017 to Feb. 2019) **Total Cost: 24200 Euros**
15.NIH/SWHD/NIH/17-20	Water efficient irrigation by using SCADA system for medium irrigation project (MIP) Shahnehar	R.P. Panday J. P. Patra Rajesh Singh N.K. Bhatnagar	3 years (Dec 2017-Dec 2020) **Total Cost:75 Lac** **NIH Component: 15 Lac**
NEW STUDIES (Internal)			
16.NIH/SWHD/NIH/18-21	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario	Ashwini Ranade Archana Sarkar	3 years (April 2018 to March 2021)

PROGRESS OF WORK PROGRAMME FOR 2018-19

PROJECT REFERENCE CODE: NIH/SWHD/NIH/15-18

Project Name:
WaterRAIN-Him: Changes in Water Resources and Adaptation options in the Indian-Himalayan basins

Project Partners:
Swedish Meteorological and Hydrological Institute (SMHI), Sweden (Lead)
Stockholm Environment Institute (SEI), Sweden
National Institute of Hydrology (NIH), Roorkee, India
Indian Institute of Technology (IIT Delhi), India

Project team (NIH):
Dr Archana Sarkar, Sc D (PI)
Dr Sanjay Jain Sc G

Time Frame:
3 Years (Jan 1, 2015 to Dec 2017)
(Extended to Dec 2018)

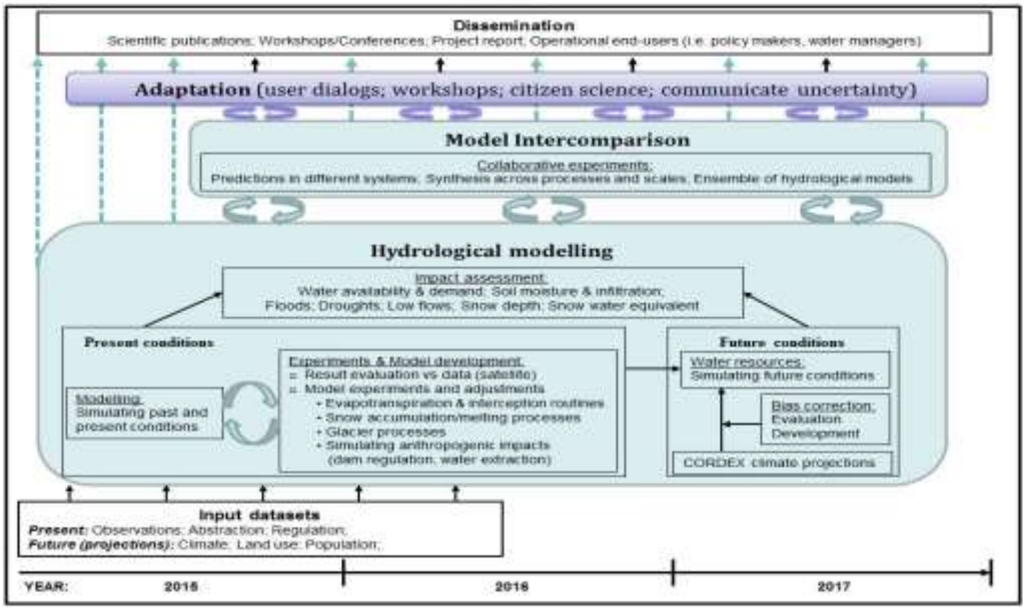
Funding:
Swedish Research Council (through SMHI, Sweden)
NIH Funds: SEK 1,88,000.00

Purpose and Aims:
The main aim of this project is to assess the impacts on the water fluxes due to change in climate, land use and population in the Indian-Himalayan basins, i.e. Ganges. With such an analysis, holistic and robust adaptation strategies can be developed to drive planning for proper and efficient water resources management for food security and poverty alleviation. This project will produce the science and models needed to address key scientific questions, with climatologists, hydrologists, policy makers, and water resource planners working together to develop new methods for integrated water management.
In particular:

- End-user needs
- System understanding, description and sensitivity
- Climate projections
- Integrated response to future changes
- Adaptation strategies (drinking water, agriculture, hydropower sectors)

Study Area: The Indian-Himalayan River basins with focus on the Ganges basin

Project Outline:



RESULTS:

Analysis at the scale of the Ganges River Basin:

- Precipitation: Change varies between 0 and +20%. However the change is smaller during the early century. The uncertainty in the climate projections increases with increasing time horizon. The duration and number of dry spells seems to decrease, yet the maximum intensity increases, indicating more frequent precipitation events and of higher intensity.
- Temperature: Consistent increase from 1 to 6oC depending on the time horizon. Yet quite significant decrease (up to 60%) of freezing degree days in the Himalayan region.
- Evapotranspiration: Change varies between 0 and +10% (end of century up to 20%).
- Runoff/discharge: High spatial variability of change in runoff (from 10% up to +40%) This is consistent at the end of century over the entire basin. High flows can increase up to 40%, whilst change in low flows varies in space (both reduction and increase).
- Drought - SPI: Projections predict higher frequency of moderate and severe wet and dry years. RCP4.5 predicts more dry years in mid-century. The pattern in end-century with RCP8.5 predicting more dry years and RCP2.6 wet years.

Analysis at the regional scale (Dehradun, Uttarkashi, Patna, Koshi)

- Seasonality: The pattern of annual cycle for precipitation, temperature and discharge will remain the same for Dehradun, Uttarkashi, Patna and Koshi. There is a posibility of a shift in the onset of precipitation for Dehradun and Uttarkashi.
- Return period: The discharge return periods will be altered, in which more extreme are expected to occur more frequently, and hence affecting the planning of infrastructures for WRM.
- Climate sensitivities: Change in discharge, particularly for Dehradun and Uttarkashi are very much linked to changes in precipitation.

- High discharge: Overall a positive change in high flows is observed for all time horizons and all four regions. Trends in change is subject to the climate model used, however the magnitude of change does not seem dependent on the emission scenario.
- Low discharge: Overall a negative change in high flows seems to be observed for all time horizons and all four regions. Trends in change is subject to the climate model used, yet on the region and future time horizon.

Contribution:

- National Action Plan on Climate Change (NAPCC)
- Ganga River Basin Management Plan (GRBMP)

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

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

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

Type of Study : **Sponsored Research**

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

Date of Commencement: October 2014

Scheduled date of completion: May 2018

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

Objectives:

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

Statement of the problem:

Extreme rain events cause severe flooding and disasters across India each year in some parts or other. They show unusual characteristics in respect of variability in the location, frequency, intensity and areal extent. Sometimes they occur in very isolated location and during the period, when most part of the country was under dry condition. They are becoming more frequent and erratic in recent years. Their case studies are pivotal in severe weather alerts, water resources and agricultural advisories. In order to understand the role of global and local climate changes, weather extremes are required to study case-by-case basis. It seems that, global temperature changes in last few decades are making changes in rainfall pattern also. Consequences of global warming on the monsoonal rainfall are studied in great details worldwide. There was a surge of studies on extreme rainfall fluctuations after general acceptance of global warming a reality, mostly to generate information useful for assessment of hydro-meteorological disasters, as well to respond to issues of importance amidst world scientific community.

Objectives vis a vis Achievements:

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

Analysis and Results:

In the year 2013, the state Uttarakhand and nearby states experienced very heavy above normal (375%) rainfall on 16-17th June. A multi-day cloudburst centered on Uttarakhand caused devasting floods and landslides. Due to continuous rain, the Chorabari Glacier at the height of 3800m melted and this triggered the flooding of the Mandakini river, which led to heavy floods near Gobindghat, Kedar Dome, Rudraprayag district. 822 were deaths occurred in flood. 1800 were missing persons, 2232 fully damaged houses, 150 bridges get damaged, 1520 roads get damaged. The objective of the current study is to understand the underlying mechanism that causes severe rainstorm along southern slopes of Himalayas during 16-17 June 2013 using the anomalies in the meteorological parameters and associated monsoon circulation

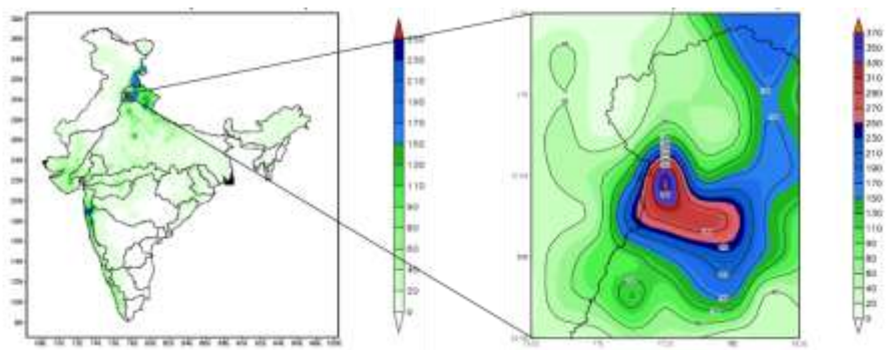


Fig. 1 Spatial Distribution of Rainfall across India on 17th June 2013.

(1) Dataset collected/used:

NCEP Climate Forecast System Reanalysis (CFSR) 6 hourly products from 1979-2016 at 2.5X2.5 degree resolution (Temperature, Geopotential height, U and V wind at 12 isobaric levels, Mean sea level pressure, and Precipitable water) and 0.25 degree gridded rainfall data from India Meteorological department are used in this study

(2) Anomalies in the global atmospheric parameters

Global atmospheric conditions associated with the rainstorm are described quantitatively by using area averaged atmospheric parameters at global, hemispheric and regional scale. The parameters are averaged for the period of 15-17th June 2013 in order to get robustness for the 16-17th June rainstorm condition. In addition, we also used Global weather charts of different atmospheric parameters showing departure from normal values (1979-2013) on 17th June in order to understand the localized anomalies in the global atmospheric parameters.

The area averaged tropospheric (1000-250hpa) temperature and thickness departures revel that, the whole globe is marginally warmer and thicker (+0.24°C/+12.9m) than its normal during 17th June 2013 rainstorm period. The northern hemisphere (NH) is comparatively more warm and thick (0.56°C/26.42m) while southern hemisphere (SH) is marginally cooler and thinner (-0.1°C/-6m). Favorable NH-SH contrast in both parameters is (0.63°C/27m) is maintained during the period. Anomalous cooling and marginal thickening of north subtropics (NSBT; -8.1°C/+32.5m) compare to south subtropics (SSBT; 0.2°C/10.8m) is the peculiar condition observed during the rainstorm period. North pole (NPL) is comparatively cooler and drastically thinner than normal (-2.1°C/-106.2m) while south pole (SPL) is marginally warmer and thicker (1.6°C/54.8m) than it normal values. NH as a whole shows marginal negative pressure anomaly (-0.7mb) while that of SH is positive (0.6mb). NPL shows negative pressure anomaly (-11.32mb) while SPL shows that of positive (7.68mb) during rain storm period.

Extreme east Tibet is warmer and thicker (3.7°C/132.8°C) than normal as compare to other parts of the Tibet. It indicates that eastward component of monsoon circulation is more intense than its western counterpart. Tropospheric temperature and thickness gradients from Tibet to SH, SSBT are positive and near normal, while to the North Pole it is steeper than normal (2.45°C/136.3m).

(3) Equatorially/Globally conditioned analysis of the rain storm

In order to understand the nature of type, intensity, depth and areal coverage of weather system formed during monsoon season over Himalayan region, equatorially/globally conditioned meteorological analysis has been performed. Departures in atmospheric parameters from their corresponding equatorial mean value termed as '*equatorially conditioned'* (EC) parameters (EC-T_{level} and EC-Z_{level} at 12 isobaric levels, EC-mslp, and EC-ppw) on 17th June 2013 are plotted. It is observed that, the surface temperature of entire Asia-pacific up to 40°N is warmer than equator. Positive EC-T_{1000} field is spread from 45°N to 15°S in Asia-Pacific sector. NP is 35°C cooler and SP is 55°C cooler than equator at surface indicating potential area for the subsidence of the air. Area under Positive EC-T field gets reduced at higher altitudes. Tropospheric temperature of Asia-pacific is 4-6°C warmer than equator in the month of June. Two hot cores (EC-T_{Trop}>0) in tropospheric temperature field are observed over Iran-Afghanistan-Saudi Arabia sector and other over Tibet-Himalaya as well China. The splitting of the one large hot tropospheric tower is continuing till 19th June. On 16-17 June (rainstorm period), The Tibetan core is more warm (EC-T_{Trop} =10°C) than that of Iran-Afghanistan (EC- T_{Trop}=6°C). Global pattern of EC-Z_{TROP} is similar to that of EC-T_{TROP}. Positive EC-Z_{TROP} condition occurs over Afroeurasia (10°S-40°N) and equatorial-tropical Pacific with core value (>+150m) over Iran Afganistan and Tibet-Himalaya sector. In general, the field value decreases poleward to less than -900m over north polar, and -1800m south polar. Wavy pattern in EC-Z in subtropical latitudes with a deep trough over Himalayan region is continuing throughout the atmosphere.

The EC-mslp field is highly negative (-8 to -12mb) over Indian subcontinent, China, Mangolia extending upto Japan as well north polar region. This intense low pressure field is surrounded by positive field over Pacific Ocean and Atlantic Ocean in east and west as well Indian Ocean in Southern hemisphere. Intense low pressure field over Himalayan region is combination of deep troughs in the higher levels becomes favorable for the development of the storm. Anomalous rise in the EC-PPW (10-15mm) can also be seen before the storm event.

(4) 3-D structure of Global Weather Regimes and circulation

For 17th June 2013, normal chart of the global weather regimes (GWRs), streamlines and GC-W at 12 standard isobaric levels (1000-100-hPa) have been analyzed by comparing them with their normal. At 925 and 850 hPa level, most intense warm-low regime occurs across Afroeurasia-Indopacific region (5°S-50°N; 20°E-150°E), which develops due to confluence/collision between deflected Indo-Pacific equatorial-tropical easterlies and Eurasian temperate westerlies. Small cyclonic circulations and convergences are the prominent weather systems appear in the warm low regime. Cool-low condition is appearing to intruded more southward especially over extreme north Himalaya. Deep troughs and ridges in midlatitude westerlies are seen in the cool low regime. In the middle troposphere (600hpa), warm-low condition prominently occurs over Indian subcontinent and adjoining water bodies, and the small part of equatorial Pacific. Trough in the temperate westerly deepen over Indogangatic plain is noticed prominently in warm low regime. At 400hPa, the trough is more prominent and area under warm low regime also reduces drastically. Two warm divergence cores are established over middle east and China sector. At 150 hpa, divergence from warm high regime over northern subtropics is divided into two cells, since temperate westerlies are still showing wavy pattern. Tropical Easterly Jet (GC-W > +15m/sec) in form of cool convergence is formed over equatorial Indian ocean.

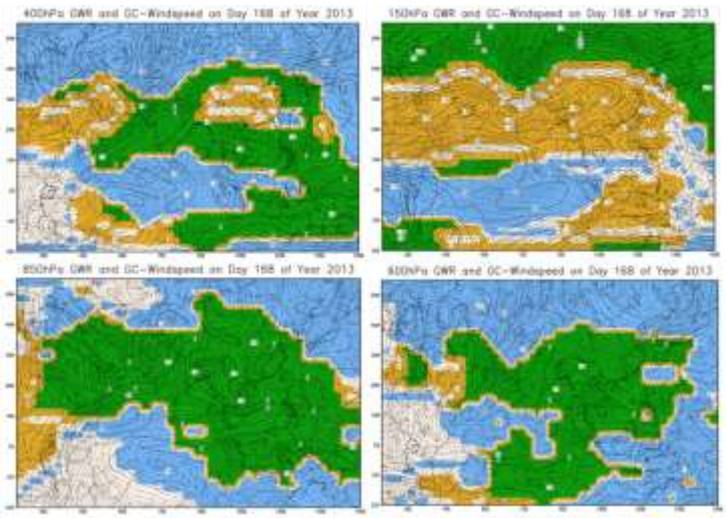


Fig 2.: Global weather regime at different atmospheric levels on 17th June 2013

Possible mechanism responsible for rainstorm occurrence

Although the monsoon is yet to establish completely during rainstorm period, sudden warming over eastern Tibet intensifies the midlatitude waves. Cool low is intruded in middle troposphere. So deep cold convergence was formed in the middle layers of the atmosphere and warm moist convergence in lower layers. Atmosphere is unstable barotropically in the lower level but baroclinically at the upper level. Intense sea level pressure drop and anomalous moisture incursion form Bay of Bengal and Arabian sea intensifies the weather system to create isolated heavy rain pour.

Adopters of the results of the study and their feedback:

Operational Forecasters, state agencies in water sector

Major items of equipment procured:

1. Workstation**; ii)** Printer; iii) UPS

Lab facilities during the study: None

Data generated in the study:

1. Climatological and Yearwise daily equatorially-conditioned atmospheric parameters maps
2. Climatological and Yearwise daily global weather regime maps

Study Benefits/Impact:

The results from this study will be helpful in order to develop operational forecasting scheme for the assessment and prediction of heavt rain storm duirng summer monsoon across the country. The study will also give some insight about the relationship between occurrences of extreme rain events and changes in general circulation features in order to cope up their consequences in advance.

Specific linkages with Institutions/beneficiaries: None

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

Future Plan: Near real-time Thematic global monitoring system for the assessment and forecast of large-scale extreme wet spells

PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-20

Title of the project	**Hydrological modelling in Alaknanda basin and assessment of climate change impact**
DST reference No	SP-06
PI's name, Address, Contact No.	Dr. A.K. Lohani, Scientist-G, WRS Division, NIH Roorkee
Total cost of the project	42.296 (Rs. in Lakh)
Duration	January 2016 – December 2020 (5 years)
Date of Start of the project	January 2016
Date of Completion	December 2020
Funds Received	
a. Sanction Number	DST/SPLICE/CCP/NMSHE/TF-4/NIH/2015-G
b. Date of sanction:	13/01/2016

Brief of Work carried out so far

The Alaknanda river is a major Himalayan glacial stream. The river traverses 229 km before its confluence with Bhagirathi at Devprayag to constitute the Ganga, the major and holiest river of India. The Alaknanda originates at a height of 3641 meters below Balakun peak 16 km upstream of Badrinath from the two glaciers of Bhagirath Kharak and Satopanth. In order to carry out hydrological modelling in the Alaknanda river basin status of the available data and information have been collected further a detailed review of the snowmelt runoff modelling methodology have been carried out. Spatial data of the study basin have been collected. Various maps such as basin map (Fig 1), drainage map, landuse map, DEM (Fig. 2), snow cover area maps of the basin have been prepared. Furthermore, grided rainfall data of the study basin have been collected and processed. Snowmelt runoff model is being setup for the study basin. Flow data is required for the calibration and validation of the model. Available G& D data in the basin has been identified and efforts are being made to collect these data.

PART-B: PHYSICAL PROGRESS

1. Approved Objectives of the Project:
   - 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.

2. Work Plan and Expected deliverables

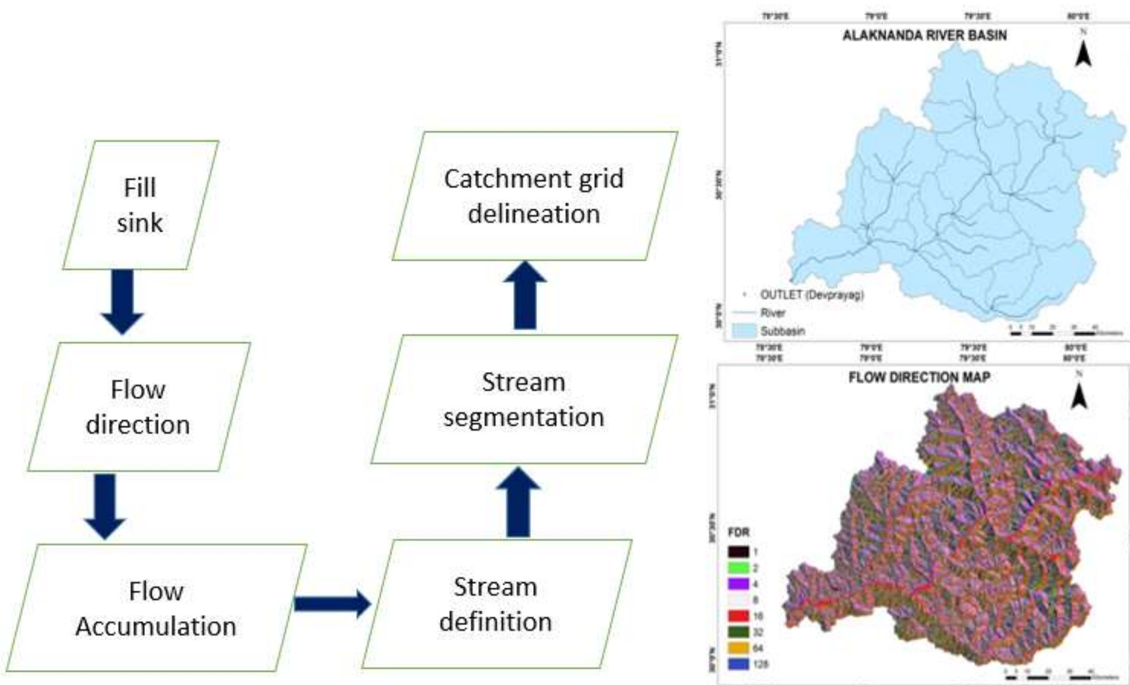
Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Collection of hydrological and hydro-meteorological data from various agencies and entry in SWDES software										
Generation/import of spatial data layers for the study area and reference database from different sources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

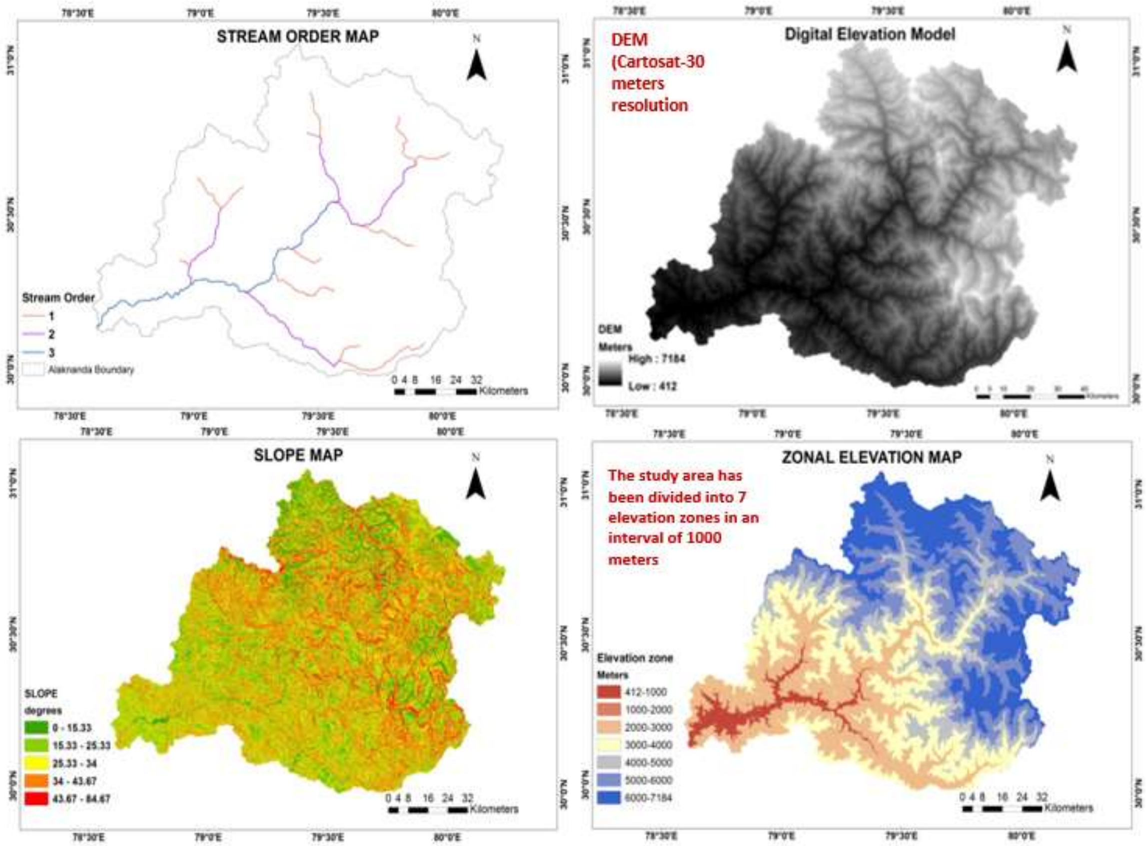
3. Methodology and Study area (Please provide a map)
All Methodology and progress attached at the last

Progress

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



Flow Direction map



STREAM ORDER MAP
Stream Order
1
2
3
Alaknanda Boundary
Kilometers
Digital Elevation Model
DEM
(Cartosat-30
meters
resolution
DEM
Meters
High : 7184
Low : 412
SLOPE MAP
SLOPE
degrees
0 - 15.33
15.33 - 25.33
25.33 - 34
34 - 43.67
43.67 - 84.67
Kilometers
ZONAL ELEVATION MAP
The study area has
been divided into 7
elevation zones in an
interval of 1000
meters
Elevation zone
Meters
412-1000
1000-2000
2000-3000
3000-4000
4000-5000
5000-6000
6000-7184
Kilometers

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

Title of the study: Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State

Thrust Area under XII five year Plan:

Project Team: Dr. Archana Sarkar, Sc 'D', SWHD (PI)
Sh. N.K. Bhatnagar, Sc'B', SWHD
Dr. Vaibhav Garg, Sc'C', IIRS, Dehradun
Dr. Rakesh Kumar, Sc'G'& Head, SWHD

Type of Study: Internal

Date of Start: 1 April 2014

Scheduled date of completion: 31 March 2018

Study Area:

Uttarakhand is a state in the northern part of India. It is often referred to as the "Land of the Gods" due to the many holy Hindu temples and pilgrimage centres found throughout the state. Uttarakhand is known for its natural beauty of the Himalayas, the Bhabhar and theTerai. It borders the Tibet Autonomous Region on the north; the Mahakali Zone of the Far-Western Region, Nepal on the east; and the Indian states of Uttar Pradesh to the south and Himachal Pradesh to the northwest. The state is divided into two divisions, Garhwal and Kumaon, with a total of 13 districts. Two of the most important rivers in Hinduism originate in the region, the Ganga at Gangotri and the Yamuna at Yamunotri.

Uttarakhand has a total area of 53,484 km², of which 93% is mountainous and 65% is covered by forest. Most of the northern part of the state is covered by high Himalayan peaks and glaciers. Uttarakhand lies on the southern slope of the Himalaya range, and the climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to subtropical forests at the lower elevations. The highest elevations are covered by ice and bare rock. Below them, between 3,000 and 5,000 metres (9,800 and 16,400 ft) are the western Himalayan alpine shrub and meadows. The temperate western Himalayan sub-alpine conifer forests grow just below the tree line. At 3,000 to 2,600 metres (9,800 to 8,500 ft) elevation

they transition to the temperate western Himalayan broadleaf forests, which lie in a belt from 2,600 to 1,500 metres (8,500 to 4,900 ft) elevation. Below 1,500 metres (4,900 ft) elevation lie the Himalayan subtropical pine forests. The Upper Gangetic Plains moist deciduous forests and the drier Terai-Duar savanna and grasslands cover the lowlands along the Uttar Pradesh border in a belt locally known as Bhabhar. These lowland forests have mostly been cleared for agriculture, but a few pockets remain.
In June 2013, several days of extremely heavy rain caused devastating floods in the region, resulting in more than 5000 people missing and presumed dead. The flooding was referred to in the Indian media as a "Himalayan Tsunami".

Objectives of the study:

1. Procurement of additional rainfall data of the available rain gauge stations in Uttarakhand State from various agencies and processing of rainfall data.
2. Spatio-temporal trend analysis of historical rainfall data.
3. Downloading and processing of rainfall data (same location as that of rain gauge stations) from TRMM satellite data as well as high resolution gridded re-analysis rainfall data from APHRODITE and IMD.
4. Comparison of rainfall data from various sources.

Statement of the problem:

Study of rainfall based on an integrated perspective of its attributes like spatio-temporal variation, persistence, trends, periodicities etc is very essential for understanding the nature of weather and climate patterns. A good knowledge of local rainfall-regime is crucial for planning and management of domestic, urban as well as industrial water use, irrigation and crop practices besides forecasting and management of extreme events like floods and droughts. In view of the recent flood disaster in the Uttarakhand state, it becomes all the more important to carry out a scientific analysis of the rainfall regime of the region.

Rainfall observations are an essential element of studies related to hydrological processes.They are utilized both for a better understanding of these processes and as input in hydrological simulation models indispensable to a correct territorial planning and to an adequate management of water resources system. Rain gauges, radars, satellite sensors, forecasts from high resolution numerical weather prediction models and high resolution gridded re-analysis rainfall data are a part of precipitation monitoring networks/data sources. These data sources provide rainfall data that are further provided to hydrological models to produce forecasts, therefore, their comparative accuracy assessment is of prime importance.

Approved action plan and timeline:

Year	**April - June**	**July-Sept**	**Oct-Dec**	**Jan-March**
2014-15	Additional rainfall data procurement, data processing	Additional rainfall data procurement, data processing	Trend Analysis of historical rainfall data	Interpretation of results and preparation of interim report-1
2015-16	Downloading APHRODITE data.Trend Analysis of historical rainfall data (different rainfall intensity series)	Downloading of TRMM satellite data and processing of downloaded data	Statistical analysis and comparison of data from different sources	Interpretation of results and preparation of interim-2

2016-17	Comparison of rainfall data from different sources using a hydrological model	Comparison of rainfall data from different sources using a hydrological model	Comparison of rainfall data from different sources using a hydrological model	Preparation & Submission of Final Report
2017	Extension period for final interpretation of results and submission of final report			NA

Progress:

Objectives	**Achievements**
April 2017-Sept 2017	
1. Processing of TRMM satellite data	Completed
2. Statistical analysis and comparison of data from different sources	Completed
3. Comparison of rainfall data from different sources using a hydrological model	Completed
4. Preparation of final report	In progress

Recommendations/suggestions in previous meetings of Working Group/TAC/GB:

Nil

Analysis and results:

Data Used:

Daily observed and gridded rainfall data from APHRODITE, IMD and TRMM for 10 stations in Uttarakhand.

Results:

TRMM daily rainfall data for ten stations namely, Almora, Bageshwar, Haridwar, Joshimath, Munsiyari, Pithoragarh, Rudraprayag, Rudrapur, Tehri, Uttarkashi has been downloaded and processed. Annual and seasonal trend analysis has been carried out with TRMM data. Comparison of data from different sources (observed, IMD, APHRODITE & TRMM) has been carried out which was done for one station, namely, Dehradun due to common data availability. A hydrological model was also simulated under a different study which was used for comparison of the rainfall data for the present study.

Expected adopters:

State Water Resources Dept and other agencies.

Deliverables:

Research papers and report

Data procured and/generated during the study:

Daily rainfall data at 50 raingauge stations around Uttarakhand State with varying length.

Future plan:

As per the approved action plan.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/15-18

Title of the study: Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin

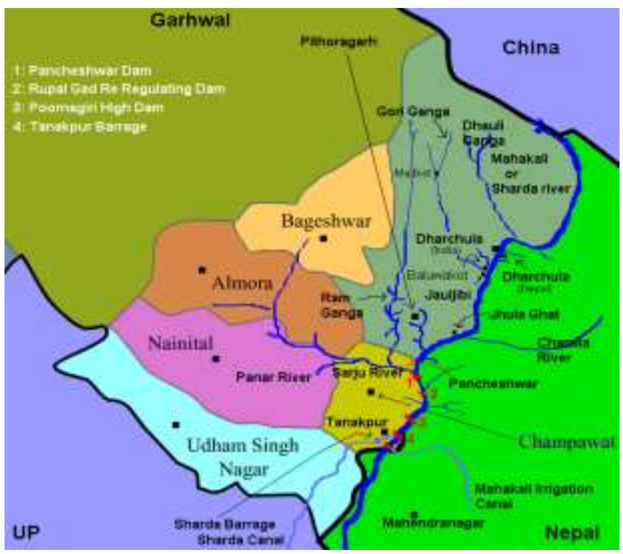
Study Group: Dr. Archana Sarkar, Sc 'D', SWHD (PI)
Dr. Vaibhav Garg, Sc'C', IIRS, Dehradun
Sh. N.K. Bhatnagar, Sc'B', SWHD

Type of study : Internal

Date of start : April 2015

Scheduled date of completion: 31 March 2018

Study area



The Sharda Valley in Uttrakhand has a vast potential for Water Resources Development, which was not tapped at all during the initial three decades of planned development. The region is mythological abode of Gods; the pilgrim route to Holy Mansarover passes along the Sarda Valley. The river Sharda (or Kali) form the international boundary between India and Nepal, towards the north, from a point called Bramhadeo, about 5 km upstream of Tanakpur. River Sharda originates in the region of Higher Himalayas, near lndo-Tibetan border, from the Glacier of Zaskara range, at about 5250 M. In the upper reaches, in the hills, it is called Mahakali. The river emerges into plains at Bramhadeo and it is called Sharda. The study area extends between 29°0'–30°38'N and 79°28 – 81°7'E covering an area of about 15280 Sqkm, with elevation ranging from 250 to 7000m above msl. About 1732 Sqkm of the total area of the basin is under glacier landscape. The Main River generally flows in north-south direction and is met with by a number of major tributaries from Indian side, namely, Dhauliganga, Goriganga, Sarju and Ladhia. The major tributary from the Nepal side is Chameliya. The Sharda river finally joins the Ghaghra (Karnali) River as its right-bank tributary in Uttar Pradesh. The Sharda Valley in Uttrakhand has a vast potential for Water Resources Development. The Tanakpur Hydroelectric Project (120MW) was commissioned in 1992 by the NHPC with a barrage on the Sharda River near the town of Tanakpur in the district of Champawat. Mahakali (Sharda in India) is one of the five major river basins of Nepal which is shared with India and of which about 34 per cent of total basin area lies in Nepal. The hydroelectric potential of the valley on the Indian side of the river as assessed by UP Irrigation Department is over 3000 MW; and the power potential of the main Sharda river is assessed as 2000 MW. Therefore, accurate estimation of the basin runoff (including snowmelt runoff) is of extreme importance.

Objectives of the study:

i. Preparation of basin maps including DEM and estimation of snow cover area using remote sensing data
ii. Calibration of conceptual snowmelt runoff models namely, SRM and SNOWMOD for Sharda River basin upto Tanakpur.
iii. Development and training of black-box models (ANN models) for simulation of runoff including snowmelt runoff of the Sharda River basin upto Tanakpur.
iv. Inter-comparison of various models.
v. Investigation of the impact of likely future changes in climate on stream flow using downscaled GCM scenarios in the study area.

Statement of the problem:

Rainfall-runoff models are of prime importance in the decision making process of water resources planning, design, development and management activities. Such models are used, for example, in the design and operation of hydraulic structures, for flood forecasting, and for evaluating possible impact of land use land cover changes as well as climate changes over a catchment. However, due to the interrelated character of driving factors, i.e., physiographic and climatic factors, the rainfall-runoff process becomes highly complex to understand and also extremely difficult to model. Further, in Himalayan region, like the Sharda River, snowmelt is a governing factor for runoff generation. So, for snow-fed basins, snowmelt runoff component is also required to be incorporated in the modelling approach. It is, therefore required to apply a suitable methodology for modelling the runoff in the Sharda river basin.

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to water resources throughout the world. The effect of climate on hydrology in tropical Asia has many facets. The Himalayas, which act as a mountain barrier on the earth, where polar, tropical and Mediterranean influences interact, play an important role in maintaining and controlling the monsoon system over the Asian continent. In the Himalayas, the storage of precipitation in the form of snow and ice (in glaciers) over a long period provides a large water reservoir that regulates annual water distribution. The majority of rivers originating in the Himalayas have their upper catchments in snow covered areas and flow through steep mountains. If there is any climatic variability in the Himalayas, the impacts could be felt in regions downstream. Therefore, besides reasonably accurate estimation of the runoff, there is an imperative need to study the impact of climate change on the runoff regime of the Sharda basin in view of its huge water resources potential including uses for hydropower, irrigation etc.

Approved action plan:

S. No.	Work Element	First Year				Second Year				Third Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collection of information and Hydro-meteorological Data												
2	Preparation of base maps												
3	Downloading MODerate resolution Image Spectral radiometer (MODIS) snowcover data products for the study area												

4	Analysis and interpretation of weekly MODIS snowcover data and preparation of snow cover maps												
5	**Preparation & Submission of Interim Report-I**												
6	Input data preparation for SRM Model												
7	Calibration and Validation of SRM Model												
8	Input data preparation for SNOWMOD Model												
9	Calibration and Validation of SNOWMOD Model												
10	Input data preparation for ANN Models												
11	Training and Validation of ANN Models												
12	Preparation & Submission of **Interim Report-II**												
13	Inter-comparison of Models												
14	Downscaling of GCM outputs for the study basin												
15	Preparation of Input data for conceptual model for changed climate scenarios												
16	Simulation of conceptual snowmelt runoff model with changed climate scenarios												
17	Preparation & Submission of Final Report												

Progress

Objectives	**Achievements**
April 2017- Oct 2017	
1. Training and Validation of ANN Models 2. Comparison of Models.	Completed Completed

Analysis and results:

a. **Data Used**

SRTM DEM data and SOI toposheets

b. **Results**

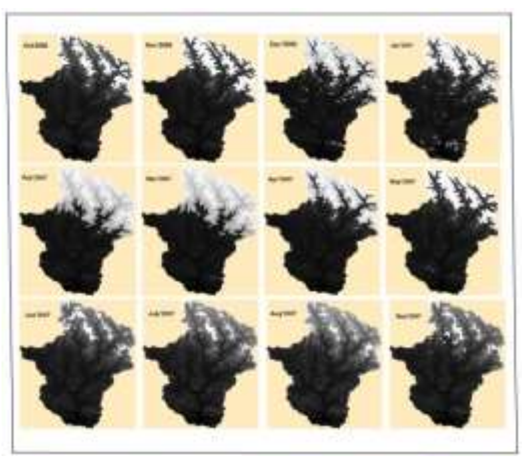


Figure 1: Sequential snow cover in Sharda basin as seen in MODIS images for the period Oct’2006–sep’2007

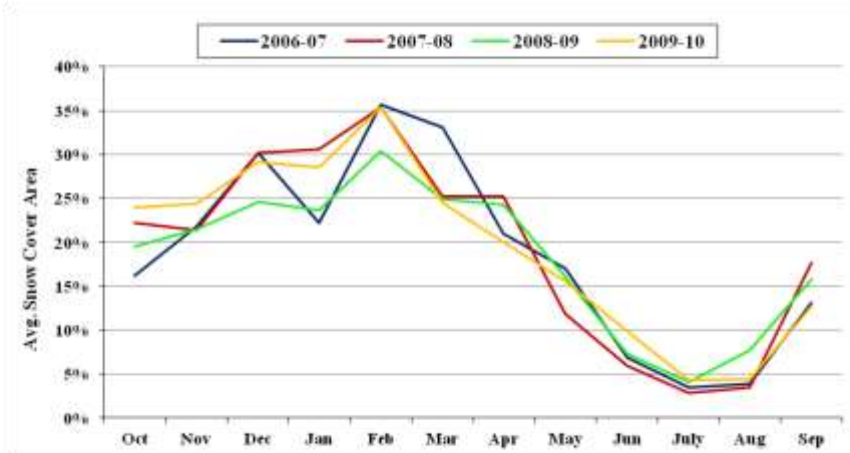


Figure 2: Monthly distribution of SCA in Sharda basin

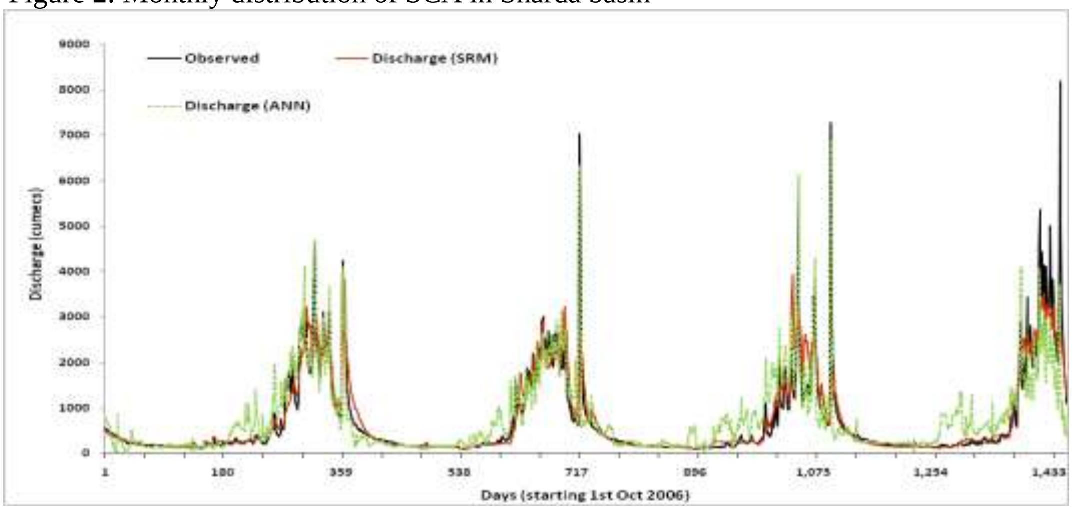


Figure 3:Measured v/s Computed Runoff for the four years using SRM and ANN Models

Expected adopters:
State Water Resources Dept and other agencies.

Deliverables:
Research papers and report

Data procured and/generated during the study:
Nil

Future plan:
As per the approved action plan.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/15-18

Title of the Project: Flood and Sediment studies in Himalayan basin using MIKE-11 Model.

Thrust Area under XII five year Plan: Flood & Sediment Modelling

Project team: Project Investigator: Dr. A.K. Lohani, Scientist 'G'
Project Co-Investigator(s): Dr. Sanjay K. Jain, Scientist 'G'

Date of Start: April 2015

Scheduled date of completion: March 2018

Objectives:

1. To collect and analyse data/information related to cloud burst events
2. To model the floods generated due to cloud burst events
3. To assess sediment dynamics in the river system

Present state-of-art

In upper Ganga basin, several water resources projects are under operation and many more are coming up to harness these resources. These projects are of considerable national and local importance in terms of hydropower generation, irrigation, flood control and subsequent socio-economic development of the region. In the recent past various cloud burst events have been observed in the Himalayan region. Therefore, it is important to analyse the cloud burst generated floods in the basin. Furthermore, the Himalayan rivers carry very high sediment load. The waters of the Ganga carry one of the highest sediment loads anywhere in the world. Therefore, keeping in view the upcoming projects and development in the Himalayan region modeling of the sediment dynamics in a river system is need of the day.

Methodology

Steps of the methodology are:

- Analysis of available precipitation data for different return period for the identified sub basin.
- Historical study of cloud bursts in the Himalayan Region.
- Study of phenomenon of cloud bursts
- Quantification of cloud burst phenomenon into flood hydrograph at the critical section in the river stream.
- Flood routing of cloud burst flood.

Analysis and Results:

Collection of data/information related to cloud burst and sediment is in progress. Contacted various Central and State organizations working in the area for the required data/ information. Model for cloud burst flood modeling has been developed for cloud burst events of Uttarakhand. MIKE-11 model has been applied for cloud burst flood routing purpose. Using the DEM slope maps, river cross section and drainage network of Assiganga river basin have been prepared. Further a cloudburst event of 2012 has been considered and it has been converted to flood event considering triangular hydrograph. This hydrograph is routed to downstream using MIKER-11 model. Further flood inundated area has been plotted. Sediment data was not available for the different tributaries /rivers therefore the sediment modelling is not possible. Furthermore, the available Mike11 model does not have sediment module. The study is in progress and likely to be completed in time.

Research outcome from the project

The research outcome will be in the form of technical report, research papers. Development of methodology for the cloud burse flood modeling and sediment modeling.

Work Schedule:

Sl. No.	Work Element	2015-16	2016-17	2017-18
1	Data Collection	Partly Completed	Mostly completed	Completed
2	Procurement of Mike- Software	Cloud solution for MIKE-11 obtained from DHI		
3	Historical study of cloud bursts in the Himalayan region.		completed	Completed
	Quantification of cloud burst phenomenon into flood hydrograph at the critical section in the river stream	Review of Literature	Partly completed/In progress	Completed
	Flood routing of cloud burst flood.		Partly completed/In progress	Completed
	Development of MIKE-11 based sediment model to assess the sediment dynamics of the river system.		In progress	Sediment data of rivers/tributaries not available Sediment module of MIKE-11 is not available
	Report writing			

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

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

Project team:

a. Project Investigator : Dr. L. N. Thakural, Sc 'C', PI

b. Co-PI Project Co-Investigator(s) : Er. D. S. Rathore, Sc'F'
Dr. Surjeet Singh, Sc'E'
Dr. Sanjay Kumar Jain, Sc'G'
Dr. Sharad Kumar Jain, Sc'G'

Date of start: April 2015

Scheduled date of completion: March 2019

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.

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.

Methodology-

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

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.

Progress of Work:

Four different watersheds located in different climatic regions namely Dhadhar river basin (Gujarat), Ramganga up to Kalagarh (Uttarakhand), Bina River basin (M.P) and Chaliyar river basin (Kerala) as shown in Figure 1. have been selected for the present study. The hydro-meteorological data pertaining to the three river basins namely Ramganga, Bina and Chaliyar basins have been processed to meet out different objectives of the study. The various inputs for the hydrological model such as dem, landuse/landcover soil map etc. have been prepared. The SRTM version 4.1 DEM has been downloaded and processed in the GIS environment for the delineation of drainage networks and watershed boundaries for the four watersheds. Moreover, land use/land cover soil map etc. have also been prepared for the study areas. Spatio-temporal temporal analysis of hydro-meteorological data using parametric and non-parametric approach have been applied to determine the trends in the time series data of rainfall.Moreover, spatial variation of ground water levels along with drought characterization for the river basins have been carried out.

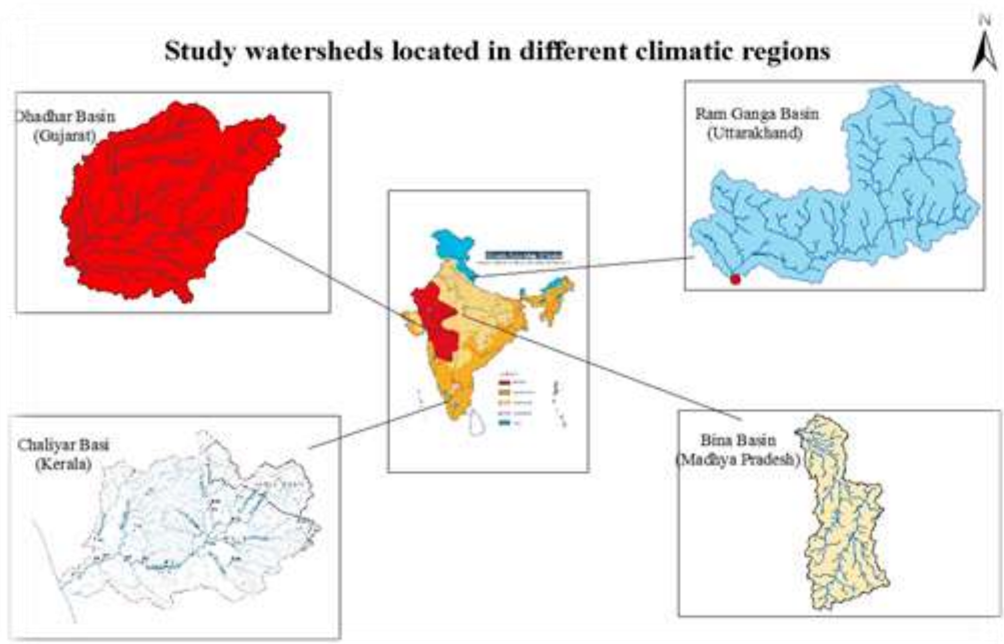


Figure 1: Study watersheds located in different climate regions of India

Progress since last working group:

The hydrological models (NAM and SWAT) have been calibrated and validated for the three river basins i.e. Ramganga, Bina and Chaliyar river basins. The Processing and analysis of collected hydro-meteorological/Soil/Satellite data for the Dhadhar basin is in progress. The soil and land use/land cover maps' soil map and stream network for the Dhadhar watershed has been also completed. Analysis of collected hydro-meteorological along with the downloading of future climatic scenarios data for these basins is in progress.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-17

Title of the study: Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data

Study group: Sushil K. Singh, Scientist F

Date of start of study: 01 April 2016

Duration and scheduled: 01 Year (with 06 month intended extension)

Date of completion of study: 30 September 2017

Type of study: Internal

Objectives of study:
To illustrate and demonstrate the practical application of the generalized GEV on the available Indian data including those collected at NIH.

Statement of problem and brief methodology:
In an earlier report, the practical unification of both type 2 and type 3 gev distributions in a single gev was taken up and a simple and an optimization methods for estimation of its parameters were considered with limited testing/application. In this report, it is intended to take up the methodology as above for application and illustration on measured/published data on Indian rivers' gd sites.

Achievement/progress:
It is an application study in which the developed methodology and analysis by the author is intended to be applied on the published Indian data at various GD sites including those available/collected at NIH. The application of the developed model on available data on few GD sites by CWC is complete and the results are encouraging. During the statistical testing of the results, a concept of deterministic confidence interval has been developed to replace the existing and widely used concept of the probabilistic confidence interval. The application is further intended to extend to possible data available with State Departments particularly of flood prone area of UP, e.g. Rapti river. The report is complete.

Adopters of the results of study and their feedback:
Practitioners, field engineers, and academic personals.

Deliverables:
Research report detailing the developed equation 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/16-19

Title of the study: Application and development of analytical models on data collected at NIH under Saph-Pani Project(Research/Application Study)

Study group: Sushil K. Singh**,** Scientist 'F'
(With possible inclusion of young scientist across the divisions' line)

Date of start of study: 01 April 2016

Duration and scheduled date of completion: 03 Year; 31 March 2019

Type of study : Internal

Objectives of study:

1. To apply and illustrate on the above surface-water groundwater interaction data, the developed and published analytical models by the author, a complied detail of which has earlier been submitted to our Ministry and Institute both directly and indirectly.
2. To possibly develop new analytical models if application on the data as at item 1 suggests so.
3. The items 1 and 2 are also with the aim to suggest general application of these and other methodology concerning the area of surface-water groundwater interaction in general with respective merits/demerits.

Statement of problem and brief methodology:

It is an application study in which the developed methodologies and analyses by the author are intended to be applied on the concerning data collected at NIH as stated above.
The intended development of new analytical model and methodology would be along those adopted in the development of earlier such models by the author.

Achievement/progress:

The compilation of the developed methodology and analytical models and new innovative solution involved therein is complete and the first part of the report containing these systematically at one place is completed, to be placed on table in the Working-group. This report is also in view of a paper published in *Ground Water* out of the collaborative work on Saph-Pani project (mainly concerning to collection of data), which shows unawareness of analytical developments at the Institute taking place 6-12 years back by the author. Non availability of Data and aims and objectives of Saph-Pani project and related new projects will further defeat the objective of this project and induce further possible plagiarism and unprotecting of the intellectual property with an intended technical and value-based financial loss to the institute. The ready availability of data collected under the project will do away with the possible-hindrances in achieving the objectives of the study and path the proper way and modus operandi based on novel analysis of data even in case of extended such projects being undertaken by NIH with adequate justification and utilization of financial support involved therein; it is submitted to the Working-group to arrange resolving for the ready availability of data for research within NIH.

Adopters of the results of study and their feedback:

Practitioners, field engineers, and academic personnel.

Deliverables:

Research report detailing the developed equation and research papers in International Journals with illustrative of ease in application in comparison to existing methods.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-18

Title of the Study: Snow cover variability in the Upper Yamuna Basin

Study Group: Naresh Kumar, Scientist B
Dr. Manohar Arora, Scientist D
Dr. Rakesh Kumar, Scientist G

Role of Team Members:

Naresh Kumar, Scientist B

- Literature review
- Down loading of MODIS Mod 10 A2 data from National Snow and Ice Data Center (NSIDC)
- Data base preparation in ArcGIS (Basin map and drainage network)
- Snow cover analysis of the study area
- Preparation of snow depletion curves for the study area for different years
- Preparation of report

Dr. Manohar Arora, Scientist D

- Guidance, Supervision and review of the work

Dr. Rakesh Kumar, Scientist G

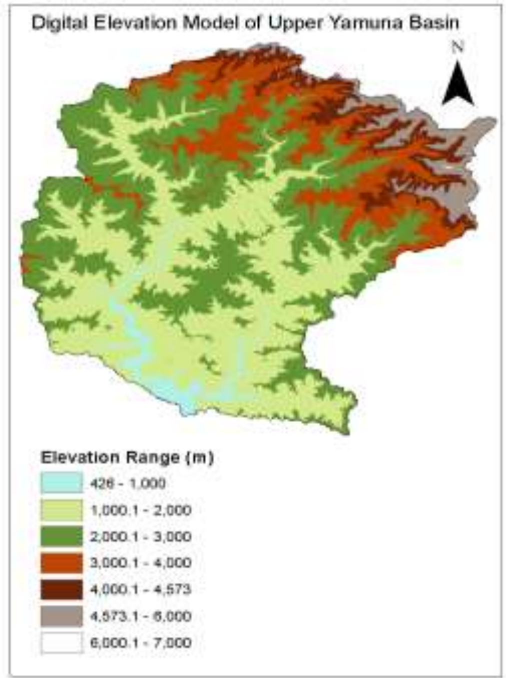
- Guidance, Supervision and review of the work

Type of Study : Applied research

Date of start : April 2016

Scheduled date of completion: June 2018

Study Area:
The Yamuna River, largest tributary of Ganga River originates from Yamnotri Glacier near Banderpoonch Peaks (Latitude 30^0 59'N and Longitude 78^0 37'E) in the Mussourie Range of Lower Himalayas at an elevation of about 6,284m in the Garhwal Himalayas. The 1,376 km long Yamuna flows through India, crossing states: Uttarakhand, Uttar Pradesh, Haryana and Delhi and joins the Ganges in Triveni Sangam, a sacred Hindu site. The study area for the present study is Upper Yamuna Basin upto Dakpatthar. Tha basin area is 7487Km^2 and elevation range is from 461 to 6284masl.



Objectives:

i. Study of snow cover variability in the Upper Yamnotri Basin
ii. Development of snow depletion curves for Upper Yamnotri Basin
iii. Modelling of melt water at Paonta Sahib

Statement of the problem :

The extent of snow cover is considered as an important parameter for various hydrological applications. In terms of spatial extent, snow cover is second largest component of the cryosphere and covers approximately 40 – 50 % of the Earth's land surface during Northern Hemisphere winters. Annual precipitation of snow feeds the accumulation zone of the glaciers. The three major river systems of India i.e the Indus, the Ganga and the Brahmputra have their origin in the snow and glacier fed areas of the Himalayas. Snow melt is also the source of fresh water required for drinking, domestic use, agriculture and industrial sectors for the low lying areas of these river systems. Estimation of snow cover is one of the important parameters for the runoff estimation and forecasting for the snow and glacier fed rivers. However the mapping and monitoring of seasonal snow cover is a challenging task especially in the harsh climatic conditions and rugged terrain of the high mountainous areas.

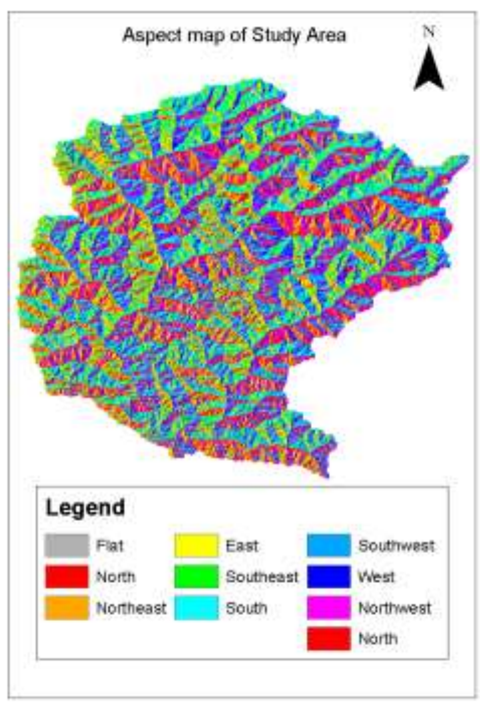
Remote sensing has emerged as a useful technique for snow monitoring. Snow cover monitoring using satellite images started in 1960 and since then potential for satellite based mapping has been enhanced by the development of sensors with higher temporal frequency and higher spatial resolution. Sensors with better radiometric resolutions, such as MODIS and AWiFS have been used for generating the snow products. MOD10A2, a product of MODIS is used for mapping of maximum snow cover extent over eight days. The algorithm used to generate maximum snow cover over eight days uses MOD10A1 data as input. The multiple days of observations for a cell are examined. If snow cover is found for any day in the period then the cell in the "Maximum_Snow_Extent" SDS is labeled as snow. The logic minimizes cloud cover extent in that a cell would need to be cloud obscured for all days observations to labeled as cloud. If all the observations for a cell are analysed but a result is not reached then that cell is labeled as no decision. Snow cover extracted from earlier data and snow products prepared using satellite images have been analysed to know the trends in the snow cover variability in many studies.

Approved action plan:

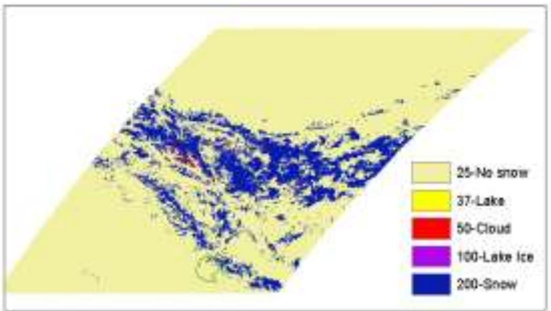
S.N	Work Element	**First Year (2016-17)**				**Second Year (2017-18)**				**Third Year (2018)**
		April-June	Jul-Sep	Oct-Dec	Jan-Mar	Apr-June	Jul-Sep	Oct-Dec	Jan-Mar	April-June
1	Literature Review & Data Downloading									
2	Preparation of basin maps etc.									
3	Data analysis									
4	Preparation of report									

Methodology:
MOD10A2, a product of MODIS is used for mapping of maximum snow cover extent over eight days. The algorithm used to generate maximum snow cover over eight days uses MOD10A1 data as input. This product is being used for snow cover mapping.

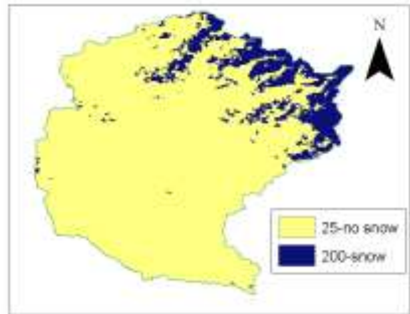
Progress of the study
Basin map, drainage network and aspect map has been prepared from the Aster DEM with the help of ArcGIS tool.



MODIS Mod 10A2 snow data from National Snow and Ice Data Center (NSIDC) for a period 2000 to 2016 has been down loaded. All the 8-day MODIS snow data were imported from HDF-EOS format to IMAGINE Image format. Transformed to the projection WGS1984-UTM44N (Universal Transverse Mercator), and clipped to the extent of the study area. Data analysis is in progress. Snow depletion curves for Upper Yamuna Basin for 15 years (2002 to 2016) will be developed.



Snow cover extent in a tile of MODIS Mod 10A2 data (1200 km by 1200 km tiles of 500 m resolution).



Maximum snows cover extent in the Basin (1st Oct. 2012 to 8th Oct. 2012).

Study is in progress

Objectives vis a vis Achievements:

Objectives	Achivements
Literature Review & Data Downloading	Literature review has been completed. MODIS Mod 10A2 data from 2000 to 2016 for basin has been down loaded from National Snow and Ice Data Center (NSIDC). Data analysis is in progress.
Preparation of basin maps etc.	Basin maps etc. have been prepared from the Aster DEM with the help of ArcGIS tool

Recommendations of Working Group/TAC/GB:

Adopters of the results of the study and their feedback:
State Disaster Management Authority
Hydropower Companies in the downstream

List of deliverables:
Snow depletion curves for Upper Yamnotri Basin
Snow cover area matrix
Extent of maximum and minimum snow cover

Major items of equipment procured: Nil

Lab facilities during the study: NIH

Data generated in the study: Nil

Study Benefits/Impact: Snow depletion curves are necessary for melt runoff studies and works as input in modeling of melt runoff. The results of the study will work as input for forecasting the stream flow of the Yamuna River.

Specific linkages with Institutions/beneficiaries:
Linkage will be established with Hydropower Companies in the downstream and State Disaster Management Authority.

Shortcomings/Difficulties: As the study area elevation range varies from 461 to 6284 meter above sea level. Snow free scenes for all the dates are difficult to get.

Future Plan: The results of the study will be used by Hydropower Companies in the downstream and for water management issues related to Yamuna River.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/17-18

Title of the study: Development and regionalization of unit hydrograph for runoff modeling on Indian catchments(Research/application Study)

Study group : Sushil K. Singh**,** Scientist ‘F’

Date of start of study : 01 April 2017

Duration and scheduleddate of completion: 01 Year; 31 March 2018

Type of study: Internal

Objectives of study:

1. To develop and systematically compile the new unit-hydrograph model for runoff modelling by the author. This is in view to analyze the parameters of the models for possible regionalization.
2. To develop the regionalization approach for the model-parameters to enable possible applicability to ungauged catchments.

Statement of problem and brief methodology:

Event based rainfall runoff modeling has been a concern for practitioners, field engineers, and academicians. It is useful for event-based runoff modelling for a catchment in general and modelling of floods in particular.

Possible regression approach and fitting of equation to data and possible development of useful empirical equations on the data collected at NIH under various projects under such theme.

Achievement/progress:

The development of the new model for runoff modeling is complete and the development of method/procedure for the estimation of its parameters is in progress. The ready availability of data collected under various NIH projects on such theme will do away with the possible-hindrances in achieving the objectives of the study and path the proper way and modus operandi based on novel analysis of data even in case of extended such projects being undertaken by NIH with adequate justification and utilization of financial support involved therein; it is submitted to the Working-group to arrange resolving for the ready availability of data for research within NIH. In view of this a possible extension of time up to March 2019 is sought and submitted for.

Adopters of the results of study and their feedback:

Practitioners, field engineers, and academic personnel.

Deliverables:

Research report detailing the developed equation and research papers in International Journals with illustrative of ease in application to ungauged catchments.

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

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

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

Period of the study: April 2017 to March 2021

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.

Statement of the problem:

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

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

Methodology:

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

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

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

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

Deliverables

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

Progress:

Relevant literature for this basin such as Flood Estimation Reports, PMP atlases and similar studies in other basins, has been collected. Various hydro-meteorological data at various gauging sites in this basin is being collected from various agencies. Compilation and statistical analysis of the collected data is under progress.

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

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

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

Date of Start: April 2017

Scheduled date of Completion: March 2020

Type of study: Internal.

Location map

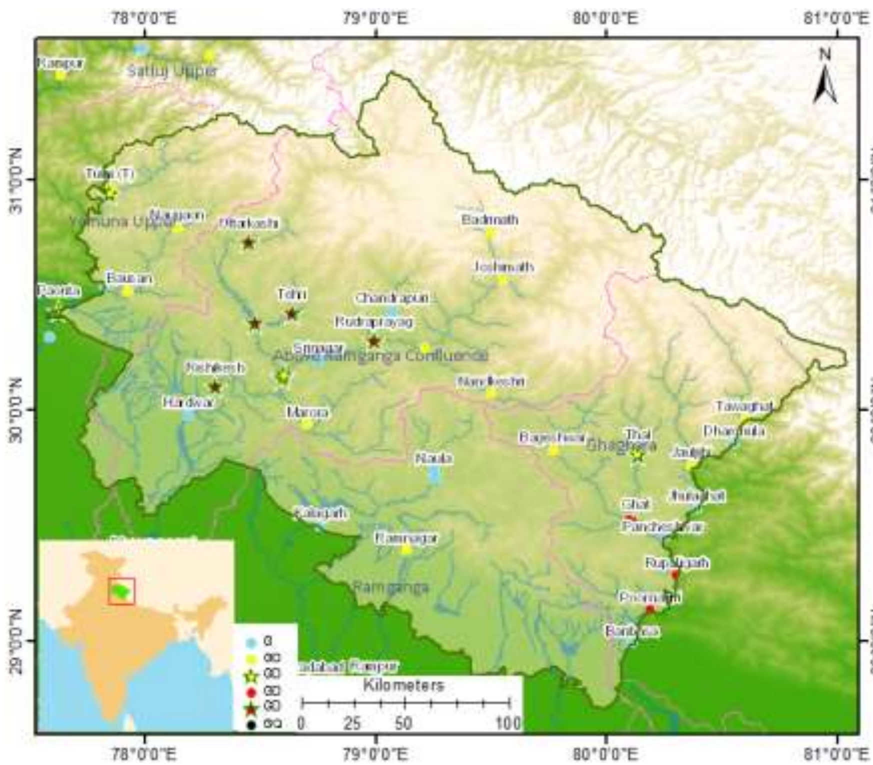


Fig. 1: Location map of study area.

Study objectives:

a) Development of at-site flood frequency relationships using L-moments.
b) Development of at-site and regional flood frequency relationships using L-moments.
c) Development of regional relationships between mean annual peak floods and physiographic and climatic characteristics.
d) Development of at-site rainfall frequency relationships using L-moments using point rainfall data.
e) Development of at-site and regional rainfall frequency relationships using L-moments using gridded rainfall data of various sources.
f) Development of regional relationships for the Nash and Clark IUH model parameters.

g) Estimation of floods of various return periods for Ganga basin in Uttarakhand.

Statement of the problem:

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

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

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

Approved action plan and timeline

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

Role of team members

S. N.	Role / Action	Member/(s)
1	Collection of hydro meteorological data, satellite images, thematic maps etc.	JPP, RK, SK, TRS
2	Compilation, statistical analysis of rainfall and river discharge	JPP, SK , TRS
3	At-site frequency analysis for point rainfall and gridded rainfall data	JPP, RK
4	Regional frequency analysis for point rainfall and gridded rainfall data	RK, JPP, SK
5	Preparation of isopluvials maps for various return periods.	JPP, RK ,PM
6	At-site and regional flood frequency analysis for gauged catchments	RK,JPP,SK
7	Estimation of catchment characteristics and parameters of UH	PM, JPP, SK
8	Development of regional relationships for peak floods with catchment characteristics.	RK ,JPP,SK
9	Report	JPP, RK, PM, SK

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

Brief Methodology:

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

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

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

Results achieved with progress/present status:

Daily station rainfall data of about 30 raingauge stations are collected from IMD along with gridded rainfall data from 1901 to 2013. These datasets are being analysed for various statistical properties and annual maximum rainfall series are extracted for rainfall frequency analysis. The APHRODITE monsoon

Asia Precipitation grided daily data from 1951 to 2007 are also downloaded. The peak annual maximum flood series data of ten gauging sites are collected from CWC (Figure 2). The box plot of annual peak flood at ten gauging sites is shown in Figure 3. At site flood frequency analysis is carried to estimated design floods of various return periods at these locations using L-moments approach. The estimated floods of 50 year and 100 year return period along with observed maximum discharge plotted against catchment area for three locations in Figure 4. Further, power equation in the form of $Q_T = a_T \times A^{b_T}$ is also fitted to estimate T-year design flood (Q_T) with catchment area of A.

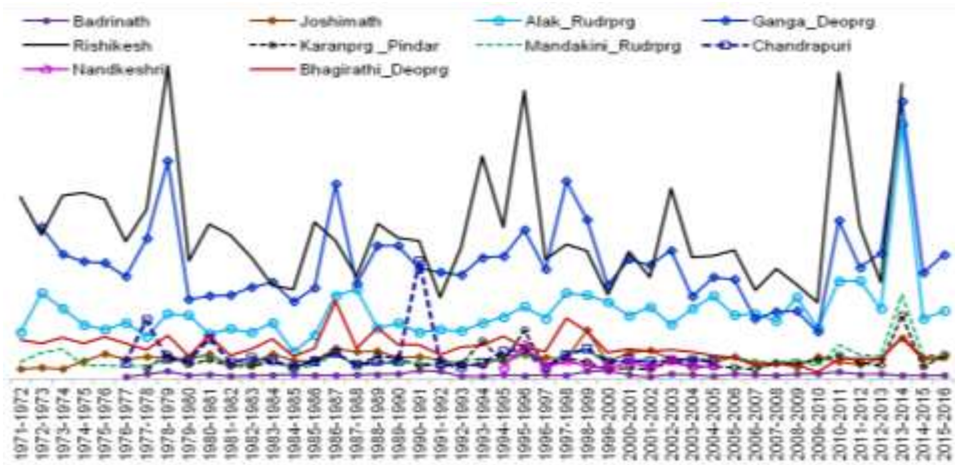


Fig. 2: Observed annual maximum flood series.

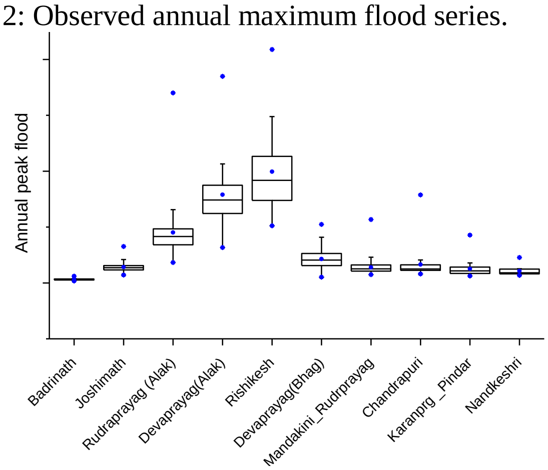


Fig. 3: Box plot of annual peak flood

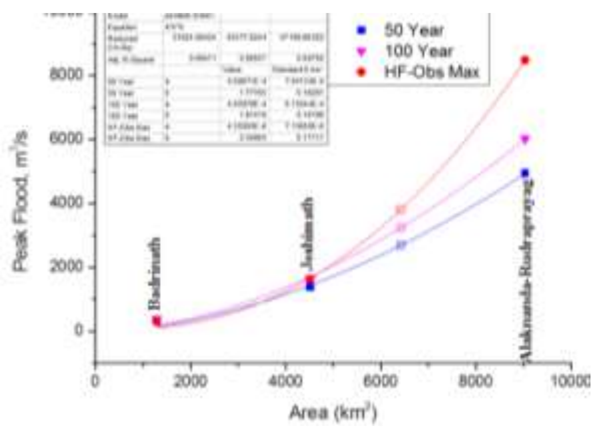


Fig. 4: Floods of various return periods

Action taken on comments of previous working group meeting:

There were no specific comments.

List of deliverables:

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

Data collected/generated:

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

Involvement of end users/beneficiaries:

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

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

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

Team members:
Dr. Archana Sarkar, Scientist-D (PI)
Dr. Surjeet Singh, Scientist-E,
Dr. T. Thomas, Scientist-D

Time frame:
18 months (Sept 1, 2017 to Feb 28, 2019)

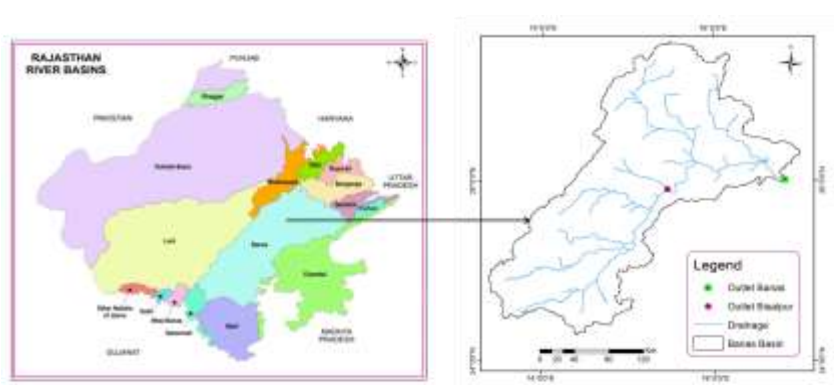
Funding:
International (ECMWF through SMHI, Sweden)
NIH funds: Euros 24,200.00

Environmental and societal issues:
1. Very high spatio-temporal variability in rainfall and shifting of monsoon season.
2. Very low water availability in the river basins.
3. Frequent droughts in almost all the river basins in Rajasthan.
4. Flood occurrences also in recent times in the tributaries of river Chambal.
5. Depleting groundwater table and deteriorating water quality.
6. Extreme temperatures and high evapotranspiration.

Large tract of land is saline and alkaline soil.

Objectives:
1. Assessment of the impacts of climate change on the water resources in the catchment and command area.
2. Assessment of the climate change impacts on the agriculture in the rainfed and irrigated areas in the basin.
3. Formulation of adaptation mechanisms to address these impacts on the water sector and agriculture sector.

Study Area:
Banas river basin in the Rajasthan State of India



Data to be Used:

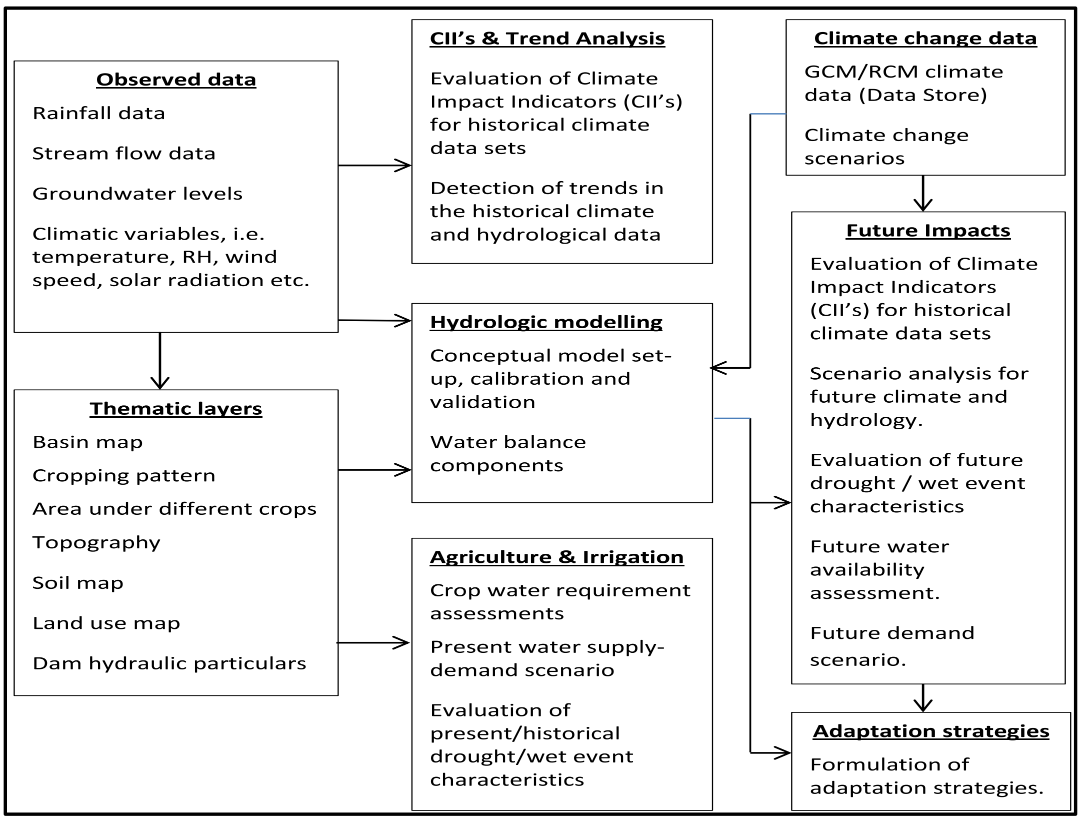
The Climate Impact Indictors (CII's) developed in this project shall be used to assess the impacts of climate change on the water resources and agriculture of the study area. Some of the well-established indicators pertaining to climate, viz., temperature, precipitation, surface and groundwater availability, drought (SPI) etc. shall also be applied.

Methodology:

The brief methodology shall cover the following work elements:

1. Reconnaissance survey and preparation of thematic layers.
2. Identification of significant trends in historical hydrometeorological and hydrological data.
3. Crop water requirement in the basin.
4. Evaluation of CII's for the historical hydro-meteorological and hydrological data.
5. Evaluation of the CII's based on the future hydro-meteorological data.
6. Evaluation of CII's based on future hydrology in the basin.
7. Evaluation of droughts using indicators (SPI).
8. Assessment of climate change on the overall agricultural scenario using CII's.
9. Formulation of climate change adaptation plan.

Schematic overview:



Detailed list of Tasks and time table, etc.

Time	Task	Lead	Team
Sep - Nov 2017	Reconnaissance survey (field visit) and preparation of thematic layers.	Dr. Archana Sarkar	Dr. Surjeet Singh Dr. T. Thomas (Proj. Staff to be hired)
Oct – Dec 2017	Identification of significant trends in historical hydrometeorological and hydrological data.	Dr. Archana Sarkar	Dr. Surjeet Singh Dr. T. Thomas (Proj. Staff to be hired)
Oct – Dec 2017	Crop water requirement in the basin and interaction with stakeholders in the basin.	Dr. Surjeet Singh	Dr. T. Thomas Dr. Archana Sarkar (Proj. Staff to be hired)
Oct – Dec 2017	Evaluation of CII's for the historical hydro-meteorological and hydrological data.	Dr. T. Thomas	Dr. Archana Sarkar Dr. Surjeet Singh (Proj. Staff to be hired)
Jan – May 2018	Evaluation of the CII's based on the future meteorological data.	Dr. T. Thomas	Dr. Surjeet Singh Dr. Archana Sarkar (Proj. Staff to be hired)
Jan – Aug 2018	Evaluation of CII's based on future hydrology in the basin.	Dr. Surjeet Singh	Dr. Archana Sarkar (Proj. Staff to be hired) Dr. T. Thomas
Aug2018 – Dec2018	Assessment of climate change on the overall agricultural scenario using CII's.	Dr. Surjeet Singh	Dr. T. Thomas Dr. Archana Sarkar (Proj. Staff to be hired)
Jun – Sep 2018	Evaluation of droughts using indicators (SPI) and interaction with relevant stakeholders (field visit)	Dr. T. Thomas	Dr. Surjeet Singh Dr. Archana Sarkar (Proj. Staff to be hired)
Aug2018 – Dec2018	Formulation of climate change adaptation plan.	Dr. Archana Sarkar	Dr. T. Thomas Dr. Surjeet Singh (Proj. Staff to be hired)
Jan –Feb 2019	Submission of Final Report	Dr. Archana Sarkar	Dr. Surjeet Singh Dr. T. Thomas (Proj. Staff to be hired)

Expected Results:
Assessment of climate change impacts on the water resources and agriculture in awater stressed basin, using the latest dataset and CII's provided by GLORIOUS C3S with recommendations for possible adaptation.

Expected Outcome/Impact:
The methodology adopted in the climate change impact assessments and development of an adaptation mechanism can be replicated to other basins in India.

Stakeholders:
1. Rajasthan Agriculture Department.
2. Department of Environment, Rajasthan.
3. Public Health Engineering Department, Rajasthan.
4. Water Resources Department, Rajasthan.

Science and Technology Department, Rajasthan

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

Title of the study: Water efficient irrigation by using SCADA system for medium irrigation project(MIP) Shahnehar

Project team: Name of PI: Dr. R.P. Pandey, Scientist 'G'.
Name of Co-PI: Er. JagdeeshPatra, Scientist 'C'
Dr. Rajesh Singh, Scientist 'C',
Sh N. K. Bhatnagar, Scientist 'B'

Type of study: PDS under NHP

Collaborating Institutions

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

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

Project Duration: 3-years

Date of start: December, 2017

Scheduled Date of Completion: December, 2020

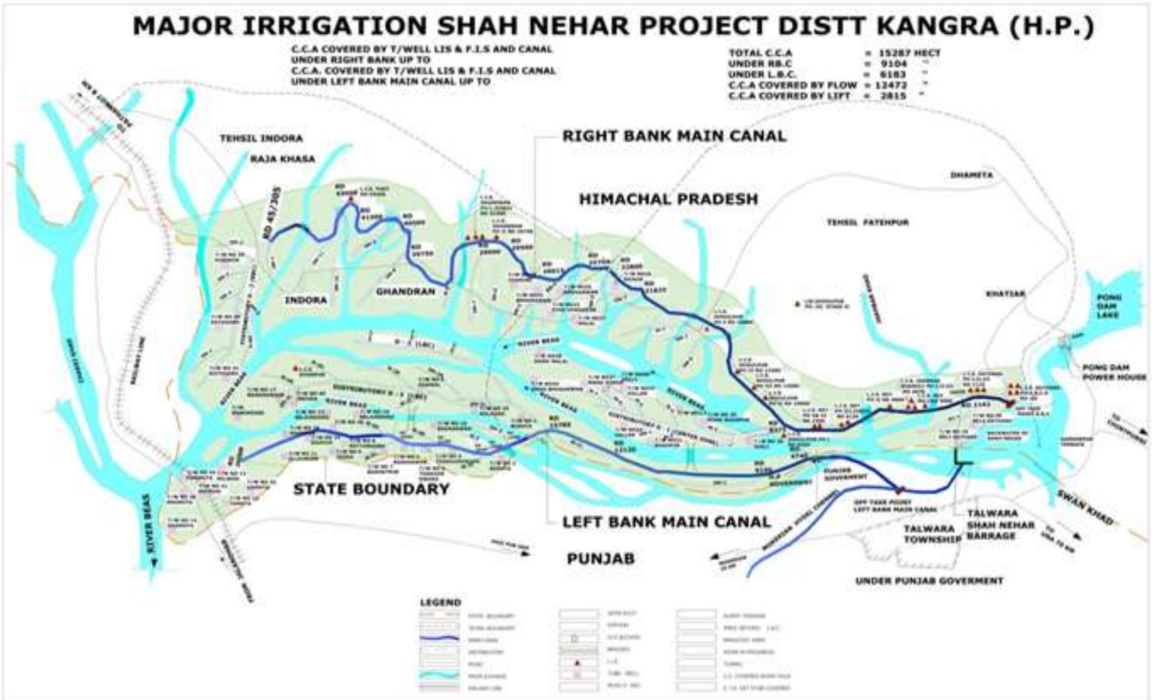
Objectives of the study:

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

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

Study Area :<u>ShahNehar Command Area, Himachal Pradesh</u>

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



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

Description of the Problem:

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

Progress of Work:

The team NIH Scientist visited study area in December to carryout reconnaissance survey of Shahnehar Project Command Area, Kangra, alongwith Himachal Pradesh I &PHE department officials. Detailed deliberations were held 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. The irrigation command site for SCADA implementation has been finalized.

1. The data requirement for the study has been worked out. The Himachal Pradesh I &PHE department has been requested to start data collection from various sources.
2. The experimental sited identified are as follows:
   i. Lift Irrigation Scheme (LIS) Sthana, Terrac Sub-Division—for SCADA experimentation.
   ii. Selected sites/field plots in distributary-1 (D-1) command area –Badukhar Sub-Division -- for experimentation-1 in middle reaches.

iii. Selected sites/field plots in distributary-2 (D-2) command area- for experimentation-2 in tail reaches.

3. Base maps for the study sites are under preparation.
4. Data collection is in progress

Deliverable:

1. Estimates of water availability at headwork's and irrigation water requirements for various crops a different growth stages & time period.
2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.
3. Identification of components of irrigation system needing intervention to enhance water use efficiency.

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

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

Title of the Project: Evaluation of Seasonal Extreme Rain Events across River Basins of India in 3D Global Temperature Change Scenario

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

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

Type of Study: Internal

Status: New Study

Duration: 3 years

Date of Start: 1 April 2018

Scheduled date of completion: 31st March 2021

Objectives:

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

Statement of the problem:

Heterogeneous changes in global tropospheric temperaturesover the last few decades have been observed to make spatiotemporalchanges in global rainfall distribution. Potential climate change and its impacts on rainfall distribution pose athreat to water resources throughout the world.The IntergovernmentalPanel on Climate Change (IPCC) concluded that climate change would have the following impacts onfreshwater resources: (i) by the middle of the twenty-first century, annual average river runoff and water availabilityare projected to increase by 10–40% at high latitudes and insome wet tropical areas and decrease by 10–30% in some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas; (ii) drought-affected or water-stressed areas will likely increase in extent; (iii)heavy precipitation events are very likely to increase in frequency and intensity thus augmenting flood risks; and (iv)water supplies stored in glaciers and snow cover are projected to decline during the course of the twenty-first century, reducingwater availability in the regions supplied by meltwaterfrom major mountain ranges, where more than one-sixth ofthe world's population currently lives.As reported by the IPCC, theIndian subcontinent will be adversely affected by enhancedclimate variation, rising temperature, and substantial reductionin summer rainfall with water stress in some areas by 2020. Annual, seasonal, and monthly rainfallacross India shows strong spatiotemporal variation and largedepartures from normal. Many of the studies show anoverall decreasing trend in monsoonal rainfall over a majorpart of the country. Earlier we have studied climatological and fluctuation features of parametersof the hydrological wet season in 11 major and 36 minorriver basins in India. We did not find any significant longtermtrends in wet season parameters for any basin, but noticed a declining tendency in wet season rainfall insome major basins of the Central India.

Extreme monsoon rains cause severe flooding and disasters across India every year in some parts or other, surprisingly even during large-scale drought years also. So there is pressing need in hydrology, to better understand the ongoing changes in hydro-meteorological extremes in order to comprehend the impact of climate change on water resources in different parts of the country. Recent understanding through global climate models predicts that, the hydrological cycle will accelerate as climate warms, and leads to changes in patterns of extreme floods and droughts. After general acceptance of global warming a reality, extreme rainfall studies have been undertaken mostly to generate information useful for assessment of hydro-meteorological disasters, as well as to respond to important issues raised by world scientific community. Numerous studies have reported the rising frequency in short period extremes especially in Central India and attributed to the significant increase in synoptic activities, convective instabilities' etc. We have studied variations in spatio-temporal extreme rainfall fields over the Indian region. It is shown that small-scale, short-duration EREs are embedded in large-scale, long-period intense wet spells, and rainwater generated during the main monsoon wet period is highly correlated with the Asia-Pacific monsoon intensity. Few case studies of extreme rain events carried out by us, (e.g. heaviest rain storm over peninsular India during 23-28 July 2005 and isolated extreme rain event over Kedarnath on 16-17 June 2013) 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. Types of weather systems and general and monsoonal circulation associated with the occurrence of extreme rain events in different parts of the country could be different. So It is important to study how the characteristics parameters of any weather system (location, shape. Size and intensity etc.) could be different in relation to asymmetric global temperature change.

Keeping in mind recent changes in global surface temperature,monsoon circulation pattern, and occurrence of EREs, theaim of the present study is to understand the nature ofthe variability of basin-scale rainfall across the India usingthe averaged longest instrumental basin scale rainfall dataset (1813-2015) and to determine thecausal factors of the dominant modes of its variability.

Dataset used:

1. The longest instrumental area-averaged monthly rainfall series for 11 major river basins and 36 minor river basins (183-2015)
2. Gridded daily rainfall data from India Meteorological Department from 1951-2015
3. Atmospheric variables (Temperature, Geopotential ht, mslp, ppw etc.) from 'Climate System Forecasting (CFSR) reanalysis dataset.

Methodology:

The purpose of the present study is to use the best available meteorological information for the hydrological applications. The longest instrumental monthly basin scale rainfall data available from 1813 to 2000 will be updated using daily gridded rainfall product up to 2015. The climatological characteristics, fluctuation features and periodical cycles of annual, seasonal and monthly rainfall of different river basins will be studied and extrapolated using suitable statistical technique in order to their use for better water management purpose.

Large-scale extreme wet spells and different types of extreme rain events concerning rainfall amount, duration and rainfall intensity over four homogeneous rainfall zones of India will be identified and studied in order to understand the recent year changes in their characteristic parameters.

Changes in global atmospheric parameters (e.g. temperature, geopotential height, mslp, ppw and wind etc.) from 1000hPa to 100hPa will be studied in order to understand their role in recent year changes in rainfall pattern across the country.

Deliverables:

1. Longest instrumental area-averaged monthly, seasonal and annual rainfall series for 11 major basins and 36 minor basins from (1813-2015).
2. Recent year changes in annual seasonal and monthly rainfall of river basins and different extreme rain events in four homogeneous subzones of India.
3. Extrapolated seasonal rainfall series of major river basins
4. Potential causes of occurrences of extreme rain events in differ parts of the country
5.

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

Cost estimates:

S. No.	Head	Amount (Rs.)
1	Remuneration/Emoluments for Manpower (Appr.)	12,00,000
2	Travelling Expenditure	3,00,000
4	Consumables/contingency/Misc. expenditure	1,00,000
5	Capacity building/Technology transfer	3,00,000
6	Dataset purchase/software/Hardware	2,00,000
	Total	21,00,000

a. Justification for manpower

The project work involves a vigorous data management of river basins rainfall dataset and global meteorological dataset. A senior research fellow having some experience of statistical analysis and meteorological background will be required in order to complete the project to its full extent.

b. Justification for traveling expenditure

PI, Co-PI and Scientific staffs are required to travel to collect actual hourly rainfall and other meteorological dataset across India. Fund also will be utilize to attend conferences in India to present project work.

c. Justification for contingency

Fundswill be required in order to purchase external hard drives in order to store the dataset collected and generated through project work. Some funds will also be used for the purchase of necessary furniture, stationary items, reference books, and preparation of research reports and training material.

d. Justification for Capacity building/Technology transfer

The results and knowledge gained from the project will be disseminated/exchanged with stakeholders and government officials and research students by organizing trainings/Workshops (2 nos) in the field of hydrometeorology and weather analysis.

e. Justification for Dataset purchase/software

It will be required to purchase hourly rainfall data and metrological parameters over selected stations across India in order to study extreme rain events in details. Funds will also be used to purchase necessary statistical and graphical analysis software as per requirement.

10. Work Schedule:

S.N.	Work Element	1st Year				2nd Year				3rd Year			
10	Updation of longest rainfall series for 11 major and 36 minor basins												
11	Statistical analysis of rainfall data												
12	Time-series modelling												
13	Identification of extreme rain events												
14	Study of Global atmospheric changes												
15	Workshop/Training												
16	Report preparation												

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

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

WORK PROGRAMME FOR THE YEAR 2017-2018

SN	Title	Study Team	Duration	Funding (Rs. in Lakhs)
Ongoing Internal Studies				
1.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel Sharad K. Jain Deepa Chalisgaonkar P. K. Mishra	3 years (04/13-12/17) Up to 06/2018	NIH (16)
2.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Thayyen S. P. Rai Sanjay K Jain Sudhir Kumar	3 years (04/14-03/18) Up to 09/2018	NIH (48)
3.	Hydrologic Modelling of a part of Satluj Basin using SWAT Model	P. K. Agarwal Sharad K. Jain M. K. Goel Sanjay K. Jain M. K. Nema	2 -3/4 years (06/14-03/18)	NIH (23)
4.	Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra	D. S. Rathore M. K. Goel R.P. Pandey Sanjay Kumar Surjeet Singh	2 years (07/14-12/17) Up to 03/2018	NIH (34)
5.	Modeling of Narmada basin by using the GWAVA model	T. Thomas (RC-Bhopal) P. K. Mishra M. K. Nema Sanjay K. Jain Sharad K. Jain P. K. Agarwal	2.25 years (12/14-03/18)	NIH
6.	Runoff modeling of Shyok River, Karakorum Range	Renoj J.Thayyen Sanjay K.Jain	3 years (12/14-12/17) Up to 09/2018	NIH (38)
7.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain Sanjay K. Jain Renoj J.Thayyen P. K. Mishra P. K. Agarwal	5 Years (12/14-12/19)	NIH+
8.	Development of Ganga Information Portal	Deepa Chalisgaonkar Sharad K. Jain D. S. Rathore Sanjay K. Jain Sudhir Kumar P. K. Mishra P. K. Agarwal M. K. Nema	3 years (04/15-03/18)	MoWR, RD & GR (65.55)

Ongoing Sponsored Studies				
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen (PI) Farooq Azam P.G. Jose A.P. Dimri	3 years (03/16-02/19)	SERB (65.14)
2.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel M. Arora A. K. Lohani D. S. Rathore Deepa Chalisgaonkar A. R. S. Kumar Surjeet Singh P. Mani A. Sarkar M. K. Nema P. K. Mishra	5 years (01/16-12/20)	DST (52.15)
3.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore Deepa Chalisgaonkar V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
4.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain A. K. Lohani Sudhir Kumar P. Thakur (IIRS)	5 years (01/16-12/20)	DST (36.79)
5.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	R. J.Thayyen Sanjay K. Jain Sharad K. Jain S. P. Rai P. K. Mishra M. Arora AP Dimri (JNU)	5 years (01/16-12/20)	DST 51.43 (NIH) + 28.29 (JNU)
6.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	Sharad K. Jain Renoj J. Thayyen Sanjay K. Jain S. P. Rai Surjeet Sing M. K. Nema P. K. Mishra P. K. Agarwal AP Dimri (JNU)	5 years (01/16-12/20)	DST (54.07)
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra M. K. Nema R. J. Thayyen P. K. Sachan	5 years (01/16-12/20)	DST (90.99)
8.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western	R. J.Thayyen P. K. Mishra	3 years (03/17-03/19)	NMHS-MoEF (58.76)

	Himalaya			
9.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M. K. Nema Renoj J. Theyyan Sharad K. Jain Sanjay K. Jain P. K. Mishra A. P. Dimri	3 years (2016-19)	MOES (98.00)
10.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)	Sanjay K. Jain (PI, NIH) Sharad K. Jain CSP Ojha (PI, IITR)	3 years (2016-2019)	MOES-NERC, Newton-Bhabha project (11.59 Lakh)
11.	Design and development of generic Decision Support System-Hydrology platform for Neeranchal Project	D. S. Rathore Deepa Chalisgaonkar Jyoti Patil	1 year (04/17-03/19)	DoLR (NNWP)
12.	Modeling of Gangotri Glacier melt runoff and simulation of stream flow variation under different climate scenarios	M. Arora	03/2018	DST
OTHER SCIENTIFIC ENGAGEMENTS				
1.	Strategic basin planning for Ganga River basin in India	Sharad K. Jain M. K. Goel L. N. Thakural	-	MoWR, RD & GR
2.	Water resources status and availability of north west Himalayas	Sanjay K. Jain, Manohar Arora and S P Rai	-	IIRS, Dehradun
3.	Water Accounting Plus (WA+)	P. K. Singh P. K. Mishra	-	MoWR, RD & GR

WORK PROGRAMME FOR THE YEAR 2018-2019

SN	Title	Study Team	Duration	Funding (Rs. in Lakhs)
Completed Sponsored/ Internal Studies				
1.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel Sharad K. Jain Deepa Chalisgaonkar P. K. Mishra	3 years (04/13-12/17)	NIH (16)
2.	Hydrologic Modelling of a part of Satluj Basin using SWAT Model	P. K. Agarwal Sharad K. Jain M. K. Goel Sanjay K. Jain M. K. Nema	2 -3/4 years (06/14-03/18)	NIH (23)
3.	Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra	D. S. Rathore M. K. Goel R.P. Pandey Sanjay Kumar Surjeet Singh	2 years (07/14-12/17)	NIH (34)
4.	Modeling of Narmada basin by using the GWAVA model	T. Thomas (RC-Bhopal) P. K. Mishra M. K. Nema Sanjay K. Jain Sharad K. Jain P. K. Agarwal	2.25 years (12/14-03/18)	NIH
5.	Development of Ganga Information Portal	Deepa Chalisgaonkar Sharad K. Jain D. S. Rathore Sanjay K. Jain Sudhir Kumar P. K. Mishra P. K. Agarwal M. K. Nema	3 years (04/15-03/18)	MoWR, RD & GR (65.55)
6.	Modeling of Gangotri Glacier melt runoff and simulation of stream flow variation under different climate scenarios	M. Arora	03/2018	DST
Ongoing Internal Studies				
1.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Thayyen S. P. Rai Sanjay K. Jain Sudhir Kumar	3 years (04/14-03/18) Up to 09/2018	NIH (48)
2.	Runoff modeling of Shyok River, Karakorum Range	Renoj J.Thayyen Sanjay K.Jain	3 years (12/14-12/17) Up to 09/2018	NIH (38)
3.	Hydrological process and characterization of Lesser Himalayan	M. K. Nema Sharad K. Jain	5 years (12/14-	NIH+

	Catchments	Sanjay K. Jain Renoj J.Thayyen P. K. Mishra P. K. Agarwal	12/19)	
Ongoing Sponsored Studies				
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen Farooq Azam P.G. Jose A.P. Dimri	3 years (03/16-02/19)	SERB (65.14)
2.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel M. Arora A. K. Lohani D. S. Rathore D. Chalisgaonkar A. R. S. Kumar Surjeet Singh P. Mani A. Sarkar M. K. Nema P. K. Mishra	5 years (01/16-12/20)	DST (52.15)
3.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
4.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain A. K. Lohani Sudhir Kumar P. Thakur (IIRS)	5 years (01/16-12/20)	DST (36.79)
5.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	Renoj J.Thayyen Sanjay K. Jain Sharad K. Jain S. P. Rai P. K. Mishra M. Arora AP Dimri (JNU)	5 years (01/16-12/20)	DST 51.43 (NIH) + 28.29 (JNU)
6.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	Sharad K. Jain Renoj J.Thayyen Sanjay K. Jain S. P. Rai Surjeet Sing M. K. Nema P. K. Mishra P. K. Agarwal AP Dimri (JNU)	5 years (01/16-12/20)	DST (54.07)
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra M. K. Nema R. J. Thayyen P. K. Sachan	5 years (01/16-12/20)	DST (90.99)

8.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya	Renoj J.Thayyen P. K. Mishra	3 years (03/17-03/19)	NMHS-MoEF (58.76 lakh)
9.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema Renoj Thayyen Sharad K. Jain Sanjay K. Jain P. K. Mishra AP Dimri (JNU)	3 years (2016-19)	MOES (Rs. 98 Lakh)
10.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)	Sanjay K. Jain (PI) Sharad K. Jain CSP Ojha (PI, IITR)	3 years (2016-2019)	MOES-NERC, Newton-Bhabha project (11.59 Lakh)
11.	Design and development of generic Decision Support System-Hydrology platform for Neeranchal Project	D. S. Rathore Deepa Chalisgaonkar Jyoti Patil	1 year (04/17-03/19)	DoLR (NNWP)
New Internal Study				
1.	Development of window based software for hydrological data processing and Unit Hydrograph Analysis	Deepa Chalisgaonkar A. K. Lohani M.K. Goel	1 year 4/18-3/19	NIH
New Sponsored Studies				
1.	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
2.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years 2018-2021	NIH/ DST
3.	Water availability analysis of Subarnarekha basin	M. K. Goel D. S. Rathore P. K. Singh P. K. Mishra	1 year 10/17-09/18	MOWR, RD & GR (10.45)
OTHER SCIENTIFIC ENGAGEMENTS				
1.	Strategic basin planning for Ganga River basin in India	Sharad K. Jain M. K. Goel	-	MoWR, RD & GR
2.	Water resources status and availability of north west Himalayas	Sanjay K. Jain	-	IIRS
3.	Water Accounting Plus (WA+)	P. K. Singh P. K. Mishra	-	MoWR, RD & GR

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/01

1. **Thrust Area:** Integrated Water Resources Development & Management
2. **Project team:**
   a. Project Investigator: Dr. M. K. Goel, Sc. "G"
   b. Project Co-Investigator(s): Dr. Sharad K. Jain, Sc. "G"
   Smt. D. Chalisgaonkar, Sc. "F"
   Dr. P. K. Mishra, Sc. "C"
3. **Title of the Project** NIH_Basin – A WINDOWS based model for water resource assessment in a river basin
4. **Objectives**

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

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

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

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

6. **Methodology**

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

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

7. Present Progress:

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

Most of these modification have been made in the computer code, being developed in FORTRAN language. The finalization of the computer program is in progress. Subsequently, the WINDOWS based forms for database preparation would be developed. It is expected that the study report along with the model would be completed by June, 2018.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/02

1. **Thrust Area** : Himalayan Cryosphere and Climate Change
2. **Project team** : Dr. R.J. Thayyen, Dr. S.P. Rai, Dr. Sanjay Jain, Dr. Sudhir Kumar
3. **Title of the project** : Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh.
4. **Objective**
   1. To improve the understanding of the climate forcing on cold-arid cryospheric system and hydrology.
   2. To improve the understanding of the melt water generation process and the role of permafrost.
   3. To study the temporal variations in isotopic characteristics of winter base flow and summer flow of the perennial reach and its cryospheric linkages.

5. **Present state of the art**

Himalayan and trans- Himalayan regions of the country have many hydrological regimes. Role of the Himalayan cryospheric systems to the downstream river flow varies across these hydrological regimes. However, lack of data and research in these areas limit our understanding of these systems and thereby our ability to manage these system under the changing climate. Cold-arid cryospheric system of the Ladakh is unique hydrological regime of the Himalayan system. The first phase of the project entitled "Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, Ladakh Range."has revealed many unknown facets of the hydrology of the cold-arid cryospheric system such as catchment specific runoff of nival/glacier system, very high temperature lapse rate under cold-arid climate, Low contribution of glacier melt and significant contribution from frozen ground etc. While the earlier project has concentrated on the high altitude Nival/glacier system with catchment outlet at 4700 m a.s.l., the present project (Phase-II) has aimed to expand the research preview to the foothill zones of the mountain to achieve a more comprehensive understanding of the cold-arid system hydrological processes with a view to assist people in managing these scarce resources.

6. **Methodology**

a) Monitoring of weather parameters by AWS at 3500 m a.s.l., 4700 m a.s.l. and 5600 m a.s.l. for studying the orographic forcing
b) Monitoring discharge and Electrical conductivity at 4700 m a.s.l & 3500 m a.s.l.
c) Measuring ground temperature for permafrost studies
d) Geophysical investigation of potential permafrost zones
e) Isotope studies of stream discharge at 4700 m a.s.l. and 3500 m a.s.l.
f) Runoff modeling by SNOWMOD by incorporating the new SELR concept

7. **Research Outcome from the Project:** The project is aimed at quantifying various hydrological components in the catchment and its seasonal responses. Better understanding of the lean season winter outflow from the groundwater system is intended to bridge the critical knowledge gap of the mountain groundwater resources and its linkages with the surface water. Understanding of the orographic processes and mountain climate at the nival/ glacier systems to decipher the climate change impact on the cold-arid cryospheric system better.

8. **Cost estimate:**

a. Total cost of the project: 48 lakhs

b. Source of funding: NIH

c. Sub Head-wise abstract of the cost

S. No.	Sub-head		Amount (in Rupees)
	Salary	Sr. Project Officer	800000
2.	Travelling Expenditure		500000
3.	Infrastructure / Equipment / Data		2500000
4.	Experimental charges		500000
5.	Misc. expenditure		500000
	Grand Total:		48,00,000

9. Work Schedule

S.	**Work Element**	**First Year**				**Second Year**				**Third Year**			
		Q1	**Q**	**Q**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1.	Monitoring weather												
2.	Monitoring Q												
3.	Permafrost temp.												
4.	Geophysics-permafrost												
5.	Isotope studies												

10. Analysis and results

Discharge and electrical conductivity measurements at 4700 m a.s.l. were continued during the summer period (May to September 2017) as well as monitoring of weather at 3700 and 4700 m a.s.l.. Data retrieved from 25 ground temperature sensors installed at 09 plots in the catchment from 4700 to 5600 m a.s.l. in September 2017, revealed significant permafrost characteristics of ground temperature in its seasonal progression for the first time in Indian Himalaya. Snow cover duration information across the catchment is also studied using ground temperature data. The surface energy balance (SEB) approach combined with one dimensional heat conduction model was used to estimate the energy balance components and ground temperatures at 4700m and 5600m elevations for the period September 2015 to August 2016. Point surface energy balance was solved to estimate the surface temperature and used as upper boundary condition for thermal profile calculations. For the study period at 4700m a.s.l elevation, the net radiation component was dominant (76%) followed by sensible (14%) and latent heat fluxes (9%). The ground heat flux is limited to 1% of the total flux. The results of estimated soil temperature show a good agreement with the observed short duration soil temperature data available at a depth of 0.01m with an r^2 value of 0.93 and RMSE of 1.7 °C. The simulated bi-monthly thermal profile at 4700 m a.s.l. shows that the maximum winter time freezing up to the depth of 3.5m over a perennially unfrozen deeper strata suggesting little chance of permafrost at this site. Seasonal freezing initiated during September/October and peaked during March/April, which further undergone thawing during May/June. At 5600 m a.s.l., frozen strata extend up to 30 m or more with an active layer of 0.5 m during the study period. The active thawing recorded in the month of July and August. The mean annual air temperature (MAAT) at AWS4700 and AWS5600 sites was -2.5 and -9.2 °C respectively. This study provided the first insight on the seasonal freeze-thaw progression at two high elevation sites in the Himalayan region for the first time and indicated the elevation range of permafrost areas in the catchment.

For the remaining period of the study, the seasonal ground temperature progression to be linked with discharge and electrical conductivity and resultant catchment hydrology and the role ground ice melt will be studied.

<u>**ONGOING STUDIES**</u>

<u>**INTERNAL RESEARCH PROJECT: NIH/WRS/2016/03**</u>

1. Thrust Area under XII five year plan: Integrated water resources management/ watershed hydrology

2. Project team:

a. Project Investigator: Shri P. K. Agarwal, Sc C

b. Project Co-Investigator(s): Dr. Sanjay K. Jain, Sc G
Dr. Sharad K. Jain, Sc G
Dr. M. K. Goel, Sc G
Shri M. K. Nema, Sc C

3. Title of the Project: Hydrological modeling of a part of Satluj basin using SWAT Model

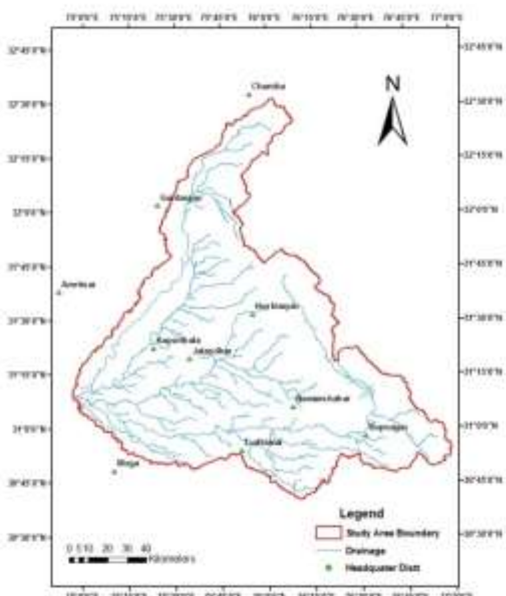
4. Objectives:

i. To develop the database of a part of Satluj river basin (between Ropar D/s of Bhakra dam to Harike) and

ii. To carry out hydrological modeling of the basin using ArcSWAT model to find out water balance components, e.g. actual evapo-transpiration etc.

5. Methodology

Study Area selected Satluj river basin (between Ropar D/s of Bhakra dam to Harike) as given figure:



In the present study, the following methodology will be adopted:

- Data base preparation in ArcGIS (DEM, Land use, soil map)
- Collection of meteorological data (rainfall, temperature, wind, solar radiation, humidity)
- Setup, calibration and validation of SWAT model
- To understand the effect of land use & other changes on stream flows.

6. Research Outcome from the Project

Water balance components (runoff, evaporation, base flow, etc.) for the basin.

7. Cost Estimate:

a. Total cost of the Project: Rs. 23.00 lakhs

b. Sources of Funding: NIH

c. Sub head wise Abstract of Cost

S N	**Sub Head**	**Amount (in Rupees)**
1.	Salary	Rs. 15,00,000.00
2.	Travelling Expenditure	Rs. 3,00,000.00
3.	Infrastructure/Equipment/Data	Rs. 3,00,000.00
4.	Experimental Charges	-
5.	Misc. Expenditure	Rs. 2,00,000.00
	Total	Rs. 23,00,000.00

8. Quarterly Break up of cost estimate for each year

Year: 2015-16

Sl. No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	Salary	150000.00	150000.00	150000.00	150000.00
2.	Travelling expenditure	40000.00	40000.00	40000.00	40000.00
3.	Infrastructure/Equipment	40000.00	40000.00	40000.00	40000.00
4.	Experimental charges	NIL	NIL	NIL	NIL
5.	Misc. expenditure	20000.00	20000.00	20000.00	20000.00
	Sub- Total:	250000.00	250000.00	250000.00	250000.00
	Grand Total	Rs. 10,00,000.00			

9. Work Schedule

a. Date of commencement of work June 2014

b. Duration of Work 2-3/4 Years

c. Stage of work and Milestone

SN	**Work Element**	**First Year (2014-15)**			**Second Year (2015-16)**				**Third Year (2016-17)**			
		Jun-Sep	**Oct-Dec**	**Jan-mar**	**April-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jen**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**
1	**Literature Review & Data Collection**											
2	**Development of data base for a river basin for SWAT model**											
3	**Application of SWAT model**											
4	**Analysis of Results**											
5	**Preparation of Report**											

10. Progress made

The outflow at Bhakra and Pong dam is available and the discharge data of Harike was obtained. After Nangal dam, flow is being diverted through two canals namely Anandpur Saheb and Nangal channel. The diverted flow from Nangal dam could not be obtained. The simulation have been carried out using SWAT model. Because, divereted flow could not be obtained therefore simulated runoff at Harike does match well with the observed inflow at Harike. Interim report has been prepared.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/04

1. **Thrust Area under XII five year Plan**: Integrated Water Resources Development and Management

2. **Project team**:
   a. **Project Investigator**: D.S. Rathore, Sc F
   b. **Project Co-Investigator(s)**: M.K. Goel, Sc G
   R.P. Pandey, Sc G
   Sanjay Kumar, Sc E
   Surjeet Singh, Sc E

3. **Title of the Project**: Decision support system for water resources planning in Upper Bhima basin, Maharashtra

4. **Objectives**:
   a. Rainfall- runoff modeling and estimation of water availability in the basin
   b. Multi-reservoir operation in the basin for project complexes
   c. Drought prediction
   d. Water quality modeling in the basin
   e. Conjunctive use operation in command area
   f. Rainfall- runoff modeling and river basin simulation for climatic change scenarios

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

   A Decision Support System (Planning) has been developed under Hydrology Project - II for State and Central implementing agencies. The project has two components, namely DSS platform and modelling systems. For modelling system, MIKE HYDRO Basin model was chosen. This is a water allocation model which also has conceptual lumped rainfall- runoff model NAM in built for generation of long term runoff time series. The platform has GIS, spreadsheet, scenario, script, time series and dashboard (for web applications) managers. On the platform, data and model scenarios may be handled. The scenarios are run with available MIKE HYDRO Basin engine.

6. **Methodology**

   MIKE HYDRO Basin is being used and database for the Upper Bhima basin up to Ujjani dam developed in HP-II project will be transferred to the new system. Rainfall- runoff modelling will be done using NAM for finding different hydrological components at sub-basins scale. Rule curves would be developed for various project complexes and multi reservoir operation would be carried out to optimize the water use in the basin. Meteorological and hydrological drought indices would be computed using rainfall and hydrological data. Conjunctive use scenario in canal command areas will be run. River water quality modelling will be carried out. Web-interfaces through Dashboards would be developed for dissemination of input and results of simulation in DSS (Planning). Downscaling will be done for climatic scenario. Downscaled climate data will be utilized and model runs would be taken to find their impact on the water availability and allocation in the basin.

7. **Research outcome from the project**
   a. Water availability in various sub-basins in present and changed future climate.
   b. Reservoir operation rules for existing and future climatic scenarios: Model was set up for reservoir operation and optimization in Khadakwasla complex.

c. Meteorological and hydrological drought indices: Data preparation was done for computing meteorological drought indices.
d. Conjunctive use in canal command areas.
e. River water quality modeling in river reaches and impact of climate change: Water quality model was set up.
f. Interfaces for decision support.

8. Location map/ study area

Upper Bhima basin up to Ujjani in Maharashtra state

9. Approved action plan and time line

S. No.	Work Element	2014-15			2015-16			
		II	III	IV	I	II	III	IV
1	Data collection							
2	Rainfall- runoff modeling							
3	River basin modeling							
4	Drought indices							
5	conjunctive use							
6	River water quality modeling							
7	Interfaces for decision support							
8	Climatic change scenarios							
9	First Interim Report							
10	Final Report							

10. Recommendations / suggestions in previous WG

None

11. Progress made

Mike Hydro Basin was used to set up conjunctive use model in New Mutha Right Band Canal (NMRBC) command area. The command area is divided in to nine sub- commands along watersheds. Land use staistics for commands is computed from available data. Model was set up for one sub- command. Release was apportioned to the sub-command using crop area statistics. A higher groundwater storage capacity is assumed compared to net yearly recharge. Releases in the command is dependent on water availability in the reservoir system. In case of reduced releases, irigated area may shrink and supplemental groundwater irrigation may be done. In model setup, three users were created, namely NMRBC release, sub- command release and irrigation users. Irrigation user can extract water from the sub-command catchment

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/05

1. Thrust Area under XII five year plan: Hydrology for sustainability of water resources

2. Project team:

a. Project Investigator:

b. Project Co-Investigator(s): Dr. T. Thomas, Sc D
Dr. P K Mishra, Sc C
Er. Manish Nema, Sc C
Er. P.K. Agarwal, Sc C
Dr. Sanjay K. Jain, Sc G
Dr. Sharad K. Jain, Sc G

3. Title of the Project: Modelling of Narmada Basin Using GWAVA Model

4. Objectives:

A major goal of the proposed study is to do hydrologic modeling of the basin. The objectives of the proposed study are as follows:

- Collection and processing of historical data
- Future climate projections will be applied to see the changes in meteorological variables.
- Modelling of rainfall runoff.
- Impact of changes on stream flow in the basin.

5. Present state-of-art

Accurate water resources assessment and re-assessment is need of the hour in view of the altered water demand and utilization scenario world-wide. This requires robust hydrological model to accurately assess the water availability at present and in the future. Narmada basin is one of the highly regulated basins in India. Several water resources projects are being implemented, under construction and proposed in the basin. Since last few decades, urbanization and population growth has also driven additional water requirement in the basin. This requires revisiting water resources assessment in the Narmada basin.

6. Methodology

Study area: Narmada basin up to Hoshangabad including Tawa basin (D/s of confluence with Tawa)

GWAVA is a hydrological model which incorporates additional water resource components such as reservoirs, abstractions, and water transfers that modify water quantity and flow regime. It was developed with funding from DFID (UK Department for International Development). The model typically operates on 0.5 or 0.1 degree latitude-longitude grid. The choice of grid size is a compromise between that needed to represent spatial variability and the availability of suitable data. The model outputs include simulated monthly flows and a cell-by-cell comparison of water availability. GWAVA can be used to examine scenarios of change, both for climate and water demands.

Inputs for first tier GWAVA application

- Spatially and temporally explicit inputs
    - Rainfall, temperature (at least daily resolution)
    - Potential evapotranspiration or wind speed + relative humidity + solar radiation (at least daily resolution)

  - If the modelled area does not include some upstream areas: River discharges into the modelled area
- Spatially explicit inputs
  - Elevation or flow direction grid
  - Coverage by different irrigated crop types
  - Map of rivers and other water bodies
  - Soil texture and land cover
  - Lake, reservoir and wetland parameters (areal cover, maximum water volume, vertical shape, type of reservoir)
  - Urban and rural water demand per capita, Industrial water demand
  - Rural population and total population, Cattle, sheep and goat population
- Temporally explicit inputs
  - Gauged river discharge
- Parameters (constants)
  - Per capita water demand for sheep, goats, and cattle
  - Irrigation efficiency
  - % Leakage from urban and rural water supply systems
  - % return flow
  - Crop characteristics and growth stage durations for individual irrigated crop types, and the start and end of their growing season

Once the database data base of the study area(s) is collected and/or procured, model set up will be done. Then model will be calibrated and validated before going for sensitivity analysis.

7. Research Outcome from the Project

- Stream flow from the study area
- Water balance components (runoff, evaporation, lateral flow etc) for the sub-basin.

8. Work Schedule

a. Date of commencement of work — November 2014
b. Duration of Work — 2-3/4 Years
c. Stage of work and Milestone

1st. Interim report	2nd. Interim report	Report	Final report
April 2015	April 2016	March 2017	Extended upto March 2018

9. Progress during the current review period

The model runs performed earlier did not perform well as it was reporting very poor performance evaluation statistics during both calibration and validation. The effect of the evapotranspiration module on the overall results was assessed by running the independent climate program. Since the Thornthwaite method was used for the computation of ET, which computes ET on a monthly time step based on the mean temperature in the basin, all the daily ET values were same for the particular month under consideration. Moreover, there were few months depicting zero ET, which is not possible in this basin as there are no sub-zero temperatures. Therefore the code was improved upon for the Thornthwaite method and Hargreaves method was also included, which computes the daily ET based on the daily maximum, minimum and mean temperature in the basin. Therefore the grid-wise daily ET was computed which formed the input for the GWAVA model. The model runs with the Hargreaves ET module gave encouraging results. The land use map was prepared again based on the fine resolution (500 m) data from the USGS and converted into the four types of GWAVA land use format and saved as ASCII file for input to GWAVA model. The cropping pattern in the command area was considered the same as evaluated at NIH. The calibration runs were again carried out, which further improved the calibration results.

To capture the real picture of the water transfers from Narmada basin to other cities and basins, the transfers out of the basin was incorporated in the model viz., water transfer to the command area of Tawa basin which falls completely outside the study area; transfer of drinking water to Bhopal city from main river near Hoshangabad; and future transfer of water to Ganga basin through the right bank canal from Bargi dam. This further improved the calibration results to a good extent.The calibration and the validation of the model could be completed after several runs with fine tuning of the obtained calibrated parameters to obtain the best model performance criteria. The details of the performance of the model on a daily time scale are given in Table 1.
Table 1: Model performance during calibration and validation (daily runoff)

S. No.	Name of gauging site	NSE (calibration) (1990-2000)	NSE (validation) (2000-2010)
1.	Manot	0.74	0.69
2.	Mohgaon	0.50	0.57
3.	Patan	0.87	0.82
4.	Belkheri	0.65	0.50
5.	Hoshangabad	0.77	0.63

The climate change scenarios for the 17 GCM’s have been run and the changes in the flow metrics are being evaluated. The model runs with the various other scenarios of land use, dams and integrated scenarios will be run and the changes in the hydrology in the basin will be evaluated for the future time horizon from 2028-2060. The future climate change scenarios were finalised and the bias corrected future precipitation and maximum and minimum temperature data of 17 GCM’s prepared and the future stream flows have been generated at the various gauging sites in the basin. The developmental scenarios have also been considered which includes a) base line project scenario comprising of existing dams (D1); b) all upcoming dams being planned in the study area (D2); c) combination of existing dams and upcoming dams in the study area.

Similarly, alternate land use change scenarios have been conceptualised, which include present land use comprising of soyabean in kharrif season and wheat in rabi season; future land use comprising of a) soyabean in kharrif season and paddy in rabi season (L1); b) paddy in kharrif season and paddy in rabi season (L2); c) 1-km buffer on both sides of main Narmada river with plantations, which was carried out in the recent monsoons (L3); d) 5-km buffer (total) of plantations along the main river (L4); combination of both soyabean in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations (L5); e) combination of paddy in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations (L6); water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands (L7); combination of paddy in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations and water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands (L8); combination of both soyabean in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations and water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands (L9). The model runs have been completed for these land use scenarios also.

The integrated scenario runs comprising of 6 integrated scenarios, namely (I1): climate change scenarios + combination of paddy in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations and water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands + all upcoming dams being planned in the study area; (I2): climate change scenarios + combination of paddy in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations and water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands + base line project scenario comprising of existing dams.(I3): climate change scenarios + combination of both soyabean in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations + base line project scenario comprising of existing dams. (I4): climate change scenarios + combination of both soyabean in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations + all upcoming dams being planned in the study area. (I5): climate change scenarios + combination of both soyabean in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations + water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands + all upcoming dams being planned in the study area. (I6): climate change scenarios + combination of both soyabean in kharrif season and paddy in rabi season with 1-km buffer on both sides of main Narmada river with plantations + water transfer scenario of 185 MLD to Bhopal city; future transfer of water to Ganga basin through right bank canal as per the planned allocation for drinking, irrigation and industrial demands + base line project scenario comprising of existing dams + all upcoming dams being planned in the study area.

All the model runs have been completed and the future streamflow data is being analysed to derive the matrix depicting the standalone impacts of climate change, land use change, developmental aspects and also the integrated impacts. The report will be completed and submitted by March 2018. A one-day Training Workshop is being planned currently at Bhopal on 09th March 2018 to disseminate the findings and outcomes of this modelling exercise to the various stakeholders and policy makers.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/06

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

2. **Project Team:**
   Project Investigator: Dr. R.J Thayyen, Sci-D
   Project Co-Investigators: Dr. Sanjay Jain, Sci-G

3. **Title of the Project:** Runoff modelling of Shyok River, Karakorum Range

4. **Objectives:**
   1. To generate runoff data at Km 150 for BRO-HIMANK
   2. To develop a baseline runoff and meteorological data of Shyok basin
   3. Runoff modelling of Shyok River at KM 150 & Shyok village

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

Shyok Basin lie in the northern most part of our country sharing its boundary with China and Pakistan. The upper Indus basin has the largest glacier reserve in the Himalaya with 5211 glaciers and 29119 km^2 of glacier cover. Within the upper Indus region, the Shyok basin has the largest number of glaciers enumerated at 2454 covering a 10810km^2. Comparing to this, the Indian Himalayan region contributing to Ganga-Brahmaputra river system only have 1578 glaciers covering just 3787km^2 of glacier cover (Data Source Raina& Srivastava,2008 sourced from GSI glacier inventory 2009). However, glaciers and cryospheric system in this region is not received the due attention till date. Discharge of Shyok river is not monitored and its hydrological characteristics and resource potential is not known. The border roads organisation, HIMANK project is in urgent need of discharge data of Shyok river for strategic purpose and the present project is planned to fulfill this requirement for BRO.

Shyok river fed by the glaciers of Karakorum range. It is well accepted that the Karakorum glaciers are gaining mass in the recent past. Long –term monitoring of River Shyok will provide valuable information on river flow response of a glacier fed river under positive mass balance regime. Being a trans-boundary river this information will be very useful different national agencies. The automatic weather station proposed in the study will be the first comprehensive weather station in the region and will provide crucial input to the armed forces and data required for snowmelt runoff model. The ongoing study in the Ladakh range south of the Karakoram in the cold-arid system has shown that the glaciers are losing it mass. The proposed will be provide a interesting comparison between two contrasting glacier systems in the Himalaya.

Head water region of the Shyok river originating from the Remo glacier has couple of surging glaciers such as Chonh Kumdan, Kichik Kumdan and Aktash glacier. Under the mass gain these glaciers are potential to surge. The Kumdan floods during 1929 to 1932 due to bursting of a 16 km long lake formed by blocking of River Shyok by the surging Kumdan glacier was devastated the Shyok basin. Hence monitoring of Shyok river is necessary for civilian and defense perspective. Hence the proposed study is being taken up by the above objectives.

6. **Methodology**
   1. Monitoring of weather parameters and discharge by AWS at Km 150 (5600 m a.s.l.) for generating climate data for runoff modeling.
   2. Generation of snow cover depletion curves through melt season
   3. Runoff modeling by SNOWMOD and Win SRM at this two stations

7. **Research Outcome from the project:** Discharge & Meteorological data, Research papers and project reports and better understanding of the Cryospheric response of the Karakorum mountains.

8. **Cost Estimate**

Total cost of the project: Rs. 37.64 lakhs

b. Source of funding: NIH

c. Sub Headwise abstract of the cost

S. No.	Sub-head		Amount (in Lacs)
1.	Salary	Resource person @Rs.22,000/- pm	2.64
2.	Travelling & Fieldwork		3.0
3.	Permanent Equipments (AWS, AWLR etc)		28.0
4.	Contingency		3.0
5.	Misc. expenditure		1.0
	Grand Total:		37.64

9. **Work Schedule**

S. No.	Work Element	**First Year**				**Second Year**				**Third Year**			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1.	Monitoring weather	■	■	■	■	■	■	■	■	■	■	■	■
2.	Monitoring Q		■	■			■	■			■	■	
4.	Runoff modeling			■				■					

10.Analysis and results

Two years of discharge data is generated from km 150 at Durbuk-DBO road along the China border under this project. The collected data has been analysed during the reporting period. While the 2015 data suggest occurrence of short duration flood, probably generated by the breaking of the dam created by the surging Aktash glacier no such events are recorded in 2016. Snow cover depletion curves of the basin for 2015 and 2016 were generated from MODIS data and trend in the snow cover depletion is studied during the reporting period. 2016 experienced higher snow cover than 2015. Correspondingly, snow cover persistence was also high during 2016. September 2015 experienced a major snowfall which covered the entire basin and the snow cover in the basin persisted through the winter since then. However in 2016 no major snow event occurred since March and snow cover remain lowest till end of October. Runoff modeling studies are hampered with lack of meteorological data from the basin and ways are being explored to overcome this limitation.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/07

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

2. **Project Team:**
   a. Project Investigator: Manish Kumar Nema, Scientist 'C'
   b. Project Co-Investigators: Dr. Sharad K. Jain, Scientist 'G'/ Head, WRSD, Dr. Sanjay K. Jain, Scientist 'G' Dr. Renoj J. Thayyen, Scientist 'D' and Dr. P. K. Mishra, Scientist 'C'

3. **Title of the Project:** Hydrological Processes and Characterization of Lesser Himalayan Catchments

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

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

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

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

6. **Methodology**

(A) Study Area:

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

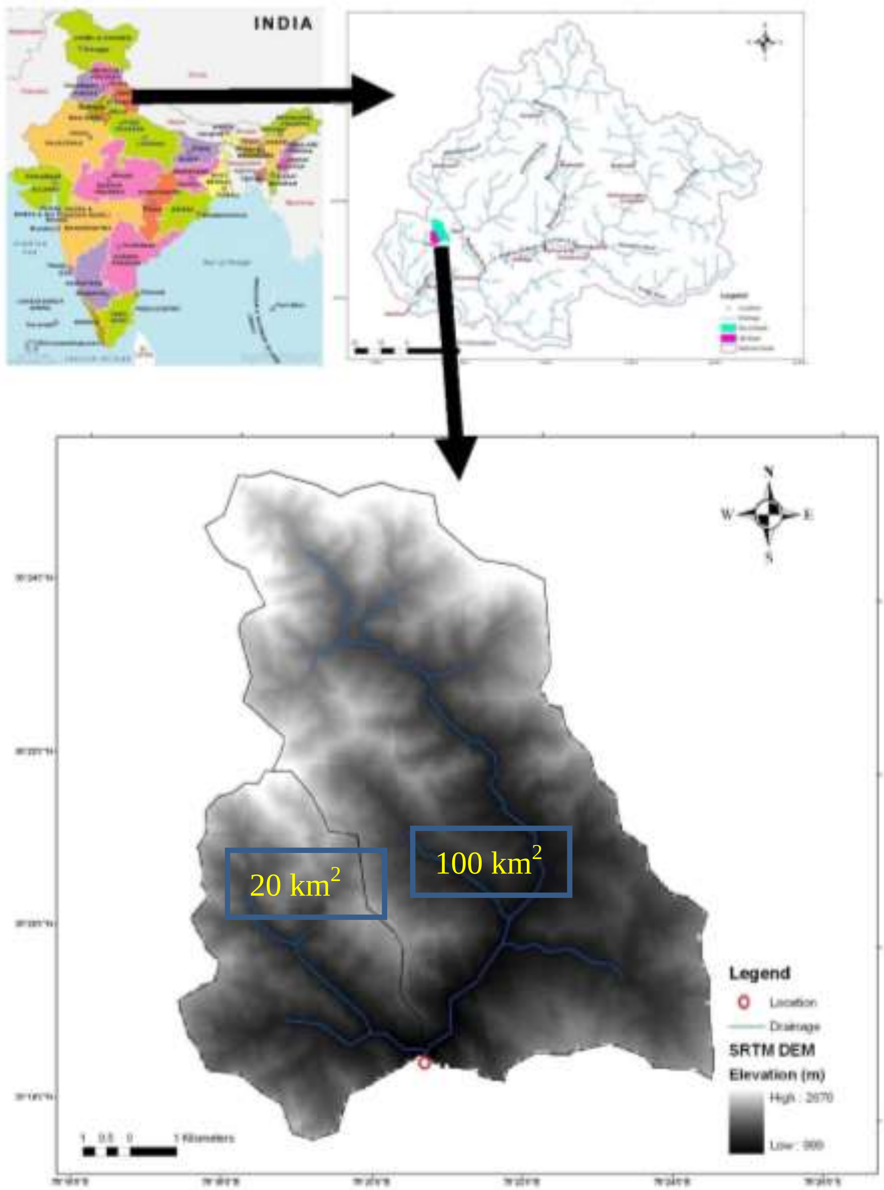


Fig. 1.0 Location of the Hinval watershed up to Jijli within India

(B) Experimental setup

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

(C) Soil Heat Flux

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

(D) Evapotranspiration (ET)

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

(E) Soil Moisture

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

(F) Hydrologic Modelling

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

7. Research Outcome from the project:

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

8. Cost estimates:

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

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

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

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

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

10. Work Schedule:

a. Date of commencement of the project: 01.01.2015

b. Duration of the project: 5 years

c. Stages of work and milestones:

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

10. Progress till date:

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

Instrumentation Progress:

SN	Name of Instrument	Parameters being monitored	Place of Installation	Date of commissioning
1.	AWS with soil parameters monitoring station	Air Temp. & Humidity sensors, four component Radiometer, Tipping Bucket Rain gauge, Heat Flux Plate, Soil Moisture & Temp. sensor at different depths, wind speed & direction sensor at different heights,	Nagani, Chamba	23.03.2016
2.	AWS with soil parameters monitoring station	-do-	Kanatal, Tehri-Garhwal	04.01.2018
3.	AWS with soil parameters monitoring station	-do-	Kumargaon, Chamba	06.01.2018
4.	AWLR-Radar Type	Water Levels at 10min intervals	Devnagar Pumping Station	01.02.2016
5.	Eddy Covariance Flux Tower	High frequency Water Vapour and Carbon Di-Oxide fluxes	Nagani, Chamba	04.01.2018
6.	COSMOS Sensor	Spatially averaged Soil Moisture	Nagani, Chamba	20.06.2017
7.	Soil Monitoring Stations	-----Pending----		

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

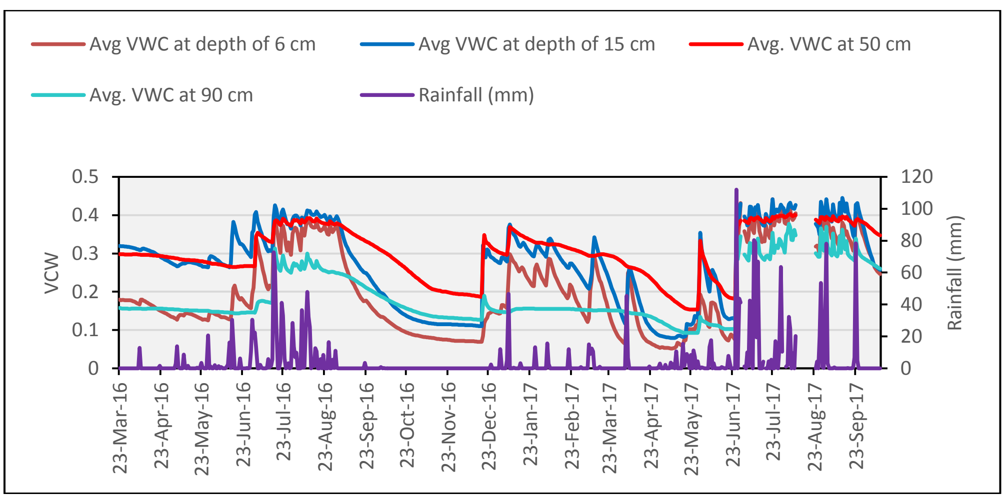


Fig.1 Inter-annual variability of Rainfall Vs Soil Moisture at different depths from March-2016 to Oct-2017

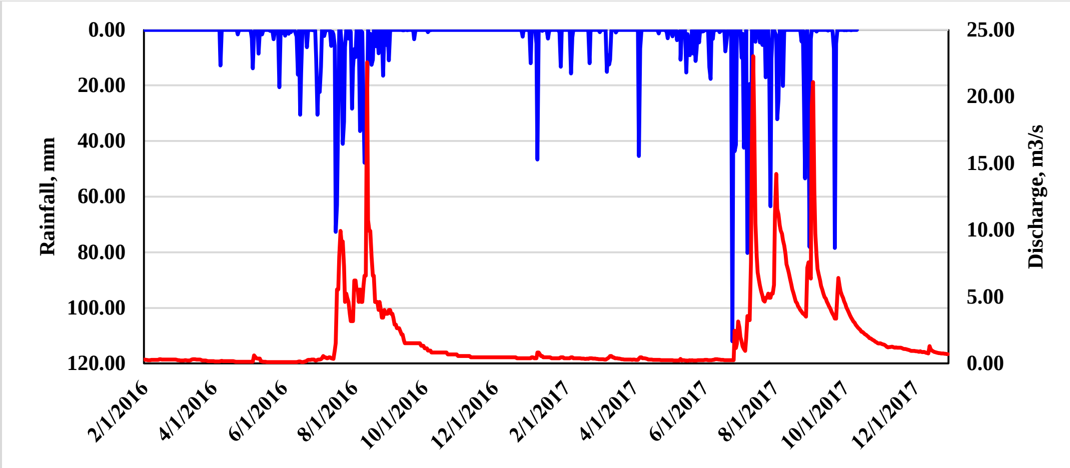


Fig.2 Daily Rainfall and Streamflow variation at Henval Valley (from Feb-2016- Nov-2017)

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

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

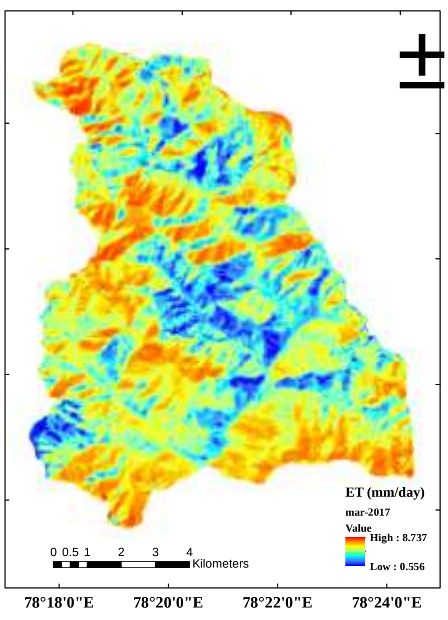


Fig.3 ET_0 map of the study area by SEBAL for the Month of March-2017

Since the project is about experimental hydrology, so only once we have some long-term data in hand then some conclusive inferences can be drawn. In between, the project team also has visited the site many a times for various objectives.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017-18/08

1. **Thrust Area under XII five year Plan** : Hydrological information

2. **Project team:**
   - a. Project Investigator: Deepa Chalisgaonkar, Sc F
   - b. Project Co-Investigator(s): Dr. Sharad K. Jain, Sc G
     Er. D. S. Rathore, Sc F; Dr. Sanjay K. Jain, Sc G
     Dr Sudhir Kumar. Sc G; Dr. P.K. Mishra, Sc C
     Er. P K Agarwal, Sc C; Er. Manish Nema, Sc C

3. **Title of the Project :** Development of Ganga Information Portal

4. **Objectives**

Ganga Information Portal is envisaged to provide a unique platform comprising multisource data and information on Ganga basin. The major objective for developing such a portal is:

- To develop a knowledge/ information e-portal (Ganga Information Portal) with updated information on Ganga basin
- To provide a world class platform as resource centre for data sharing, retrieving pertaining to Ganga basin
- To operate and maintain the e-portal on 24x7 basis

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

The Government of India has recently launched the ambitious 'Namami Gange' an Integrated Ganga Conservation Mission with activities related with conservation and rejuvenation of the Ganga. Recognizing the multi-sectoral, multi-dimensional and multi-stakeholder nature of information in the Ganga basin, it is need of the hour to develop a web-based platform where different types of data/ information (facts; publications; data; maps; photographs; etc.) related to Ganga basin is available at one place. 'Ganga Information Portal' (GIP) is a step in this direction to develop a web-based information portal where variety of information on Ganga basin will be uploaded and maintained at National Institute of Hydrology, Roorkee.

6. **Methodology**

The GIP is being developed by using the World Wide Web (WWW) technology which is based on an open unstructured distributed hypermedia information system. It consists of non-linear, flexibly linked HTML (Hyper Text Media Language) documents, in which different types of WWW objects are being embedded.

The system is being developed in HTML and java script language. The main and drop down menus will allow the user to interact with the system very easily. The information relating to the Ganga will be collected from many different sources, agencies and organizations and will be arranged between the time-spaces, and it will be possible to share, to search, to display, and to output (print) it.

7. **Research outcome from the project**

A portal as shown in Fig.1 will be developed which will support quick and timely access of the information related to Ganga, anytime and from anywhere in the world.

8. **Cost estimate:**

a. Total cost of the project : Rs.65.55 lakhs

b. Source of funding : NIH

c. Sub Headwise abstract of the cost

Sl. No.	Item	Nos. required	Duration (Man months)	Unit amount (Rs.)	Amount (Rs.)
A	**Manpower**				
i.	Scientist G and above	3	1 (Total)	175000.00	1750000.00
ii.	Scientist F	2	8	150000.00	2400000.00
ii.	Scientist B and C	3	1	80000.00	240000.00
iv.	JRF	2	30	28000.00	1680000.00
B	**Equipments (Hardware & Software)**				
	Workstations with UPS	2		50000.00	100000.00
	Scanner-A3	1		55000.00	55000.00
	Printer	1		30000.00	30000.00
C	**TA/DA**				
	Traveling by experts & JRFs	LS			300000.00
	Total (A+B+C)				**6555000.00**

9. **Quarterly Break up of cost estimate for each year**

2015-2016

Sl.No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	Salary	365800.00	365800.00	365800.00	365800.00
2	Traveling expenditure	-	-	-	50000.00
3	Infrastructure/Equipment	-	-	-	185000.00
5	Misc. expenditure	-	-	-	50000.00
	Sub- Total:	365800.00	365800.00	365800.00	650800.00
	Grand Total				1748200.00

10. **Work Schedule:**

a. Date of commencement of the project : April 1, 2015

b. Duration of the project: 3 years, however, GIP is an integrated information portal which requires continuous efforts in up-gradation and maintenance.

c. Stages of work and milestone:

Sl.No	Item/Activity	Timeframe
i.	Creation/ Establishment of Infrastructures	9 months
ii.	Collection of different types of data/ information from different stakeholders on Ganga basin	6 months & beyond
iii.	Portal development and management	6 months & beyond
iv.	Operation and maintenance of GIP on 24x7 basis	On regular basis
v.	Retrieving critics, comments and feedback from different users	On regular basis

The system is being developed in HTML and java script language. The main and drop down menus will allow the user to interact with the system very easily. The information relating to the Ganga basin is being collected from different sources, agencies and organizations.

11. **Progress :** The portal is being developed as per the themes shown in Table 1.

Table 1: Different Themes of GIP

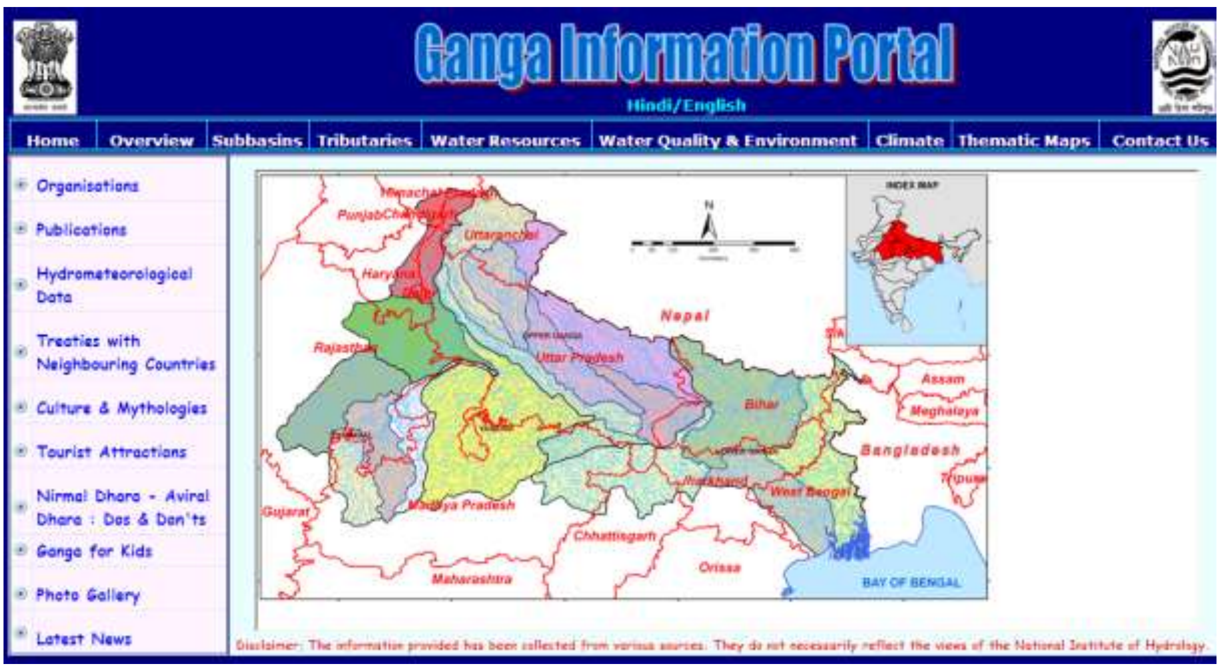
Overview	Subbasins	Tributaries	Water Resources	Water Quality and Environment	Climate	Thematic Maps
• Salient Features • Topography • Hydrology with River Line Diagram • Soils • Agro_Climatic Zones • Agro_Ecological Zones • Demography • States and Districts • Inland Navigation	• Above Ramganga Confluence • Banas • Bhagirathi & Others (Ganga Lower) • Chambal – Lower • Chambal – Upper • Damodar, Gandak & Others • Ghaghara • Ghaghara Confluence to Gomti Confluence • Gomti • Kali Singh & others confluences with Parbati • Kosi • Ramganga • Sone • Tons • Upstream of Gomati Confluence to Muzaffarnagar • Yamuna – Lower • Yamuna – Middle • Yamuna - Upper	• Ajay • Banganga • Chambal • Damodar • Gandak • Ghaghara • Gomti • Hindon • Kali • Karamnasa • Ken & Betwa • Kosi • Mahananda • Mayurakhi • Punpun • Ramganga • Sindh • Sone • Tons • Yamuna	• Water Resources Projects • Drinking Water Projects • Irrigation Projects • Hydropower Projects • Interbasin Water Transfer • Ground Water Resources ➢ *Ground Water Observation Wells* ➢ *Ground Water Level Fluctuations* ➢ *Lithology* • Wetlands • Glaciers	• River Water Quality • Ground Water Quality • Environment and Ecology	• Rainfall ➢ *Annual Precipitation* • Temperature • Evaporation	• Agro_Climatic Zones • Agro-Ecological Zones • Annual Average Rainfall • Command Areas & Canal Network • Drainage & Subbasins • Elevation Zones • Ganga Basin Map • Ground Water Level Fluctuations • Ground Water Observation Wells • Index Map • Interbasin Transfer • Landuse / Landcover • Litholog Well Locations • Hydrometeorological Stations • Population Density • Structures & Projects • Satellite Imagery • Soil Erosion • Soil Productivity • Soil Slopes • Soil Texture • Water Tourism Sites • Inland Navigation Waterways

Research outcome from the project

The information dissemination using a portal has several significant advantages like :

- Platform independent system
- No Installation required
- Thin client; maintenance is minimized.
- Quick and timely access, anytime, and from anywhere in the world
- Larger access to the products in a more structured manner

A portal as shown in fig.1 is being developed which will support quick and timely access of the information related to Ganga, anytime and from anywhere in the world.



ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/01

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

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

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

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

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

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

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

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

7. Research Outcome from the project:

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

8. Cost Estimate : 65.14 lacs

Total cost of the project: Rs. 65.14 lakhs

b. Source of funding: SERB-DST

9. Work schedule

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

10. Analysis and results

During the reporting period, procurement of field instrumentation has been completed which include automatic weather stations and glacier ice temperature profiler. Two automatic weather stations with four-component radiometer has installed over the glacier ice on Phuche and Khardung glaciers in the month of September 2017. Ice temperature profiler of 10m also installed on both the glaciers with 0.5 m sensor interval. Summer and winter mass balance measurements were carried out during the reporting period.

Winter mass balance measurements of Phuche glacier was carried out on May 30, 2017. The measured standing snow depth over the glacier was up to 2.1 meters and average snowpack density was 0.53 gm/cc. The snowpack density was used to calculate the point mass balance of each stakes and estimated glacier wide winter mass balance (B_w) was about (+) 1.03 m w.e. The melting of snowpack thickness was monitored on 15-20 days interval. The sequential snowpack thickness measurement revealed that the snowpack melt on the glacier continued till end of the August and lower part (ablation zone) of the glacier got exposed after August 22, 2017. The annual mass balance of the glacier was measured in Sep 15, 2017. The estimated glacier wide annual (B_a) and summer (B_s) mass balance was (+) 0.13 m w.e. and (-) 0.90 m w.e. respectively. The positive mass balance was observed in this year. The equilibrium line altitude (ELA) for the year observed 5481m a.s.l and corresponding Accumulation Area Ratio (AAR) was 0.91.

Winter mass balance measurements of Khardung glacier was carried out on May 21, 2017. Standing snow depth over the glacier was up to 1.7 meters and an average snowpack density measured was 0.46 gm/cc. The estimated glacier wide winter mass balance (B_w) was 0.71 m w.e. The sequential snowpack thickness measurement revealed that the snowpack melt on the glacier continued first week of August and major part of the glacier was exposed for melting after August 8, 2017. The annual mass balance of the glacier was measured in Sep 11, 2017. The estimated glacier wide annual (B_a) and summer (B_s) mass balance was (-) 0.24m w.e. and (-) 0.94 m w.e. respectively. Contrary to Phuche glacier negative mass balance was observed for Khardung glacier is this year. The ELA for the year lay at 5488m a.s.l and corresponding AAR was 0.18.

Phuche meteorological data for surface energy balance model

To investigate glacier-climate interaction on Phuche glacier, one automatic weather station (AWS) installed at 5600 m a.s.l. Past one year (1 October 2016 to 15 September 2017) data downloaded during the reporting period and found to be of good quality without any gap. Data sets is generated half-hourly includes global radiation (incoming and outgoing shortwave radiation), albedo, net radiation, air temperature, relative humidity and wind speed and direction. The minimum and maximum temperature was recorded in 14thJanuary 2017 (-29.8 °C) and 1st August 2017 (14.1 °C) with a mean air temperature of -9.4 °C during the period. The coldest month of the period was January with a mean T_a of -21.3°C and warmest month was July with mean T_a of 2.6 °C. The daily mean net short wave radiation (SWR) was varying from 13.9 Wm^{-2} in midwinter to 345.3 Wm^{-2} in summer with a mean value of 140.1 Wm^{-2}. The lowest value of mean monthly net SWR was observed in January (57.6 Wm^{-2}) and maximum was observed in August (244.2 Wm^{-2}). The daily mean value of net radiation (NR) varies from -71.4 to 135.5 Wm^{-2} with a mean value of 17.8 Wm^{-2}. The mean monthly minimum and maximum value of NR was observed in June (-19.0 Wm^{-2}) and August (90.0 Wm^{-2}) of the study period. The variation of daily mean relative humidity (RH) varies from 10.4% to 100.0% with a mean value of 58.0%. The mean monthly minimum and maximum RH was observed in October (33.4%) and June (69.6%). Instantaneous minimum RH of 3.5% recorded in October and maximum (100%) in the month of May, June, July August and September. The mean monthly minimum and maximum value of wind speed was observed in July (3.5 ms^{-1}) and February (5.2 ms^{-1}) of the period. The total positive degree day (PDD) and freezing degree day (FDD) was observed 251.3 °C and -3533.7 °C during the study period. The maximum PDD and FDD was observed in August (102.9 °C) and January (-661.5°C). The daily mean value of latent heat (LE) varies from 18.6 to -120.9 Wm^{-2} with a mean value of -38.0 Wm^{-2}. The mean monthly minimum and maximum value of LE was observed in October (-71.9 Wm^{-2}) and July (-12.6 Wm^{-2}) of the study period. The daily mean value of sensible heat (H) varies from -63.0 to 97.9 Wm^{-2} with a mean value of 3.9 Wm^{-2}. The mean monthly minimum and maximum value of H was observed in November (-18.9 Wm^{-2}) and June (26.6 Wm^{-2}) of the study period. Future work include studying SEB from AWS installed over the two glaciers.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/02
NMSHE STUDIES

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

2. Study team

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

3. Objectives

The objectives of the project are:

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

4. Sponsored by DST, New Delhi

5. Project Cost Rs.113.22 Lakh

6. Brief Background

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

Data collected on hydrologic variables are generally raw which may not be used directly in most hydrologic analysis work. Processing of hydrological data has two major objectives: one to evaluate the data for its accuracy and the other to prepare the data in a form valuable to the users. The rapid advance in computer technology, in speed of operation and data storage capacity as well as the capability of hydrological software has greatly simplified the management of large quantities of hydrological data. All hydrological datasets can be maintained in well-defined computerized databases using standard database management system. Surface Water Data Entry System (SWDES), developed under Hydrology Project – I, and HYMOS software can be used for entry and processing of hydrological data in standardized format. This is essential for the long-term sustainability of the datasets in proper form and their dissemination to the end users. Both, raw and processed data sets are to be properly stored and archived to specified standards so that there is no loss of information. NIH has trained manpower on SWDES and HYMOS software which can be used entry and process the hydrological database for the Upper Ganga basin up to Rishikesh and to build capacity in other organizations dealing with hydrological data for their effective utilization. For mountainous areas, significant variation in altitude, slope, aspect, soil, and land use characteristics over short distances requires high density of hydrometric networks for reliable assessment of hydrological variables. However, due to various operational problems such as approachability, low temperatures, snowfall, high velocity flows with boulders and sediments etc., hydro-meteorological information available in the mountainous regions is quite limited due to lack of proper observation network. There is an urgent need to properly design and upgrade automated hydro-meteorological networks suitable for the prevailing climate in the region for long-term monitoring and database development. It is envisaged to analyze the existing hydro-meteorological network in the study area and analyze its adequacy using different techniques.

There has been widespread concern over the global change in climate and its impact on various hydrological variables. This impact is not uniform globally and mountainous regions are considered to be more susceptible to climate change (IPCC, 2007). 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.

7. Present Progress

Spatial Data: Digital Elevation Models (ASTER/SRTM); Soil Map (FAO); Landuse Map (Bhuvan); Shape Files (Ganga River Basin Management Plan, IITD Server); Landsat Imageries (NASA Earth Explore/Bhuvan) have been downloaded from different free sources.

Temporal Data: Precipitation, minimum & maximum Temperature, relative humidity, sun-shine hours, wind speed, solar radiation, dew point, ground forest frequency, potential evapotranspiration, reference evapotranspiration, vapour pressure and wet day frequency have been downloaded from different free sources.

Satellite based Data: Data of TRMM (3B43) & APHRODITE have been downloaded for the study area under NMSHE project.

Miscellaneous:

1) Study area has been demarcated/delineated up to Triveni Ghat using DEM.
2) G&D sites are identified under the study area as per India WRIS web site under SP-1

3) Catchment area of basin 21,762 km^2, covered in 45 SoI Toposheets (1:50,000 scale).
4) Daily observed rainfall data of 48 stations have been collected and imported in SWDES. In addition, hydro-meteorological data of various AWS of SASE has also been obtained.
5) IMD 0.25 deg grids have been identified and daily gridded data has been extracted.
6) Village level population data has been downloaded for study area.
7) Tentative website design has been prepared and its coding is in progress.
8) Efforts are underway to install the HYMOS system for detailed processing of hydro-meteorological data of the study area.
9) Health-status report for the Himalayas has been prepared and submitted to DST in the desired format.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/03
NMSHE STUDIES

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

2. Study team

a) Project Investigator:	D. S. Rathore, Sc. “F”
b) Project Co- investigators:	Deepa Chalisgaonkar, Sc. “F” V.S. Jeyakanthan, Sc. “E” L.N. Thakural, Sc. “C”
c) Project Staff (JRF)	Suman S. Baral, JRF Sumit Kumar, JRF

3. Objectives

The objectives of the project are:

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

4. Sponsored by DST, New Delhi

5. Project Cost Rs.77.992 Lakh

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

6. Statement of Problem

For obtaining snow depletion curve, high temporal resolution data are highly desirable for small basins. Availability of high temporal and spatial resolution has a trade-off. In such case, error introduced due to mixed pixels may be important. Microwave data has good potential in study of snow water content. Spatial information obtained from multiple sources may be easily disseminated through web GIS applications. Web GIS has potential for interactive applications in addition to visualization.

7. Present state-of-art

MODIS snow cover data are available as daily, eight day composite, real time fractional snow etc. Products use global automatic processing for snow, fractional snow and grains extraction from MODIS data. MODIS snow cover cloud estimation technique maximizes cloud area. Texture products have been utilized snow and cloud. Several Web GIS software are available for creating web GIS services. Library and development tools are available for accessing web GIS services for visualization of spatial data on client machines.

8. Methodology

Satellite remote sensing imagery will be used for the extraction of areal snow cover extent, fractional snow cover and snow underneath cloud/vegetation. Various techniques e.g. NDVI-NDSI regions for snow underneath forests, change detection/image matching of cloud obscured images with reference images, comparing multi resolution images for fraction snow cover, different sensor data merging etc. will be employed. Snow cover statistics will be observed from merged sensor (Terra and Aqua) data as well from individual sensors. Moreover, microwave data of Sentinel 1-A and ALOS PALSAR imagery will also be utilized. Further, the snow cover maps and its statistics generated will be published using

Web GIS technologies such as Geoserver, Open layers, GeoExt etc. In addition, the available web services of spatial data e.g. Open Street Maps, Google maps etc. will also be utilized.

9. Location map/ study area

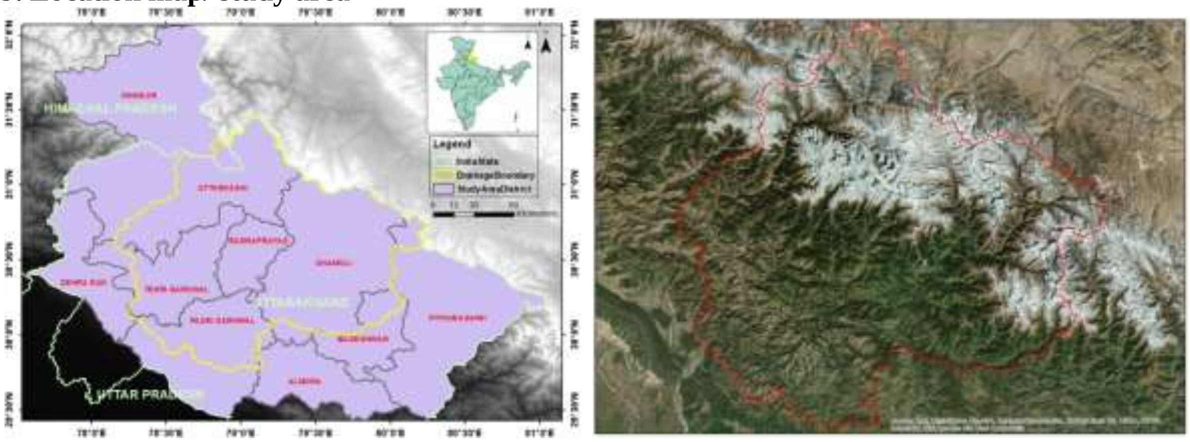


Fig. 1: Ganga basin up to Haridwar (Left) Snow mapping for Trivenighat basin in upper Ganges (Right).

9. Approved action plan and time line

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

10. Recommendations/ suggestions in previous WG

None.

11. Achievements

Year	Objectives	Achievements
2017-18	Snow mapping	Snow cover maps (using Snowmap algorithm) are provided by National Snow and Ice Data Centre (NSIDC), University of Colorado, Boulder, USA. MODIS Terra and Aqua data of 8 days temporal coverage with 500 meter spatial resolution have been obtained from NASA LP DAAC and processed in batch using Arc GIS model builder tool creating subset for the area of interest and computing its statistics (Fig. 2 and 3). From the data without post-processing, an increasing trend in monthly median snow cover extent in months of January, April to July and decreasing trend in months of February, March and August to December was observed. A decreasing trend in seasonal median snow cover extent in autumn, winter and summer season and increasing trend in spring season was observed. The entire data series along with median daily and yearly values are depicted Fig. 2 & 3.

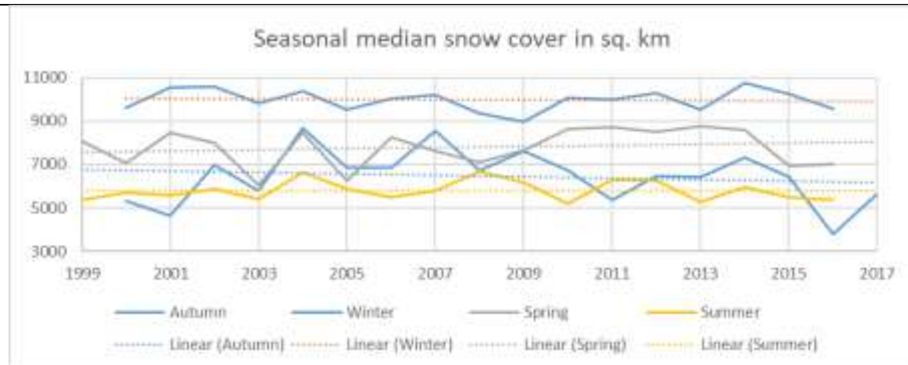
<table>
<tr>
<td></td>
<td></td>
<td>


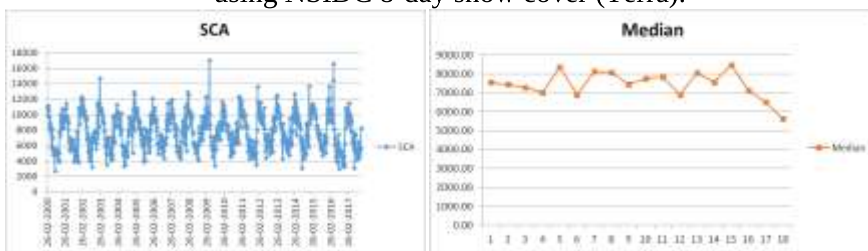
Fig. 2 Seasonal median snow cover extent in sq. km for Upper Ganga basin using NSIDC 8-day snow cover (Terra).


Fig. 3 SCA (sq. km) distribution (Left) and Median SCA (sq. km) from 2000 to 2017 (Right).
</td>
</tr>
<tr>
<td>2017-18</td>
<td>Web GIS application</td>
<td>
A web application has been developed to visualize the areal snow cover extent (for NSIDC snow cover maps of MODIS- Terra). The application will also provide the areal snow cover information both in tabular and chart form for the Upper Ganga basin (Fig. 4 and 5). The developed application uses HTML, CSS, JavaScript, jQuery, open source library fusion chart and PostgreSQL. Moreover, the histogram and table of snow cover area between two dates (all data or monthly/ yearly minimum and maximum) can be visualized.


Fig. 4 Web application for getting snow extent table (all data or monthly/ yearly minimum and maximum).
</td>
</tr>
</table>

		 Fig. 5 Web application for getting snow extent chart (all data or monthly/ yearly minimum and maximum).

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/04
NMSHE STUDIES

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

2. Study team

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

3. Objectives

The objectives of the project are:

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

4. Sponsored by DST, New Delhi

5. Project Cost Rs. 41.796 Lakh

6. Brief Background

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

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

7. Methodology

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

(i) Collation of literature & reference documents, procurement Remote Sensing Data from appropriate agencies-national and though on line sources.
(ii) Formulation of data on Glacial Inventory of the Basins defining snow line, different glaciers, their attributes and classification.
(iii) Establishing Glacial Lake and Moraine Dam Inventory in the Basins and defining geometric parameters of lakes, possibility of their inter-connectivity, and geomorphic classification to work out their vulnerability status.
(iv) Analysis of Glacial Lake database to identify the vulnerable lakes and their possibility of out burst under different causative modes. Defining breach parameters to estimate the scale of hazard on incidence of the GLOF.
(v) Defining slope attributes of the river from vulnerable lake/lakes to project sites and cross sections of the river-valley which would carry the flood on incidence of GLOF; the parameters would be defined based on remote sensing data.
(vi) Hydrological studies on GLOF/ Moraine Dam Break Simulation and consequent lake breach flood using the hydro-dynamic mathematical modeling.
(vii) Recommendation for the establishment of a system for monitoring potential risk lakes.
(viii) Information to be given to relevant institutions regarding the results and potential risks, thereby increasing the capability to plan for and prevent or mitigate the risks.

8. Present progress

In this project four study basins: Sutlej, Beas, Chenab and Ganga have been selected.

For the basins, Landsat data has been downloaded for the years 2000 and 2015.

The processing of the data has been carried out through ERDAS. The subset has been prepared and then mosaic of the data has been prepared. Finally the study basin for the years has been extracted.

Image processing of these Glacier maps for Sutlej basin have been carried out. The NDSI map and slope map have been prepared. Using these maps, GLIMS maps and Google maps, delineation of the glaciers for the two years 2000 and 2015 is under progress. The satellite data of other years i.e. 1990 will also be downloaded for glacier area.

The literature review is under progress and recent papers related to glacier and glacier lakes have been downloaded.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/05
NMSHE STUDIES

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

2. **Project Team:**
    1. Dr. R. J. Thayyen, Scientist 'D', NIH, Roorkee - PI
    2. Dr. Sanjay K. Jain, Scientist 'F', NIH, Roorkee – Co-PI
    3. Dr. Sharad K. Jain, Scientist 'G' & Head, WRS Div., NIH, Roorkee
    4. Dr. S. P. Rai, Scientist 'E', NIH, Roorkee
    5. Dr. P. K. Mishra, Scientist 'B', NIH, Roorkee
    6. Dr. M. Arora, Scientist 'D', NIH, Roorkee
    7. ***Collaborator: Dr. A. P. Dimri, Assoc. Professor, SES, JNU, New Delhi***

3. **Title of the Project:** Assessment of downstream impact of Gangotri glacier system at Maneri and Future runoff variations under climate change scenarios

4. **Objectives:**

    1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri
    2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri
    3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling.
    4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change.

5. Present state-of-art

River Ganga originates from the Gangotri glacier and fed by around 238 glaciers in the Bhagirathi catchment and 407 glaciers in the Alaknanda catchment covering around 1959 km^2 of the catchment area above Deoprayag. Discharge in these headwater tributaries of the Ganga is influenced by snow, rain and glacier melt. Melting glaciers of this region have raised serious concerns over the future trajectory of water availability in this crucial river system. There are conflicting viewpoints exists on the impact of glacier melt in the downstream flow regimes. IPCC 2007 report and many other studies in the Alpine systems suggested increased river flows during the early stages of glacier melt. However, Thayyen and Gergan (2010) distinguished between Alpine and Himalayan systems on the basis of annual precipitation distribution and flow regimes and pointed out that the runoff variations in the precipitation (Monsoon and winter snow) dominant systems such as Bhagirathi and Alaknanada basins are not dominated by the glacier discharge. Here precipitation variability plays the key role in runoff fluctuations with glacier melt helps to reduce the inter-annual runoff variability. Hence assessment of future runoff variation in this headwater streams required some robust future projections on precipitation and temperature. The impact of glacier melt dividend is found to be maximum for a basin with 20-30% glacier cover under the Alpine conditions. However, such assessment is non-existent in the Himalaya barring Dingad catchment, Garhwal Himalaya. As Gangotri is the largest glacier in the Ganga headwaters, extent and nature of its impact on downstream flow is critical issue for glacier resource management. The proposed project aims to understand this critical knowledge gap in the headwater regions of the Bhagirathi River at Maneri with 14.19% glacier cover. This catchment has 4205 km^2 area and 232 glaciers covering 596 km^2 (14.19%) The understanding of climate forcing on river flow under a data free regime is challenging. Key knowledge gap are precipitation and temperature gradients in the higher altitude regions. This knowledge gap will be addressed with collaborations with Jawaharlal Nehru University on atmospheric process modeling. Future runoff will be modelled using the future climate projections from this sub project.

6. Methodology

A) Discharge data of Maneri will be collected from the state agencies and inter-annual variations and long-term trends will be assessed.

B) Weather monitoring near Harsil: Weather data at the high altitude Himalayan region is very sparse. Hence orographic processes of the Himalayan slopes are poorly understood. Recent studies have shown that the orography is a key factor controlling the weather variables in the Himalaya. A full-fledged automatic weather station with four component radiometer, precipitation gauge and soil heat flux sensors will be installed near Harsil. Data from this weather station will be used for runoff modelling and climate downscaling.

C) Runoff modelling by SNOWMOD: Runoff modelling will be carried out by the established in-house model SNOWMOD. SNOWMOD is capable of providing snow, glacier, rainfall and base flow components separately. The glacier melt component in the discharge will be derived through modelling exercise. Glacier change in the Bhagirathi catchment during the past three decades will be estimated and correlations will be established between temperature/precipitation variations in the catchment with that of glacier change with the help of reanalysis data. Future glacier area change will be determined by using the inputs from the climate downscaling exercise and future runoff and glacier component will be modelled.

D) Climate downscaling and future predictions: Climate of the region is dominated by Indian winter monsoon and Indian summer Monsoon. Keeping such broad scale flow in mind climate downscaling will be done in conjuncture with the study of interaction of large scale monsoonal flow with existing variable topography and to study land surface processes in association with hydrological balance over the region of study with existing CORDEX simulation (from IITM, Pune), downscaling over the catchment region and modelling experiments. As it is understood that the region of study is of complex topography and hence such topography will not be truly represented within the model domain and hence dynamical downscaling will be used to established the atmospheric-topographic interaction in defining primarily precipitation forming processes. Statistical downscaling methods will be used to overcome the coarser horizontal model resolution problem and establish moisture-temperature interplay processes.

7. Research Outcome from the project:

Understanding of the downstream impact of Gangotri glacier system with glacier, snow & rainfall component and its probable future variability.

8. Cost Estimate:

a. Total cost of the project:	Rs. 153.716 lakhs
NIH	Rs. 80.42
JNU	Rs.73.296
b. Source of funding:	NMSHE-DST

9. Progress of the project

MODIS Tera (MOD) and Aqua (MYD) data were download and implemented number of pre-processing steps to generate the cloud free snow cover extent and depletion for 16 years from 2000 to 2016. Snow cover area is computed for each 500 m elevation zones of the basin and analysed for the snow cover variability for 16 years of mountain hydrological years. Maximum snow cover in the basin is observed in the month of March/February and minimum in August/September. During the observation period, no significant long-term trend in the snow cover distribution observed in the basin. However, there is significant inter-annual variations do occur. The impact of snow cover variations is expected to be better represented in the snow cover days. Annual snow cover days have been estimated for each 500m elevation band in the basin. The result show a slight reducing trend of annual snow cover days in the elevation band of 4000-4500 m a.s.l. Above and below this altitude band no discerning trend is visible during the past one and a half decade. These are glacier elevations and this imply that the lower elevations of the glaciers are getting exposed early and could be factor in the enhanced melting of the glaciers in the region. As a next step, snow cover data generated will be used for modeling basin runoff along with bias corrected model temperature and precipitation data of the basin.

Discharge data at Maneri dam site, where contributions from all 231 glaciers in the Bhagirathi basin congregate has studied during the period. Total basin area of the basin is 4205.46 km2 and 14.19% of the basin is covered by glaciers (596.19 km2). Discharge data of nearly 27 years show no significant trend in discharge. Inter-annual discharge variations, represented in terms of coefficient of variations, shows a low value of 0.12 suggesting a stable runoff regime annually. Most stable discharge regime is observed during the winter months representing the low flow regime. Second most stable period observed during the high flow period of July and August that coincides with peak monsoon and glacier melt. Most unstable flow regimes are observed in the month of May, June and September months with a coefficient of variation ranging from 0.27 to 0.32 for twenty-seven year time span from 1989 to 2015. Decadal scale analysis shows a significant increase in the inter-annual variations during the pre-monsoon months of May and June as well as in the post- monsoon month of September during 2000-2015 period as compared to 1989 to 1999 period. May values show increase from 0.28 to 0.36 and June values from 0.23 to 0.33 followed by September values from 0.15 to 0.35. The increased uncertainty of runoff in the month of May, June and September is linked to the snow cover variations and steady runoff in the month of July and August indicate steady monsoon precipitation or effective compensation by the glacier melt during the period. Considering the large snow cover area in the basin, observed uncertainty in the river flow during pre and post monsoon month is indicative of the local water availability as well.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/06
NMSHE STUDIES

1. **Thrust Area:** Himalayan Hydrology
2. **Project Team**

Project Investigator	:	Dr. Sharad K. Jain, Scientist 'G'
Co-Project Investigator	:	Dr. R. J. Thayyen, Scientist 'D'
Project Co-Investigators	:	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. S. P. Rai, Scientist 'F'
	:	Dr. Surjeet Singh, Scientist 'E'
	:	Mr. M. K. Nema, Scientist 'C'
	:	Dr. P. K. Singh, Scientist 'C'
	:	Dr. P. K. Mishra, Scientist 'C'
	:	Mr. P. K. Agarwal, Scientist 'B'
	:	Dr. A. P. Dimri, Professor, JNU
Research Associate	:	Dr. Pravin Rangrao Patil

3. **Title of the Project:** Observation and Modelling of Various Hydrological Processes in a Small Watershed in Upper Ganga Basin

4. **Objectives:**
   1. To establish relationship between climatic and hydrologic variables and their seasonal variations in Himalayan environment.
   2. To study the atmospheric dynamics including seasonal variations in atmospheric water budget, land-surface flux, orographic interactions during Indian summer and winter monsoon.
   3. To develop the understanding of the hydrological processes in the watershed though isotope geochemistry.
   4. To study the ground water dynamics in a lesser Himalayan watershed.
   5. To study the soil erosion characteristics and sediment routing of the watershed.
   6. To model various water balance components for a small watershed.

5. **Present State-of-the-Art**

Climate – Hydrology interaction in the mountain areas is complex due to closer and dynamic land-atmospheric exchange on account of orographic updraft and drainage winds. Indian Summer Monsoon (ISM) and Indian Winter Monsoon (IWM) is a major factor controlling climate of the Himalaya (Thayyen and Dimri, 2014). Hence, understanding the atmospheric, land surface and hydrological processes and its linkages is key to our understanding of climate change forcing on the Himalayan hydrological system. We did not succeed in attributing the regional climate change to the anthropogenic forcing till date. There is a clear need to move beyond the status quo and expand from this narrow hydrological perspective to generate hypotheses governing general behaviour across places and scales, with the ultimate aim to advance our understanding of the mountain hydrological processes. The project is envisaged to cover major components and processes of the water cycle; starting from the seasonal atmospheric water budgeting, atmosphere-land surface interaction and feedback, surface water balance, soil moisutre-soil temperature-sediment and water quality responses, groundwater dynamics and hydrological process studies and atmospheric moisture source assessment by stable isotope measurement.

6. **Methodology**

Study Area: The small Himalayan watersheds (Henval & Jijali) in the upper Ganga basin in Tehri Garhwal district of the state of Uttarakhand are proposed for the study.

- **i.** Analysis of factors influencing local weather, land surface flux including soil temperature and diurnal & seasonal forcing at AWS site.
- **ii.** Application of updated Regional Climate Model-RegCM4 (Giorgi et al. 2012) for atmospheric modelling along with CORDEX and subgrid land surface parameterization using mosaic-type scheme of the RegCM 3 (Giorgi et al. 2003).
- **iii.** Water and sediment sampling for water quality investigations and modelling with advance use of isotopes.
- **iv.** Develop understanding of the groundwater dynamics or interactions and recharge through installation of piezometer's longitudinally along the river, modeling and isotopic analysis.
- **v.** Water balance modelling using field experiment based input data to understand the components of the hydrological cycle.
- **vi.** Quantitative assessment of soil erosion and spatial distribution using USLE, RUSLE and MMF, RSSYM, WERM, SWAT Models with GIS and Remote Sensing in order to plan soil conservation measures.

7. **Research Outcome from the Project:** Enhanced understanding of the Lesser Himalayan hydrology-atmospheric interactions and climate change forcing aiding water resources management.

8. **Cost Estimate: 134.32 lakhs**

Total cost of the project	:	Rs. 134.32 lakhs
Source of funding	:	NMSHE-DST

9. **Work schedule:**

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Development of procedure for scientific work										
Recruitment and deployment of Project Personnel										
Purchase of instruments and experimental setup										
Data generation and acquisition										
Data analysis and modelling (Isotopic analysis / Sediment Modelling)										
Atmospheric Dynamics (water budgeting / Land Surface Flux)										
Watershed water balance and budgeting										
Ground Water Dynamics										
Final Reporting										

10. **Progress of Work:**

- **i. AWS Setup:** After continuous efforts, permission for installation of an AWS has been obtained from the Uttarakhand Forest Department. It has been installed recently in the Jijali catchment near the ridge through NMSHE-5 funds, will aid in studying lapse rate. TDR sensors, heat flux plates, tipping bucket rain gauge were also placed around AWS.

- **ii. Other Instrumentation:** Ordinary rain gauges have been installed at 10 different sites for monitoring rainfall distribution across elevations. A pan evaporimeter is installed at NIH-AWS site. The local peoples have been trained and engaged for monitoring rainfall and evaporation. The locations for installation of piezometer were identified in Henval valley.

iii. Apparent Thermal Diffusivity at Lesser Himalayan Henval Experimental Station:

Duration	Pre-Monsoon M-A-M	Monsoon J-J-A-S	Early-Winter O-N-D	Core-Winter J-F-M-A	For all 4 Seasons
Thermal diffusivity D_h (m^2/hr)					
average:	0.0021	0.0022	0.0019	0.0019	**0.0020**
minimum:	0.0013	0.0015	0.0014	0.0013	0.0013
maximum:	0.0026	0.0038	0.0025	0.0029	0.0038
Damping depth = $2 D_h / w$ (m)					
average:	0.13	0.13	0.12	0.12	**0.12**
minimum:	0.10	0.11	0.10	0.10	0.10
maximum:	0.14	0.17	0.14	0.15	0.17

Adopting the diffusivity based damping depths the temperature profiles at any depth (within selected soil reach < 30 cm) and time can be derived. The average efficiency of temperature prediction for the 4 subsoil depths (2, 6, 15 & 30 cm) is 96.29%. The diffusivities can also be applicable to identical soil types (Silt Loam). The values aids in filling soil temperature data gaps during sensors malfunction.

iv. Sine-exponential Modeling of Diurnal Air & Skin Temperature: During stable nighttime air temperature, decreases continually up to sunrise. Sinusoidal component: (sunrise — sunset) reproducing the temporal influence of solar heating. Exponential component: (sunset — next sunrise) reproducing Newton's law of cooling for a heated surface. Inputs: Daily max. & min. temperature, day & night length, sunset temp., time of sunrise and sunset. The R^2 between obs. & modeled air as well as skin temperature for the period 24th March, 2016 to 11th April, 2017 is 0.97 and 0.95, respectively.

v. Mountain Wind Statistic: Wind frequencies w.r.t. 16 directions & 6 wind speed classes have been estimated from April-16 to March-17 over the NW-SE aspect of Henval valley. The average air temperature as well as wind speed have also been analysed w.r.t. wind directions. This analysis further revised on daytime & night time basis. Overall anabatic winds dominance at the site is restricted for monsoon months of July and August. Rest of the months katabatic wind dominance is observed.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/07
NMSHE STUDIES

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

2. Study team

1. Dr. P. K. Mishra, Scientist 'C', NIH, Roorkee - PI
2. Dr. R. J. Thayyen, Scientist 'D', NIH, Roorkee
3. Er. M. K. Nema, Scientist 'C', NIH, Roorkee
4. Dr. P. K. Sachan, Scientist 'C', NIH, Roorkee
5. Swagatam Das (JRF)
6. Sanjay Kumar (PA)
7. Pankaj Kumar (PA)
8. Vishal (PA)

3. Objectives

The objectives of the project are:

a) To map water use pattern and livelihood linkages.
b) To map potential water hazard zones in the catchment.
c) To identify hotspot matrix components, hotspots analysis and adaptation strategies.

4. Sponsored by DST, New Delhi

5. Project Cost Rs. 90.99 Lakh

6. Brief Background

Himalaya is called the water tower of Asia. Himalayan rivers gather melt water from glaciers, snow and rainfall and deliver it to the millions living in the nearby plains across the Shivaliks. But the paradox lies in the fact this pristine water flowing in the Himalayan gorges have little use for the mountain people living on its slopes. Their livelihood is solely sustained by the springs and small rivulets as well as the rain and snowfall. The issues of the mountain people is often neglected in the Himalayan climate change discourse. This project is framed with the strong conviction that the sustainable Himalayan ecosystem is a mirage without addressing burning issues of the mountain people. Flash floods and landslides triggered by the frequent extreme events is becoming a regular feature for the mountain people. Reducing winter snowfall/extent/duration in consonant with the increase in winter temperature has already impacted the mountain hydrological regime as evident in the changing spring flow characteristics. The prime objective of the water census is to identify the water sources of the mountain villages and habitat, their issues and concerns, their habits and water use pattern. This fundamental understanding is necessary for evaluating the climate change impact on the mountain habitat and structuring and implementing adaptive strategies for sustaining the Himalayan ecosystem.

Water accounting, otherwise known as 'water census' is as important as other census activities for population, livestock, etc. carried out by the Government every decade. The Water Census is an emerging concept vital for creating Decision Support Capacity for water management agencies and policy makers. This provide a detailed accounting of water availability and use in a region. The main aim of the Water Census is to integrate diverse research on water availability and use as well as enhancing the understanding of relationship between water quality and water availability. Further, water census can be an umbrella platform in the hands of the stakeholders working in the field of water resources with information on water availability, water uses, potential water hazards, and most importantly the livelihood linkages. Livelihood- water linkage is core to sustaining the Himalayan ecosystem for the mountain people. Water disasters are increasingly become a threat to the mountain habitat and economic

development under changing climate. Identification and management of potential water disaster zones are also key to sustaining Himalayan eco-system.
Considering these issues, this project is aimed to map and develop the water census (preliminary) for the Upper Ganga basin with information at micro (village) level on water availability, water use pattern and livelihood linkage, potential water threat, water structures not only for the major streams but also for tributary streams and rivulets close to habitat. It is also envisaged to identify the hot spot matrix components and its analysis to identify the most vulnerable sites (villages). This can only be accomplished by extensive survey at micro-level (village). The project could become a platform to integrate input from all other studies and information aiding policy formulation and strategic planning. Methodology developed and refined through this project can be replicated across the Himalayan region in subsequent stages of this mission.

An inter-linked approach to water resources management is envisaged in this project with following key components of water governance.

- Consider all water resources
- Address water demand as well as water supply
- Address wastewater management as well as water supply
- Involve all sectors and civil society stakeholders
- Promote access and gender equality
- Recognize the economic (livelihood), social, and environmental value of water.
- Recognize the water related threat and hazards for preventive measures (adaptation and mitigation strategies)

7. Methodology
The project will be executed as per the following roadmap:

Sampling
The study requires extensive survey work of two distinct nature, one is to develop water census of at least 100 selected villages distributed across the altitudes of the upper Ganga basin and another is of engineering survey of selected water structures/ sites. The engineering survey will capture L-section, X-section and other design flood parameters of selected bridges and culverts in the area.
The upper Ganga is divided into two major zones comprising of Alaknanda basin and Bhagirathi basin. Each of this major zones will be sub-divided into five sub-zones based on the elevation (altitude), climate etc. At least 10 villages will be screened from each sub-zones through scientific assessment and field visit as well as with discussion with other stakeholders.

Water census will be carried out by developing an elaborative matrix to capture various WRM components. A structured questionnaire and field mapping will be done to gather the information. An engineering survey will include mapping of the water structures, bridges, culverts etc. Landslide and earth quake hazard zonation maps will be integrated in the engineering survey.

Road map/ work components:
1. Preparation of GIS layers and Base line data collection
2. Selection of villages
3. Training of Resource Persons
4. Launch workshop
5. Stage I survey
    a. Attributes for water census
6. Mid-term Workshop

7. Diagnostics report
8. Stage II survey
9. Finalisation of Hotspot analysis
10. Development of adaptive strategies
11. Concluding workshop
12. Report preparation and submission

Activity chart (5 years)

Activity	**1st year**		**2nd year**		**3rd year**		**4th year**		**5th year**	
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

- Preparation of GIS layers and collection of baseline data, mainly from secondary sources is going on. Few thematic maps of the study area is provided separately.
- About 7000 villages (as per Census 2011) has been browsed and identified their location (latitude, longitude, elevation) from Google Earth. The identified villages has been mapped using ArcGIS to identify the villages based on different criteria.
- Digitized village boundary from the SOI, Dehradun has been procured and utilized.
- Process for identification and selection of villages is finalized.
- The rainfall induced extreme events (monsoon periods) since 2010 were followed in newspaper clippings for the study area. The year-wise extreme events are then plotted to investigate the pattern of occurrence. About 20% of the villages (out of 100) has been identified based on this. The database has been supplemented with the last monsoon (2017).
- Rainfall variability map has been prepared using 0.25x0.25 degree IMD data.
- A pilot surveyed using the developed questionnaire has been carried out in Neergaon village (Rishikesh) has been carried out on 27th October, 2017. Short-comings in the questionnaire during survey has been identified and corrections incorporated.
- A village level survey was carried out for 27 villages in the Henvel valley during 26-30 December, 2017 to gather different water-related information.
- Again a field level survey was conducted during 02-07 January, 2018 in the stretch between Uttarkashi to Harsil. During the survey 22 villages were visited and primary information on water were collected. GPSs were utilized to capture the village location (Lat, Lon, Elevation), springs, water sources, etc. A brief analysis of the survey will be presented before the members.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/08
NMHS STUDY

1. Title - Dynamics of Himalayan Ecosystem and its impact under changing climate scenario- Western Himalaya

2. Project team

National Team

Lead : Prof. A. P. Dimri, SES, Jawaharlal Nehru University, New Delhi, India
Co-Lead: Dr. R. Thayyen, National Institute of Hydrology, Roorkee, Uttarakhand, India

Institutional PI's

Dr. Subimal Ghosh (Indian Institute of Technology, Mumbai, Maharashtra, India)
Dr. Renoj Thayyen (National Institute of Hydrology, Roorkee, Uttarakhand, India)
Dr. P. K. Mishra (National Institute of Hydrology, Roorkee, Uttarakhand, India)
Dr. Sarat Kar (National Center for Medium Range Weather Forecasting, Noida, UP, India)
Dr. Soumya Prasad (Jawaharlal Nehru University, New Delhi, India)
Dr. Sumanta Bagchi (Indian Institute of Science, Bangalore, India)
Dr. Raman Kumar (Nature Conservation Foundation, Mysore, Karnataka, India)
Prof. A. P. Dimri (Jawaharlal Nehru University, New Delhi, India)

3. Objectives

The proposed project will address the following objectives, in particular for the Ganges and Indus within the western Himalayan Region, spanning select states:

1. *Develop database for climate* and ecological processes across the elevation gradients
2. Regional climate modeling with sub-grid orographic forcing, extreme hydrological events, biodiversity dynamics for the present (1970-2010)
3. Regional climate model simulations for climate change scenarios (upto ~ 2100)
4. Identify ecological restoration strategies to adapt to future climatic scenarios
5. Communicate findings to stakeholders

4. Present state-of-art

Developing a clear understanding of climate change impacts on Himalayan snow cover, glaciers, water storage and associated rivers, forest and ecosystems are key scientific questions which need to be assessed as these affect large a proportion of the Indian population living along the southern rim of the Himalayas. To address these issues we need a comprehensive understanding of climatic and ecological process for the Himalayan region. Due to limitations imposed by availability of climatic and ecological data layers, we have a limited understanding of impacts of future climates on ecological, hydrological and climate regimes in the Indian Himalayan Region.

The Himalayan region consists of diverse ecosystems, and encompasses a global biodiversity hotspot, and several Important Bird Areas. They span alpine, temperate, tropical non-monsoonal and monsoonal forest habitats, with heterogeneous topographic and landuse characteristics. As the world warms, several species and communities in mountain ecosystems have been documented to be moving to higher altitudes to keep track of suitable habitats. Faced with changing climates, species can (a) evolve adaptations to new climatic conditions, (b) adapt to new climatic conditions if they have pre-existing adaptations, (c) migrate to suitable habitats which have climatic conditions that match the species requirements or (d) go extinct if the species cannot evolve, adapt or migrate in response to changing climates (Corlett 2009). Anthropogenic climate change has already influenced biodiversity and ecological processes, and this is certain to increase in the coming decades. Changes in the distribution of species has been well documented in the temperate regions in the recent decades (Walther et al. 2002; Parmesan and Yohe 2003). There is limited baseline data to document such range shifts for the Himalayan region, and it has been forecast that a vast majority of species will display changes in distributions along rainfall and temperature gradients (Colwell et al. 2008; XU et al. 2009; Joshi et al. 2012))

5. Methodology (NIH)

Objective 1: NIH component of the project to install 50 AT/RH stations and 10 rainfall stations in the western Himalaya and develop data.

Objective 2: Climate data will be upended with IMD station data and mathematical formulations for temperature and precipitation gradients will be derived. This will provide better insights on the orographic processes controlling these variables. Climate envelope – biodiversity distribution relationships will be examined using niche models, including Maxium Entrophy models.

6. Research Outcome from the project

Deliverables (NIH): Fine resolution temperature data from 50 AT/RH stations and 10 precipitation stations for at least 3years. Regional slope environmental lapse rate of temperature and precipitation gradients.

7. Cost Estimate:

Total cost of the project:	Rs. 2.1 Crore
a. NIH	Rs. 58.76 Lakh
b. Source of funding:	NMHS-MoEF

8. Progress of the project

During the reporting period, procurement of 50 AT/RH and 10 rainfall stations sanctioned in the project are completed. Selection of proposed station locations are initiated using multiple criteria such as regional wind flow and SELR (Ridge to ridge), local wind flow (Valley-ridge), precipitation regime, LST etc. 5 profiles were shortlisted for Uttarakhand state and 5-10 standalone stations were proposed for Himachal and J& K states. Installation of the stations are in progress. Investigation of Slope lapse rate of temperature were carried out in Sutlej/Beas and Upper Ganga basin under monsoon regime. Two distinct temperature lapse rates, one constrained at higher altitude and one valley scale has been identified. Monsoon lowering is identified as a regional phenomenon. It is also suggested that the SELR variations linked with regional liquid condensation Level (LCL) which is in turn linked with the meso- scale climate systems. The study also suggests that the higher altitude SELR has higher interannual variability as compared to valley scale lapse rate. Hence it is suggested to use valley scale lapse rate for modeling purpose. Further work in this project include completion of sensor installation/ data collection and analysis.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/11

1. Title - Design and development of DSS (H) platform for Neeranchal National Watershed Project

2. Project team

a) Principal Investigator: Mr D.S. Rathore, Sc F
b) Project Co- investigators: Mrs Deepa Chalisgaonkar, Sc F
Dr Jyoti Patil, Sc C
Dr V C Goyal, Sc G

Approved budget

Source of funding: Neeranchal National Hydrology Project (NNWP), DoLR, GOI, WB
Date of commencement of sub project : April, 2016
Duration of sub project : 2 years

3. Objectives

To develop a web-based Decision Support System platform for deriving hydrological information required in preparation of DPRs for watershed development.

4. Statement of the Problem

The World Bank funded Neeranchal project plans to address a number of key issues defined by the Planning Commission and various other reports/experts for watershed programs in India, especially for IWMP watersheds in nine states. The project is a component of the PMKSY scheme of GoI. The Sub-component 2.2 of the Project (Decision Support System and Data Bases for Hydrology and Watershed Management) would develop and pilot a new decision-support system (DSS) to support DoLR and project states to implement IWMP in a more comprehensive and scientific manner, particularly around hydrology.

5. Present State-of-Art

Global practice is now shifting to initiate planning with watershed assessment at a larger scale, and incorporating better hydrological data. These planning processes are proving useful in facilitating more effective program integration. Various existing DSS at national and international level are review. These are ICAR-IISWC DSS for Farm Pond 1.0 and Drop Structure 1.0, ICAR-CRIDA Jal-DSS Watershed Development Monitoring and Evaluation Tool (WDMET), 2016, ICAR-Central Institute of Agricultural Engineering (Bhopal) software for design and data analysis, Fujian Normal University (China) DSS-WMRJ Watershed Management, Purdue University L-THIA etc. The DSS cover design, data analysis, impact assessment and use tools and hydrological models etc.

6. Methodology

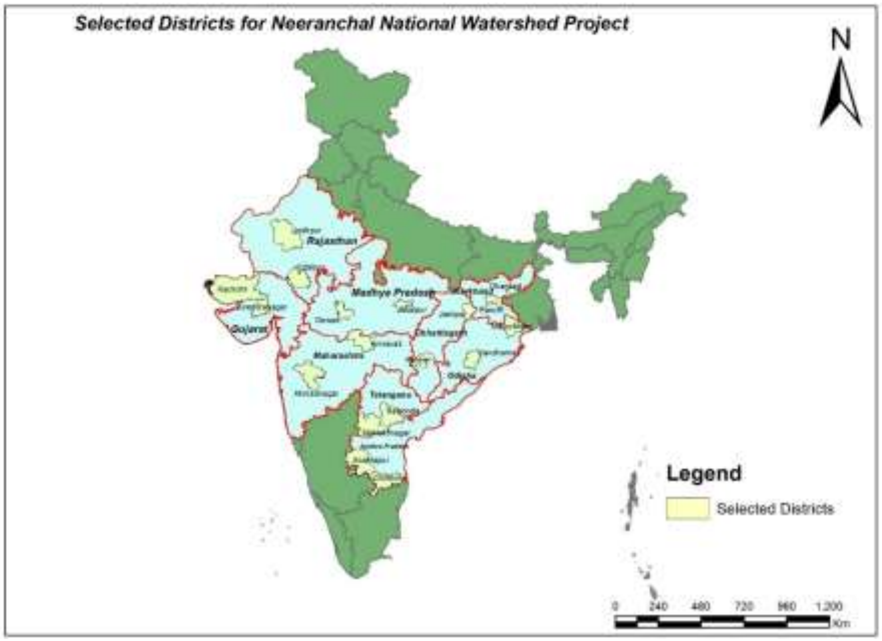
The DSS(H) shall address the following requirements of watershed development projects:

1. Water availability and demand planning;
2. Assessment of gap in water demand (at both spatial and temporal scales), and water allocation planning for addressing the gap;
3. Selection of suitable sites and structures for water harvesting and water conservation;
4. Impact assessment of the soil and water conservation interventions, leading to development of watershed scorecard; and
5. Improved hydrological information to support preparation of DPRs for the identified watersheds.

DSS-H will be developed as a web based system with thin client and three tiered structure. Three tiers will consist of front end, application layer and database layer. Database is an important component of a DSS. For specific hydrological and SDSS application, specific data input is needed. The applications provide tools for processing the data to create specific output relevant to users. DSS-H shall be enabled to act as data repository for hydro-meteorological, satellite remote sensing and GIS data. It shall be possible to integrate available web GIS OGC services for spatial data visualization.

7. Location map/ study area

DSS will be developed for nine states. Two district in each state and six watershed in each district are selected. DSS will operate at scale of basin, sub-basin and watershed.



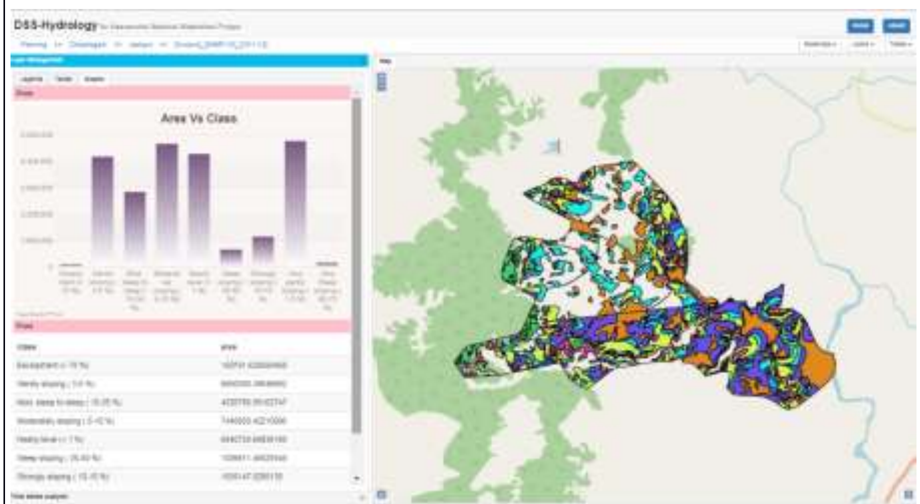
8. Approved action plan and time line

S N	Work Element	2017-18				2018-19			
		I	II	III	IV	I	II	III	IV
1	DSS model conceptualization								
2	Design of protocol of database generation								
3	Generic DSS development								
4	Design of GUI for DSS								
5	DSS customization as per user needs								
6	DSS testing and refinement								

9. Recommendations / suggestions in previous WG

None

10. Achievements

Year	Objectives	Achievements
2017-18	Generic DSS development	 Development of DSS-H platform is in progress as web- enabled platform. Main software components, used in DSS development are PHP, OpenLayers, Geoserver, PostgreSQL, PostGIS and Fusion Charts. DSS-H platform is organized around modules, namely planning, site selection, impact assessment and input to DPR. For each module, selection of watershed precedes further action. For watersheds, functions of visualization and processing are organized in layer, table, chart and tool groups. One layer at a time can be visualized along with its legend. All spatial and non- spatial tables can be visualized along with its chart. Few test spatial and non- spatial data were entered in to DSS database. Development of tools e.g. water quality index, NRCS rainfall- runoff modeling is in progress. The tools can be run using test data for watersheds.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017-18/12

1. Title - Monitoring and Modeling of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

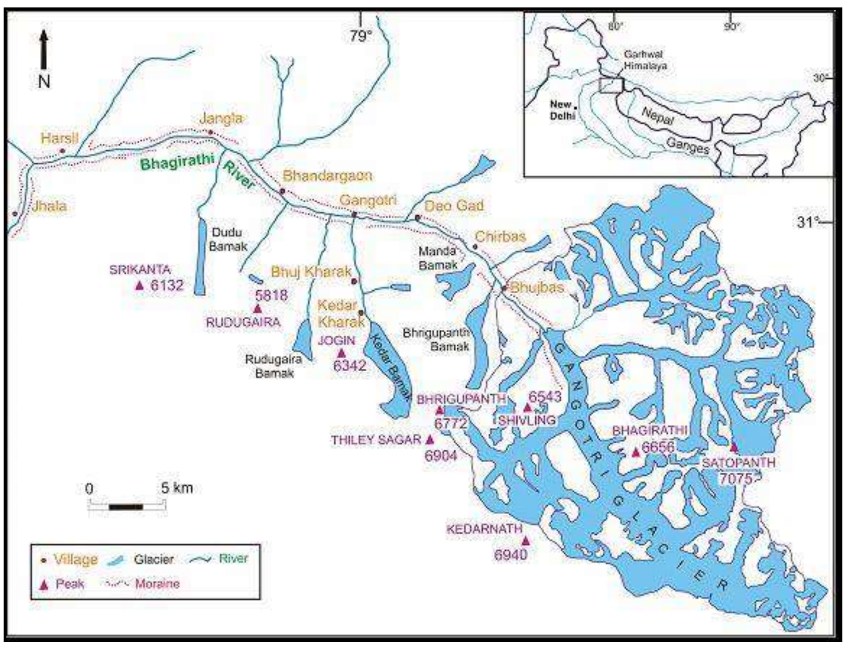
2. Study Group: Dr Manohar Arora Sc 'D'
Dr Rakesh Kumar Sc 'G'

3. Role of Team Members:

1. **Dr. Manohar Arora, Scientist D&PI:** Conduction field investigations, analyzing data/information, report preparation and overall responsible for the study completion.
2. **Dr Rakesh Kumar, Scientist G&Co-PI**: Guidance in development of methodology, modelling and structuring of report.

Date of start: 01.5. 2014
Scheduled date of completion: 31.03.2017. Extension from DST received for 3 months. Further extension till 31.03.2018 in progress.

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.
- To study the melt water storage and drainage characteristics of the glacier and to simulate daily streamflow using a conceptual hydrological model using observed meteorological and hydrological data.
- Modeling the role of glacier in catchment runoff variation.
- 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 develop and apply a snow melt model for streamflow generation and identification of different runoff components. The third step is to model role of glacier in catchment runoff variation and catchment runoff variation under different scenarios.

7. Approved action plan

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

8. Objectives vis-a-vis Achivements

Objectives	Achivements
Continuous monitoring of meteorological and hydrological data for monthly and seasonal specific water yield and its variability from the year to year	The data collected in summer 2017was processed and analysed. The results will be presented before the Working Group Experts.
To study the melt water storage and drainage characteristics of the glacier and to simulate daily streamflow using a conceptual hydrological model using observed meteorological and hydrological data.	The melt water storage and drainage characteristics for the year 2017 have been completed.
Modeling the catchment runoff variation under different climatic scenarios	The model parameters have been determined. The HBV model is used and 2014-15 data is used for calibration and 2016-2017 data is used for validation purpose. The study will be completed by 31st March 2018.

9. Recommendations of Working Group/TAC/GB

The study may be continued for long term to link with climate change.

10. Analysis and Results

The Department of Science and Technology has sponsored this study.

11. Adopters of the results of the study and their feedback

The study is a sponsored study and the results will be disseminated by DST.

12. List of deliverables

Major items of equipment procured: Nil

Lab facilities during the study: Analysis of suspended sediment samples will be carried out in Soil Lab.

Data generated in the study: Meteorological and hydrological data for the Gangotri Glacier.

13. Study Benefits/Impact

The study is being sponsored by DST. The meteorological and discharge data would be utilised in studying the characteristics of the Gangotri glacier under changing climate.

14. Specific linkages with Institutions/beneficiaries

The data collected is also being shared with the authorities of Gangotri National Park. The details of sediment concentration are being communicated to the downstream Dam authorities.

15. Shortcomings/Difficulties

The study involves four months of extensive field work and maintenance of construction site etc. Without the support of project staff it is difficult to manage data collection.

16. Future Plan

The study will be conducted for long term. The Himalayan glaciers are poorly monitored. There is very little or sparse data of Himalayan Glaciers The collected data will be used for climate change studies.

NEW STUDIES
RESEARCH PROJECT: NIH/WRS/2018-19/01

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

2. Project team:

c) **Principal Investigator:** Mr D.S. Rathore, Sc F

d) **Project Co- investigators:** Dr. L.N. Thakural, Sc C
Dr. Sanjay Kumar, Sc E
Dr. B. Venkatesh, Sc F
Dr. M.K. Jose, Sc D
Dr. T. Chandramohan, Sc D

3. Statement of the Problem

Large part of states such as Maharashtra, Karnataka and Andhra Pradesh in Peninsular India are affected by drought condition frequently. Due to availability of surface irrigation, large areas in Andhra Pradesh and some areas in Maharashtra and Karnataka, the drought conditions are mitigated in some parts only. Droughts and water stress conditions have socio- economic and environmental effects, necessitating scientific investigation of the conditions, response and mitigation measures. Drought response and mitigation causes moisture conservation, reduction in water demand and increase in supply. Changes in storages, thus caused, need to be simulated.

4. Objectives

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

5. Present State-of-Art

Drought indices:

Hydro meteorological data based:
Several indices for different time scale have been developed using hydro meteorological data. SPI is widely used as drought index and utilizes monthly rainfall data. There are indices which are based on stream flow, evapotranspiration and soil moisture. Indices are devised using water balance and also integrate multiple inputs. Soil Moisture Drought Index (SODI) is based on monthly soil moisture departure estimates from water balance model (Sohrabi et al. 2015). Aggregated Drought Index (ADI) and Nonlinear ADI (NADI) indices aggregate multiple inputs using linear and non linear principal component analysis ((Barua et al. 2012, Keyantash and Dracup 2004).

Remote sensing data based:
NDVI, NDWI, VCI and TCI have been widely used in characterizing drought. Soil Moisture Aggregated Drought Index (SMADI) combined using VCI, MTCI and SMCI using MODIS (for vegetation condition and temperature) and SMOS data (for soil moisture) (Sanchez et al. 2016). Vegetation TCI (VTCI) normalized LST based on its range over wide area representing varied soil moisture conditions (Tian et al. 2016). Vegetation Anomaly Index (VAI) is an index with normalized NDVI (Zribi et al. 2016).

Regionalization

Regionalization of drought severity and duration estimated from monthly Standardized Streamflow Index (SSFI) was done using Directional Information Transform (DIT) and average annual severity and average drought duration were estimated for homogeneous regions (Rajsekhar 2013). Principal Component Analysis (PCA) technique was used by Portela et al. (2017) in Slovakia on SPI. PCA and K-mean clustering technique was applied in Portugal on SPI (Santos et al. 2011).

Forecasting

Barua et al. (2012) used three-layer Recursive multistep ANN (RMSNN), Direct multistep ANN (DMSNN) and ARIMA (0, 1, 2) in forecasting of monthly NADI up to 6 months lead time in Yarra Catchment, Australia. Forecasts were validated using R, RMSE, MSE and difference in drought class. Tian et al. (2016) applied SARIMA (1, 1, 1) and (2, 1, 0) on VTCI in China for three ten day periods. Models were found to be better capable in forecasting the drought categories compared to AR-1.

Reservoir operation

Hue et al. (2016) developed hedging technique for reservoir operation, Comparison with dynamic programming, standard operation policy, conventional rule curve and existing hedging techniques showed improvement in average performance indices.

6. Methodology

Data collection: Hydro meteorological data, reservoir performance table (daily) and salient features (elevation- area- capacity curve/ table, characteristics levels etc.) will be collected. District Irrigation Plan (DIP), District Agriculture Plan (DAP), crop calendar cropping pattern, crop contingency plan, crop coefficient information will be collected.

Satellite data: Multi-date satellite data will be obtained (procured/ downloaded) for the area.
Field observation: Sites will be selected for root zone soil moisture observations. Soil moisture prob., raingauges will be procured. Soil moisture observation will be made at fortnightly interval and close interval immediately post rainfall events/ irrigation water supply. Raingauge data will be collected at regular interval.

Data pre- processing: Data will be pre-processed to remove trends, data consistency check, data filling etc. Inflows will be computed from reservoir working tables. Naturalized flows will be computed. Hydrological time series will be extended based on availability of data.

Computation of drought indices: Drought indices will be computed from hydro meteorological data and remotely sensed data.

Regionalization of indices: Drought indices will be regionalized using available methodologies and homogeneous regions will be identified.

Forecasting: Forecasting model will be fitted from historic time series of drought indices and its accuracy will be assessed.

Drought identification: Drought identification will be done from historic time series.
Unsaturated zone modeling: Unsaturated zone modeling will be carried out.
Reservoir operating policy: Conventional rule curve will be derived by simulating reservoir operation at different dependable flows. Simulation/ optimization techniques will be used for devising reservoir operating policy for water stress situation. The results will be compared using performance indices e.g. maximum shortage ratio, shortage index, modified shortage index etc. Software namely Mike Basin, HEC PRM etc. will be used.

Scenario analysis: Scenario analysis will be done for identified droughts in the historic data. Water balance modelling will be done for the scenario and indices will be re computed. Efficacy of the response and mitigation measures will be studies by comparing the indices of historic and scenario indices.

Research outcome from the project
Following are the envisaged outcome of the study:

Work schedule

a) ***Date of commencement of project:*** *September 2017*
b) ***Duration of the project:*** *3 years*
c) ***Stages of work and milestone:***

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												

NEW STUDIES
RESEARCH PROJECT: NIH/WRS/2018-19/02

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

2. Study Group : Dr Manohar Arora, Sc 'D'
Dr Sanjay Kumar Jain, Sc 'G'

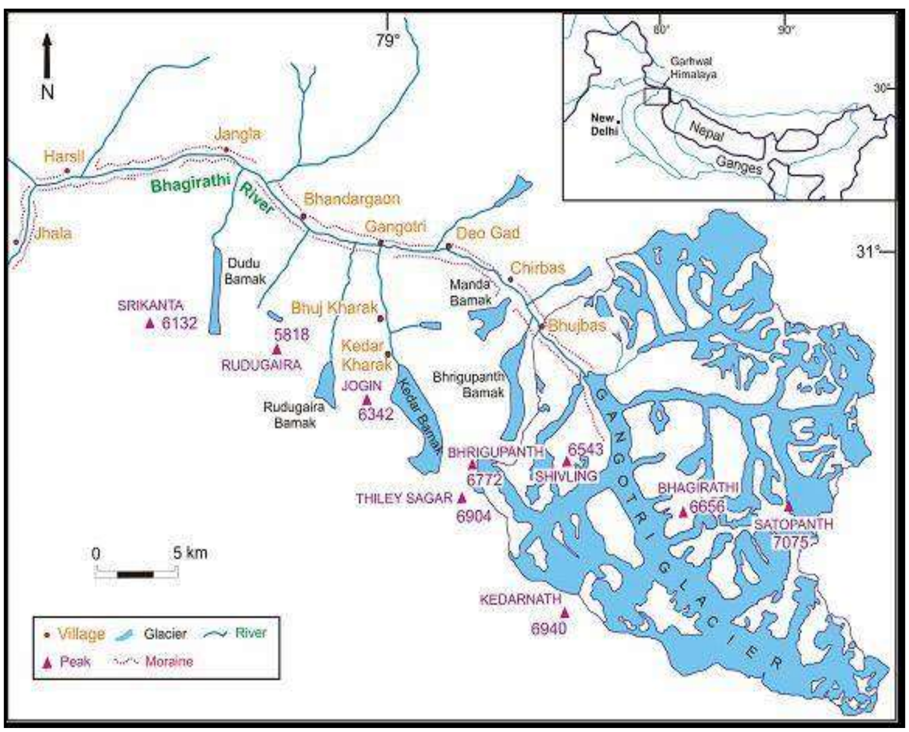
3. Role of Team Members:

Dr Manohar Arora, Sc-D&PI: Conduction field investigations, analyzing data/information, report preparation and overall responsible for the study completion.
Dr Sanjay Kumar Jain, Sc-G&Co-PI: Guidance in development of methodology, modelling and structuring of report.

4. Type of Study : Internal. Project will be submitted to DST for funding.

Date of start : 01.04.2018
Scheduled date of completion: 31.03.2021.

5. Location Map:



6. Objectives: The objective of this study includes:

- Continuous observations of meteorological, hydrological and suspended sediment data for the melt season to determine monthly and seasonal specific water and sediment yield from the study glacier.

- Seasonal characterization of the glacier melt.
- Estimation of suspended sediment yield from the Glacier.
- Modeling the catchment runoff variation under different climatic scenarios.

6. Statement of the problem

The study involves collection and analysis of hydro-meteorological and discharge data of the glacier site. The second step is to use a snow melt model for streamflow generation and identification of different runoff components. The third step is to simulate catchment runoff variation under different scenarios.

7. Action Plan

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

8. Adopters of the results of the study and their feedback

The study is a sponsored study and the results will be disseminated by DST.

9. Lab facilities during the study

Analysis of suspended sediment samples will be carried out in Soil Lab.

10. Data generated in the study

Meteorological and hydrological data for the Gangotri Glacier.

11. Study Benefits/Impact

The meteorological and discharge data would be utilised in studying the characteristics of the Gangotri glacier under changing climate.

12. Specific linkages with Institutions/beneficiaries

The data collected is also being shared with the authorities of Gangotri National Park. The details of sediment concentration are being communicated to the downstream Dam authorities.

13. Shortcomings/Difficulties

The study involves four months of extensive field work and maintenance of construction site etc. Without the support of project staff it is difficult to manage data collection.

14. Future Plan

The study will be conducted for long term. The Himalayan glaciers are poorly monitored. There is very little or sparse data of Himalayan Glaciers The collected data will be used for climate change studies.

NEW STUDY

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

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

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

4. Statement of The Problem:

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

5. **Objective** : To develop a WINDOWS based Software package for hydrological data processing and Unit Hydrograph analysis

6. Methodology:

The software will have a user friendly environment for carrying out the various computations involved in the hydrological data processing unit hydrograph analysis. The software will include following main components: (i) Processing and analysis of precipitation data, (ii) Computation of discharge and rating curve analysis, (iii) Computation of excess rainfall and direct surface runoff, (iv) Unit hydrograph derivation, (v) Reproduction of direct surface runoff and estimation of flood hydrograph and, (vi) Calculation of design flood. It is proposed to include online help at each stage of running the package. The interface will be capable of presenting the results in tabular as well as graphical form. Descriptive data forms will be prepared for easy preparation of data files.

7. Research Outcome of the Project:

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

RESEARCH MANAGEMENT AND OUTREACH DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. V C Goyal	Scientist G & Head
2	Er Omkar Singh	Scientist F
3	Dr. A R Senthil Kumar	Scientist E
4	Er. Digamber Singh	Scientist C
5	Dr. (Mrs.) Jyoti Patil	Scientist C (LCU)
6	Sri Subhash Kichlu	PRA
7	Sri Rajesh Agrawal	SRA
8	Sri N R Allaka	RA

WORK PROGRAMME FOR 2017-18

SN	Title of Project/Study	Source of Fund	Study Team	Duration	Status
Internal Study					
1	Development of IWRM Plan for Ibrahim-Masahi village (Haridwar district)	NIH	Omkar Singh V C Goyal Subhash Kichlu Rajesh Agarwal	Apr 2013-Sep 2017	IWRM Plan& NTS developed and being commissioned by March 2018
2	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar J V Tyagi S D Khobragade Manohar Arora	Apr 2015-MAr 2018	Extension sought up to Sep 2018
3	Effect of climate change on evaporation at point scale	NIH	Digambar singh A R Senthil kumar Manohar Arora	Jun 2014-oct 2017	Extension sought up to Jun 2018
	Sponsored Projects				
1	Development of IWRM Plan for identified watersheds in Jhansi, Lalitpur and Chhatarpur districts	NIH	**NIH:** V C Goyal, Jyoti Patil **MPCST:** Sandeep Goyal, Rajesh Saxena **UP-RSAC:** Rajiva Mohan, Sudhakar Shukla	Apr 2016-Mar 2018	To be completed by March 2018
2	Vulnerability assessment of identified watersheds in Neeranchal Project States	DoLR (GoI)-Neeranchal Sub project	Jyoti P Patil + RCs	Jul 2017-Jun 2019	Ongoing
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts	MoWR-funded project	V C Goyal Omkar Singh Digambar Singh Rajesh Agarwal	Apr 2017-Mar 2020	Ongoing (DPRs of 12 ponds Prepared)
4	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	NMSHE	A R Senthil kumar J. V. Tyagi, M. K. Goel S. D. Khobragade P. C. Nayak, Manohar Arora, Digambar Singh	Mar 2016-Mar 2021	Ongoing

WORK PROGRAMME FOR 2018-19

SN	Title of Project/Study	Source of Fund	Study Team	Duration	Status
Internal Study					
1	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar (PI) J V Tyagi, S D Khobragade	Apr 2015- Mar 2018	Ongoing Extension up to Sep 2018
2	Effect of climate change on evaporation at point scale	NIH	Digambar singh (PI) A R Senthil Kumar, Manohar Arora	Jun 2014- Oct 2017	Ongoing Extension up to Jun 2018
3	Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of water management plan	NIH	Digambar Singh (PI) Omkar Singh, Subhash Kichlu N R Allaka	Apr 2018- Mar 2020	New Study (Follow up of Bundelkhand 4-district project)
4	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH & CEH (UK)	Omkar Singh (PI) V C Goyal, Digambar Singh, Subhash Kichlu, NR Allaka	Apr 2018- Mar 2020	New Study (Follow up of earlier study)
	Sponsored Projects				
1	Vulnerability assessment of identified watersheds in Neeranchal Project States	Neeranchal Project	Jyoti P Patil (PI) + RCs	Jul 2017- Jun 2019	Ongoing
2	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	NMSHE	A R Senthil kumar (PI) J. V. Tyagi, M. K. Goel S. D. Khobragade P. C. Nayak, Manohar Arora	Mar 2016- Mar 2021	Ongoing
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts	MoWR-funded project	V C Goyal (PI) Omkar Singh, Digambar Singh, Subhash Kichlu	Apr 2017- Mar 2020	Ongoing (DPRs of 12 ponds Prepared)
4	Development of water allocation plan for a Neeranchal watershed in Chhattisgarh	Neeranchal Project	A R Senthil kumar (PI) T R Nayak, Jyoti P Patil Rajesh Agarwal	Apr 2018- Mar 2020	New Study
5	Development of Innovation centre for EcoPrudent Wastewater Solutions	DST (submitted in April 2017)	V C Goyal (PI), Jyoti P Patil, Amrendra Bhushan + from NIT Jaipur, IIT Bombay and IRMA Anand	5 Years	New Study (subject to approval)

Study- 1 (RMOD/2017-18/TS-4)
Internal Study (To be completed by Mar 2018)

1. **Title of the study: Water Conservation and Management in Ibrahimpur Masahi Village of Haridwar District (Uttarakhand)**

   Sub Title: Development of IWRM Plan for Ibrahimpur-Masahi village (Haridwar district).

2. **Study Group:**
   Sh. Omkar Singh, Sc "F"
   Dr. V. C. Goyal, Sc "G"

3. **Type of Study: Internal**

4. **Date of Start: April, 2013**

5. **Re-scheduled Date of Completion: Sept., 2017**

6. **Duration of the Study: 3.5 years**

7. **Study Objectives:**
   a. Assessment of water demand in the study area.
   b. Assessment of water availability in the study area.
   c. Assessment of water quality in the study area & eutrophication status of ponds.
   d. Preparation of IWRM plan for the study area.
   e. Rejuvenation of village pond/s by establishing a CW-based Natural Treatment System (NTS)
   f. Mass Awareness Activities.

8. **Statement of the Problem:**

In our country, most of the traditional sources of water (i.e. ponds) in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and face severe eutrophication mainly due to untreated input of wastewater in the ponds. The ponds located in the Haridwar District are also suffering from various hydrological problems and are at the verge of extinction, which require immediate intervention to restore for various uses. Rain water harvesting is a popular technique of developing surface water resources that can be used to provide water for livestock, domestic use and irrigation purposes. The purpose of rain water harvesting is to either augment existing water supplies or to provide water where other sources are not available. It also aims to provide water in sufficient quantity and of suitable quality for the intended use. Therefore, water conservation and its management of village ponds is essential for proper utilizing the water for beneficial use in the society. The water conservation and rain harvesting may be helpful for improving the livelihood of the peoples. The present study has been taken for Ibrahimpur Masahi revenue village, lying under Shipla Nadi-Halzora Nadi watershed (a tributary of Solani River), District Haridwar (Uttarakhand). The area of Ibrahimpur Masahi revenue village is 14.26 km^2. The Ibrahimpur Masahi revenue village consists of 5 five sub-villages under its jurisdiction, namely- Ibrahimpur, Masahi, Belki, Inayatpur and Halzora.

9. **Methodology:**

In this study, the necessary data from different sources was obtained for human population, cattle and crop acreage and types in the area. The village level data on demography, dwelling amenities, public buildings, etc. was also collected door to door during surveys. Field investigations were carried out to study soil characteristics (infiltration, soil texture and soil moisture, etc.) under different land uses. The surface and ground water quality monitoring and analysis was carried out as per standard procedures (APHA 1989; Jain and Bhatia, 1987). The water quality was evaluated for drinking (BIS-2012) and agriculture purposes (BIS-1987/2001; USDA 1954). Eutrophication of ponds was assessed using Carlson's Trophic State Index (Carlson, 1977) and to suggest rejuvenation of the ponds. Rainfall data for 27 years (1987 to 2013) was used to decipher dependable rainfall at 50% and 75% frequency levels based on data of nearest hydro-meteorological observatory at Roorkee. The rainwater harvesting potential of the sub-villages covering roof top water structures (school & Govt. building) would assessed using Ghisi et. al. (2006). The planning of wastewater management vis-vis rejuvenation of existing ponds using environmentally hazards free CW-based Natural Treatment System (NTS) is also proposed in the study. The brief methodology is given below:

Estimation of Domestic Water Requirement (Human Needs): In this study, the quantity of domestic water (m^3) per capita per day (DWR_d), per month (DWR_m), and per annum (DWR_a) was estimated as follows (based on vision of M/o DW&S, GoI):

$$DWR_d\,(m^3/day) = (P_{rural} \text{ x } 70 + P_{urban} \text{ x } 135) \text{ x}10^{-3}$$
$$DWR_m(m^3/month) = (P_{rural} \text{ x } 70 + P_{urban} \text{ x } 135)\text{x}10^{-3} \text{ x } 30$$
$$DWR_a(m^3/annum) = (P_{rural} \text{ x } 70 + P_{urban} \text{ x } 135)\text{x}10^{-3} \text{ x } 365$$

Livestock Water Requirement: Livestock Water requirement (LWR) refers to the quantity of water required for drinking and animal hygiene conditions (animal and place washing). The water required for livestock rearing depends on the number of animals and consumptive use per head (Amarasinghe *et al.*, 2004). The total livestock water requirement daily (LWR_d, m^3/day), monthly (LWR_m, m^3/month) and annually (LWR_a, m^3/annum) were estimated by adding water required for all domestic animals such as- cattle (cow family), buffaloes, bovines (cow family)/yak, sheep, goat, swine, and poultry (Frasier and Hyers, 1983):

$$LWR_d\,(m^3/day) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \text{ x}10^{-3}$$
$$LWR_m\,(m^3/month) = \{C\times85 + B\times85+B_o\times 85+S\times10 + G\times10 +S_W\times15+P \times0.40\} \text{ x } 10^{-3} \text{ x } 30$$
$$LWR_a\,(m^3/yr) = \{C\times85 + B\times85 + B_o\times 85+ S\times10 + G\times10 + S_W \times 15 + P \times 0.40\} \text{ x } 10^{-3} \text{ x } 365$$

Where, C is number of Cattles, B is number Buffaloes, B_o is number of Bovines/yalk, S is number of Sheep, G is number of Goats, S_W is number of Swines, P is no. of birds (poultry).

Crop Water Requirement: Crop water requirement was estimated broadly using Inductive method based on standard crop deltas (Varshney, et. al, 1983; Garg, 2005). Accordingly, the quantity of water requirements (IWR, m^3) is the product of cropped area (CA, m^2) and standard delta (Δ, m) of respective crops during different seasons as given below:

$$CWR\,(m^3) = CA\,(m^2) \text{ x } \Delta\,(m)$$

Typical values of standard deltas (S_Δ) are adopted from Table (Varshney, et. al, 1983).

Probability Analysis of Rainfall Data: The analysis of rainfall trend for the study area was carried out using 27 years monthly rainfall data pertaining to Hydro-meteorological Observatory of NIH Roorkee. The monthly data was arranged in descending order of their magnitude. The recurrence interval T (return period) of a particular magnitude was determined using Kimball's method (Weibull, 1939) as below:

$$T = (n + 1)/m$$

Where, T= recurrence interval (return period), n= total number of items data series, m= order number or rank of any particular storm value after arranging in descending order of their magnitude. The frequency F (expressed as percent of time) of that storm magnitude (having recurrence interval, T) is given by:

$$F\ (\%) = (1/T)100$$

In the present study, frequency curve (Precipitation P or I v/s F%) were developed for monthly rainfall data of the Roorkee using 27 years rainfall data.

Eutrophication

Assessment of Ponds: Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977) based on Secchi disk transparency, phosphate concentration and chlorophyll content. The equations are given below:

$$TSI\ (TP) = 14.42 \ln (TP) + 4.15 \quad .....(Eq.\ 1)$$
$$TSI\ (SD) = 60 - 14.41 \ln (SD) \quad .....(Eq.2)$$
$$TSI\ (CHL) = 9.81 \ln (CHL) + 30.6 \quad .....(Eq.\ 3)$$

Preparation of Water Conservation Plan: The water conservation plan in the sub villages consist of following steps:

Step 1: Estimation of rainwater harvesting potential in sub-Villages: The volume of rainwater that could be harvested per household per month was estimated as per Eq. given by Ghisi et al., 2006, as below (Aladenola and Adeboye, 2010; Ishaku, et al., 2013):

$$VR = \frac{R.HRA.RC}{1000}$$

Where, VR= monthly volume of rainwater per household (m^3), R= monthly rainfall depth (mm), HRA= household roof area (m^2), and RC= runoff coefficient (dimensionless). The basic monthly balance would be estimated by subtracting monthly water demand from collected monthly rainwater and is expressed as below:

$$Wa = Iv + Vc - Vu$$

Where, Wa= water available, Iv=initial volume in storage, Vc=volume collected and Vu= volume used.

The analysis will include estimation of:

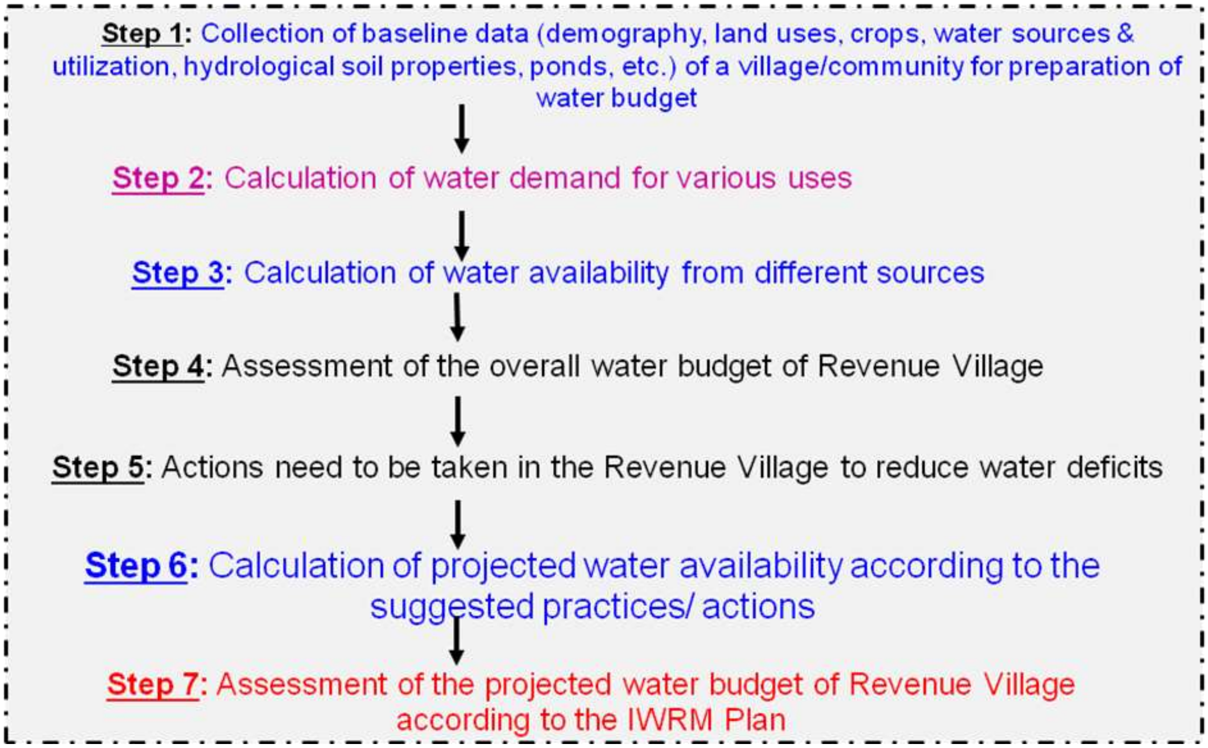
- Household monthly harvested rainwater & balance after flushing
- Household monthly harvested rainwater & balance after flushing & laundry (combined)

Apart from above, the following analysis will also be carried out:

- Rainwater harvesting potential of village ponds
- Monthly roof top water harvesting potential of schools/govt. buildings

Step 2: Planning for Wastewater Management (CW based-NTS) of Village ponds: The ponds are generally used as sink for all wastewater as well as for solid waste generated in the villages. Accordingly, village ponds are going to vanish due to the entry of sewage causing eutrophication. Therefore, it is proposed to rejuvenate pond (s) through establishment of a CW based Natural Treatment System (NTS) for treating village wastewater entering in the ponds and developing ponds for increasing rainwater harvesting potential for the benefit of local peoples.

Flow Chart Showing Integration of Various Inputs for IWRM Plan:



10. Timeline:

S. N.	Major Activities	2013-14			2014-15			2015-16			2016-17		2017-18	
		Q1	Q 2	Q3-Q4	Q1-Q2	Q3	Q4	Q1-Q2	Q 3	Q 4	Q1-Q2	Q3-Q4	Q1-Q2	Q3-Q4
1	Review of literature													
2	Reconnaissance survey of the study area													
3	Procurement/Collection of necessary data													
4	Field investigations (WQ, survey of ponds													
5	Analysis of data for assessment of water demand, availability, WQ													
6	Door to door survey for village level data/ bathymetric survey of pond/eutrophication assessment													
7	Preparation of IWRM Plan													

8	Establishing and development of CW-based NTS												
9	Report/s preparation												

11. Objectives and achievements:

Objectives	Achievements
i) Assessment of water demand in Ibrahimpur Masahi Revenue Village of the Haridwar District.	• Estimation of water demand for domestic, livestock and agriculture has been completed based on data obtained from various sources. (June, 14).
ii) Assessment of water availability in Ibrahimpur Masahi Revenue Village of the Haridwar District.	• Frequency analysis of monthly rainfall data pertaining to Roorkee for 27 Years (1987-2013) was carried out and deciphered dependable rainfall at F=50% and F=75%, respectively. Accordingly, Rain Water Availability at village and watershed level was carried out. (June, 14). • Measurement of cross section, water level and velocity data (Sept., 2014) of Shipla-Halzora Nadi was monitored at Imlikhera. The data was analysed to estimate the discharge of the river for Sept., 2014(March, 2015). • The soil texture and soil moisture data was analysed for the study area (March, 2015). • Drainage pattern was prepared using DEM (March, 2015). • Landuse/Landcover map of Ibrahimpur Masahi village was prepared using google earth images. • Groundwater utilization data pertaining to Hand pumps and Tub wells used for drinking and irrigation purposes was collected in the study area.
iii) Assessment of Water Quality Status & Eutrophication of Ponds in Ibrahimpur Masahi Revenue Village of the Haridwar District.	• Water quality sampling from River, Ponds, Hand Pumps/Tubewells, etc. was carried out in the study area and data was analyzed (March, 2015). • Water quality parameters necessary for Eutrophication analysis (Secchi depth, phosphate, Blue Green Algae, Chlorophyll, etc.) of ponds was monitored (Dec. 2015).
iv) Preparation of IWRM Plan	• Bathymetric survey of village pond at Masahi was completed (Dec. 2015). • A door to door survey was conducted in the sub-villages to collect necessary data pertaining to demography, dwelling amenities, public buildings, etc. for preparation of water conservation plan in the study. • Capacity estimation of village ponds was completed for RWH potential of ponds using depth data of bathymetric survey. • Estimated monthly rainwater harvesting potential of 5 sub villages based on door to door survey. • Water budget of village (Existing & Proposed as per suggested practices)
v) Mass Awareness Activities	**(i)** Conducted a villager's meet to interact with selected Farmers along with Gram Pradhan on dated 8/10/2016 at NIH, Roorkee

	regarding IWRM Plan. **(ii) Activities on NIH Foundation Day in Villages involving Scientists/staff of NIH (16/12/2016):** • Rally/Prabhat Feri and oath taking by children (Sankalp) in different Schools of 5 Sub Villages of by involving their respective school teachers for creating awareness amongst children and villagers. • Plantation in different schools of the Ibrahimpur Masahi revenue sub villages in association of ATHAK Foundation, Roorkee. • General awareness program on water and cleanliness issues (bhajan/Lokgeet, etc.) for villagers through hiring services of Rashtriya Jagriti Dal (Village Banjarewala, Dist. Haridwar). • Screening of water related films/activities on Bioscope for school children (through Delhi based Agency) • Theater Program on water related issues by local School children (through a Delhi based Agency) (iii) Soil Testing using PUSA-STFR Meter at selected farmers field, preparation/distribution of Soil Health Card to selected Farmers in the study area. (iv) The Division has coordinated Pond Cleaning work through involvement of Scientists/staff of all Divisions of the Institute under Swachh Bharat Abhiyan of GoI/MoWR during 16-31 March, 2017 at Village Masahi in the study area.
vi) Establishing a CW-based Natural Treatment System (NTS)	The works related to rejuvenation of pond: • De-weeding & de-silting of pond Ibrahimpur Masahi • Establishment of a CW-based NTS in pond • Barbed wire Fencing of pond • Plantation of suitable plants (Canna indica/Fragmites) in CW-NTS for development of phyto-remedation based waste-water treatment system.

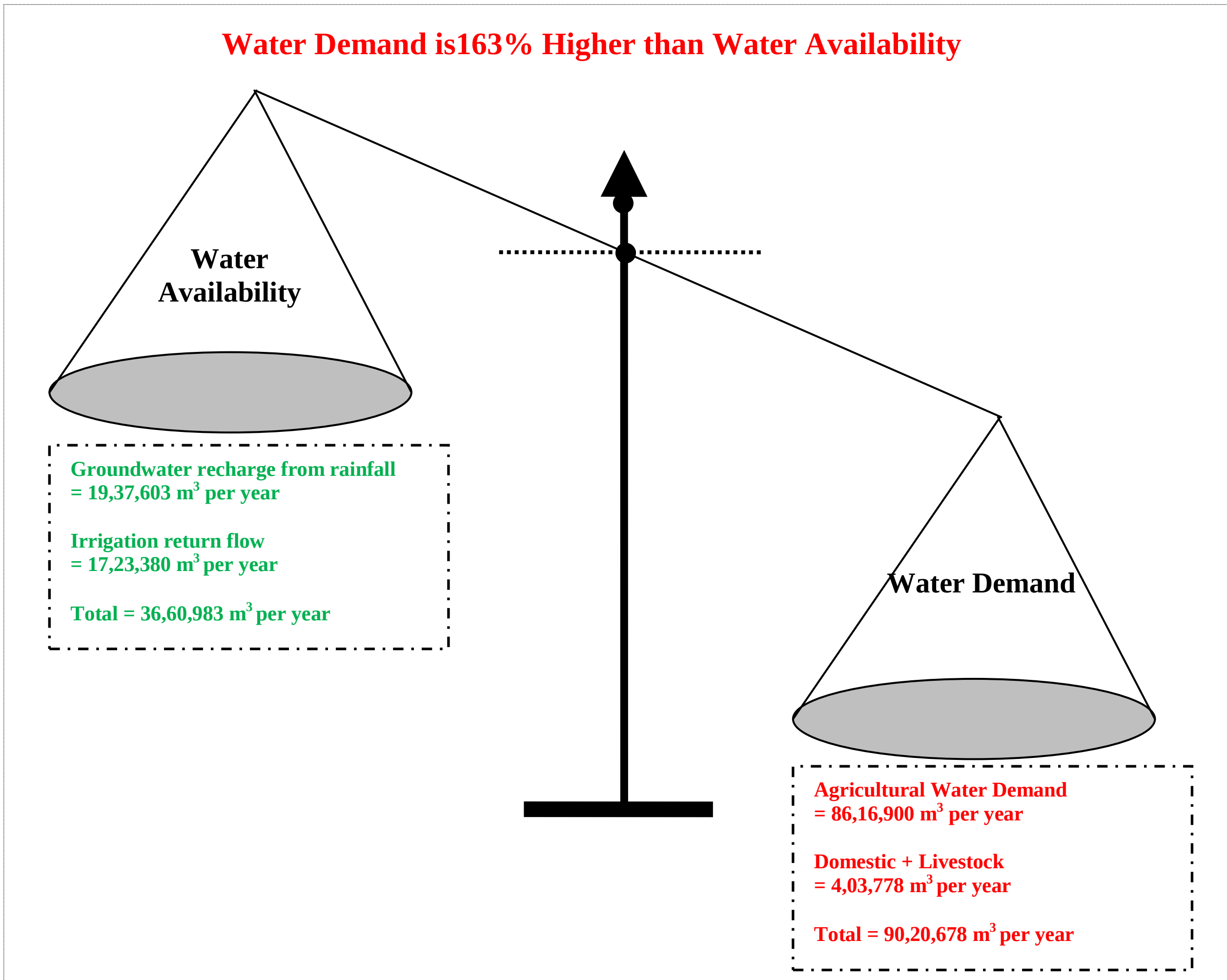
12. Recommendation / Suggestion:

Recommendation / Suggestion/Queries	Action Taken
-	-

13. Analysis & Results:

The major works already completed in the study include: water demand estimation for domestic, livestock, agricultural, water quality assessment, soil sampling and analysis and preparation of soil health cards for progressive farmers, bathymetric survey of pond, capacity estimation of RWH potential of ponds, monthly roof top rainwater harvesting potential of 5 sub-villages based on door to door survey of family wise dwelling amenities, mass awareness activities, etc.. The latest progress includes: Completion of civil works related to CW-based NTS in the pond including de-weeding, de-silting, improvement of pond periphery and barbed wire fencing and suitable plantation in constructed wetland for phyto-remediation based wastewater treatment. Field investigations related to ground water level variation and water quality investigations were also carried out during the year.

- The IWRM plan showing water budget with existing practices for Ibrahimpur Masahi village is given below:



<u>Figure</u>: Water budget of the Revenue Village (existing practices)

<u>As per Step 5 of IWRM Plan, the a</u>ctions need to be taken in the Revenue Village to reduce water deficits are given below:

I. Change of flood irrigation system to drip irrigation to reduced the crop water requirement (upto % 50).
II. Collection of water runoff from villages and creation of ponds in the vicinity aimed to enhance groundwater recharge.
III. Implementation of roof-top rainwater harvesting system to conserve rain water.
IV. Implementation of natural wastewater treatment system for gainful recycling and reuse.

- Accordingly, the IWRM plan (according to suggested practices) for Ibrahimpur Masahi village is given below:

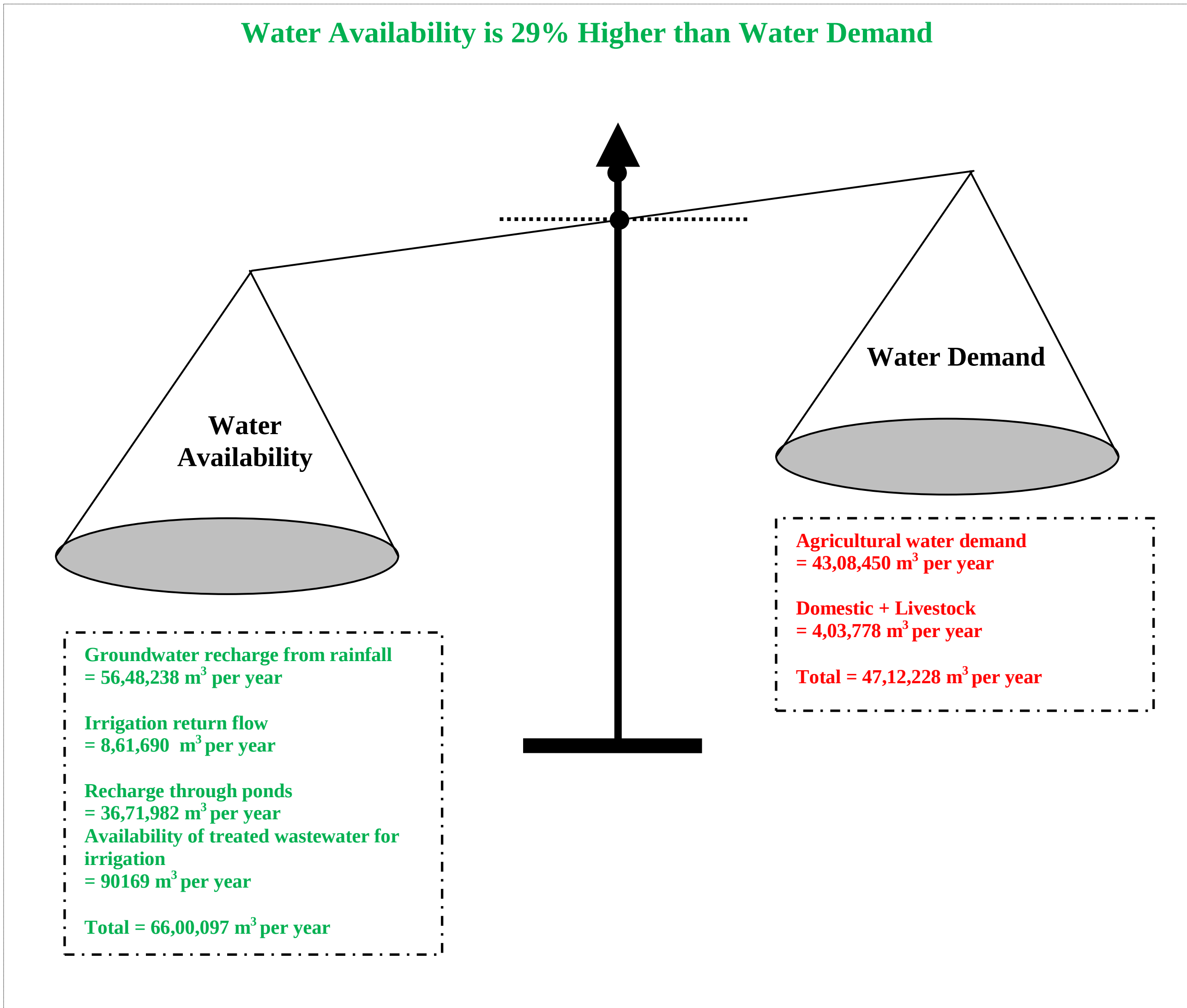


Figure: Water budget of the Revenue Village (according to suggested practices)

14. **End Users/Beneficiaries of the Study:** Village Panchayats and Dist. Administration

15. **Deliverables:** Technical report/papers, soil health cards, establishment of CW-based NTS in pond/s for village wastewater treatment.

16. **Major items of equipment procured:** Pusa STFR meter and Paddle boat

17. **Lab facilities used during the study:** Soil & GW Lab, WQ Lab

18. **Data procured or generated during the study**: Soil properties, water & wastewater quality, GWL, bathymetric survey, village amenities (cattle population, households & population, dwelling amenities, cropping pattern, educational amenities, etc.)

19. **Study Benefits / Impacts:** Helpful for improving the livelihood of the local people

20. **Involvement of end users/beneficiaries:** Local people

21. **Specific linkage with Institution and /or end users / beneficiaries:** Village Panchayat, Tehsil and Block level Institutions of State Govt.

22. **Shortcoming/Difficulties:** Observed initial difficulties of executing civil works in the pond for establishing NTS in the field.

23. **Future Plan:** Performance evaluation of constructed wetland based NTS in collaboration with CEH-UK (a separate study).

Study– 2 (2017-18)

Sponsored Project (To be completed by Mar 2018)

1. **Title of the Study:**
Development of IWRM Plan for Jhansi, Lalitpur and Chhatarpur districts (MoWR-funded Bundelkhand-4 district project)

2. **Study Group:**
Dr V. C. Goyal, Sc "G"
Dr Jyoti P. Patil ,Sc "C"
Dr Sandeep Goyal and Dr Rajesh Saxena, MPCST, Bhopal
Sri Rajiva Mohan and Sri Sudhakar Shukla UP-RSAC, Lucknow

3. **Type of Study:** Action research

4. **Date of start:** 01.04.2016

5. **Scheduled date of completion:** 31.03.2018

6. **Duration of the Study:** 2 years

7. **Study Objectives:**
The main objective of the study is to develop IWRM plan for three watersheds of Bundelkhand region

8. **Statement of the Problem:**

Bundelkhand is witnessing fluctuations between extremes in weather conditions– long drought spell and intense monsoon rainfall. For most part of the year, the residents of Bundelkhand region experience acute scarcity of water for domestic, agricultural and industrial use. Water sources are varied and often seasonal, ranging from ponds, tanks, lakes and streams to open wells, bore wells and irrigation canals radiating out from large-scale dams. Most agriculture is single-crop and rainfed with supplementary water from open wells. Thus, large numbers of farmers are highly dependent on the monsoon rains to recharge these wells.

To improve the water situation in the region, it is felt that an integrated approach to water management has to be undertaken. The water management approach has to be built around the concept of efficient management and sustainability (quality and quantity), and building of livelihood systems at village level for community based management of water challenges.

9. **Brief methodology**

The methodology of the study includes conducting a rapid vulnerability assessment using IPCC approach, and working out water budgeting in the three watersheds using secondary data. Finally an IWRM Plan will be developed to introduce an integrated approach of water management linked with the concept of livelihood in the identified three watersheds of Bundelkhand region. The IWRM Plan will have three sections- (i) Water management, (ii) crop management, and (iii) livelihood management.

With a view to address the scarcity of water availability in the study region, establishment of demonstration rainwater harvesting systems is planned at few identified village sites (mainly school buildings). With the help of MPCST, Bhopal, demonstration and training of stakeholders on livelihood activities is being taken up in few identified villages. Experiences of such demonstrations provide useful inputs in preparing the "Livelihood Management" section of IWRM Plan.

Maps have been prepared showing suitable water harvesting sites in the three watersheds. Field verification of these suggested sites was undertaken for finalization of the suitable sites based on the local site conditions. Also, a number of ponds are available in the three watersheds. Water quality assessment of these ponds is completed in these watersheds. The results of water quality analysis provide useful inputs for the "Water Management" section of the IWRM Plan.

For the "Crop Management" section, the secondary data from KVKs and the results from the Focused Group Discussions (FGD) conducted at few field sites will be used.

The draft IWRM Plans will be discussed with the stakeholders in the respective watersheds by organizing Stakeholders' workshops. After incorporating the feedback and suggestions of the stakeholders, final IWRM Plan will be handed over to the district authorities in the respective watersheds.

10. Timeline:

S. N.	**Work Element/ Milestone**	**2016-17**				**2017-18**			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
	Collection of data from secondary sources in UP & MP								
	Water balance estimation								
	First stakeholders' workshop								
1	Vulnerability assessment								
2	Establishment of demonstration rainwater harvesting systems at identified sites								
3	Demonstration/training of stakeholders on livelihood activities in identified villages								
4	Field verification of suitable water harvesting sites								
5	Bathymetry survey and water quality assessment of ponds								
6	Preparation of draft IWRM plan								
7	Stakeholders' feedback workshop on draft IWRM plan								
8	Submission of IWRM plan to district authorities								

11. Objective and achievement during last six months: To be presented.

Demonstration/training of stakeholders on livelihood activities in identified villages	Completed in Tikamgarh and Chhatarpur districts. Villages are identified in Jhansi and Lalitpur
Bathymetry survey and water quality assessment of ponds	Bathymetric survey was done in Tikamgarh. Water quality analysis of ponds is completed in all three districts.
Preparation of draft IWRM plan	Draft IWRM is prepared
Stakeholders' feedback workshop on draft IWRM plan	Stakeholders feedback workshops are planned during February and March, 2018

12. Analysis & Results:

Suggestions for agricultural management

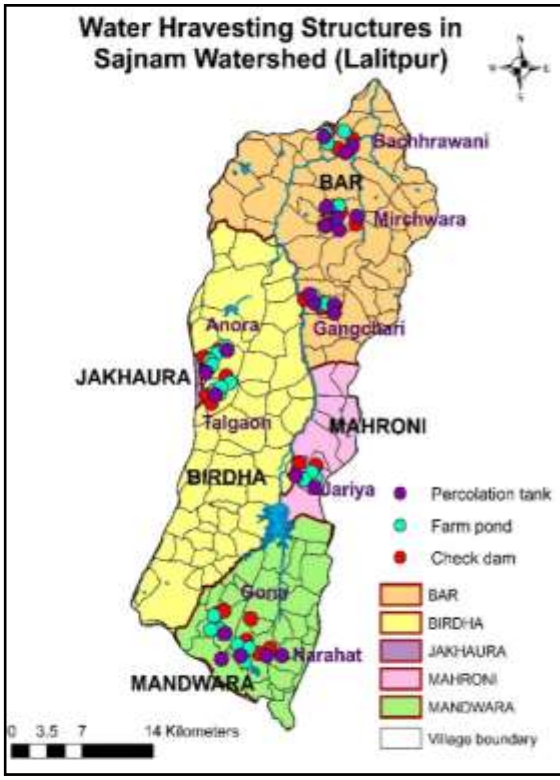
<table>
<tr><th>Component</th><th colspan="2">Water Efficient Irrigation Technologies</th><th colspan="2">Crop Rotation</th></tr>
<tr><td rowspan="3">Agriculture Technology and Management Agency (ATMA)</td><td>SRI (System of Rice Intensification)</td><td>Rice</td><td colspan="2" rowspan="2">✓ Wheat → Green gram → Rice
✓ Wheat → Green gram → Maize
✓ Soybean → Wheat → Blackgram → Mustard → Soybean
✓ Groundnut → Cowpea → Rice</td></tr>
<tr><td>SWI (System of Wheat Intensification)</td><td>Wheat</td></tr>
<tr><td>SCI (System of Crop Intensification)</td><td>Maize, Sorghum, Mustard, Blackgram</td><td colspan="2" rowspan="2">Component: Integrated Nutrient Management (INM)</td></tr>
<tr><td>Per drop more crop (Micro Irrigation)</td><td>Drip Irrigation</td><td>Maize, Vegetable and Fruit crops</td></tr>
<tr><td rowspan="2">AIBP</td><td rowspan="2">Irrigation at critical stages</td><td rowspan="2">Wheat (including crown root initiation and flowering stage), Soybean</td><td colspan="2">Crop Diversification</td></tr>
<tr><td>Kharif</td><td>Rabi</td></tr>
<tr><td>National Horticulture Mission</td><td>Wadi (Agri-Horti based model)</td><td>Fruit (Aonla, Guava, Mango) and vegetable crops</td><td>Cowpea + Groundnut + Sorghum Groundnut + Blackgram</td><td>Gram + Wheat + Pea</td></tr>
<tr><td>National food Security Mission (NFSM)</td><td colspan="4">Line Sowing for all types of crops like Blackgram, Groundnut, Rice, Wheat, Mustard, Maize etc.</td></tr>
</table>

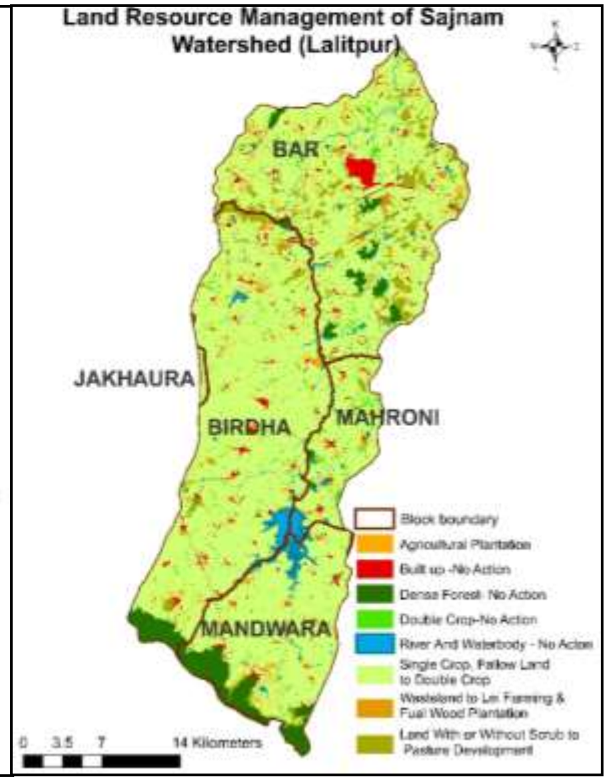
Land use change suggestions for LRM

Current Land Use	Blocks	Suggested change
Land with or without scrub	Bar	Pasture development
Single Crop, Fallow Land	All blocks	Double Crop
Wasteland	Bar and Birdha	Lei Farming and Fuel wood plantation
Built up	All blocks	No action
Dense forest	All blocks	No action
Double Crop	All blocks	No action
River and Water bodies	All blocks	No action
-	All blocks	Agricultural Plantation

Livelihood activities proposed in the selected villages of Sajnam Watershed

Block	Village	Activities
Mahroni	Jariya	Pisciculture, Organic farming/Vermicomposting, Bee Keeping, Edible mushroom cultivation, Jute items making/ bamboo craft, Roof water harvesting model.
Birdha	Talgaon	Organic farming / Vermicomposting, Bee Keeping, Pisciculture, Jute items making/ bamboo craft, Roof water harvesting model.
Birdha	Anora	Organic farming / Vermicomposting, Bee Keeping, Jute items making/ bamboo craft, Roof water harvesting model.
Mandwara	Gona	Pisciculture, Organic farming /Vermicomposting, Bee Keeping, demonstration, Edible mushroom cultivation, Jute items making/ bamboo craft, terracotta, Roof water harvesting model.
Mandwara	Narahat	Organic farming/Vermicomposting , Bee Keeping, Jute items making/ bamboo craft, Edible mushroom cultivation, Roof water harvesting model.
Bar	Gangchari	Organic farming/Vermicomposting , Jute items making/ bamboo craft, Edible mushroom cultivation, Roof water harvesting model.
Bar	Mirchwara	Organic farming/Vermicomposting , Jute items making/ bamboo craft, Edible mushroom cultivation, Bee Keeping, Roof water harvesting model.
Bar	Bachhrawani	Organic farming/Vermicomposting , Bee Keeping, Edible mushroom cultivation, Jute items making/ bamboo craft,Roof water harvesting model.





13. **End Users / Beneficiaries of the study:** Water Resources Planners of respective district

14. **Deliverables:** IWRM Plan. Awareness on the water situation and management through training workshop for the stakeholders

15. **Major items of equipment procured:** Remote survey boat

16. **Lab facilities used during the study:** Nil

17. **Data procured or generated during the study: -**

18. **Study Benefits / Impacts:** Outputs of the study will be used in preparation of District Irrigation Plans and District Agricultural Plans by the respective line departments

<u>Study– 3 (2018-19)</u>
Internal Study (Ongoing)

1. Title of the study: Study on effect of climate change on sediment yield to Pong reservoir

2. Study Group:
Dr. A. R. Senthil kumar Sc E
Dr. J. V. Tyagi, Sc "G"
Dr. Suhas Khobragade, Sc "F"
Dr Manohar Arora, Sc "D"

3. Date of start: 1 April 2015

4. Duration of the study: 3 Years

5. Whether externally funded or not: No

6. Objectives of the study:

a. To model sediment yield at Pong dam.
b. To investigate the impact of likely future changes in climate on sediment yield up to Pong dam using future climatic scenarios.
c. To assess the life of the reservoir for the likely sediment yield under the projected different climatic scenarios.

7. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Pong reservoir.

8. Brief methodology:

Sediment yield model

The sediment yield up to Pong reservoir is modeled by Soil and Water Assessment Tool (SWAT) with the information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed.

Climate Scenarios

The different scenarios of climatic conditions such as RCP2.6, 4.5, 6 and RCP8.5 are obtained from CMIP5 models available from different institutes.

Computation of sediment yield under different scenarios

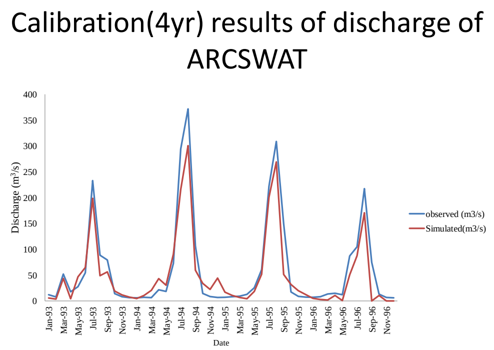
The parameters of the SWAT are calibrated using the historical hydro-meteorological data. The future sediment yield is simulated using SWAT with the data of different climatic scenarios. The impact of likely future changes in climate on stream sediment yield up to Pong is analyzed by the output of SWAT for future climate scenarios.

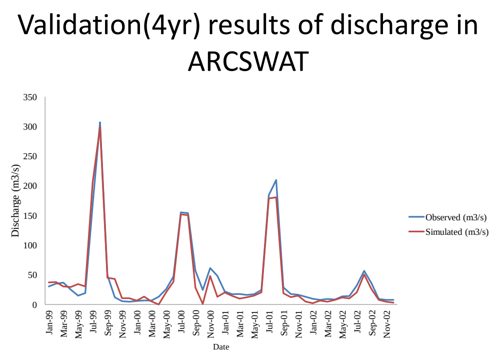
Revision of elevation-area-capacity table

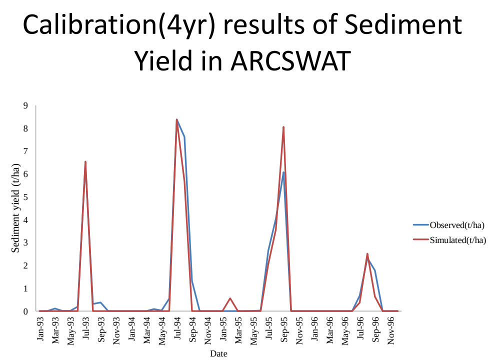
The projected sediment volume for future periods is distributed in the reservoir by empirical-area reduction method to find out the revised elevation-area-capacity table.

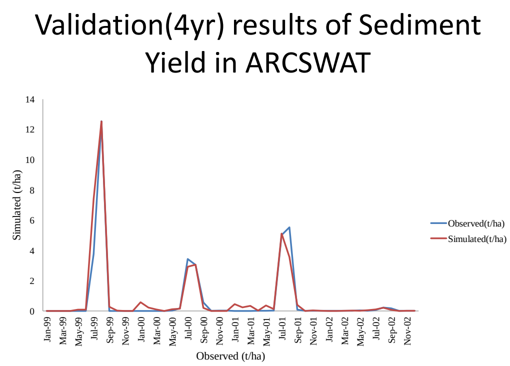
9. **Results achieved with progress/present status**

The sediment entering into Pong Reservoir is measured at Jwala Mukhi (Nadaun Bridge) located on Beas River. The sediment yield at Jwala Mukhi is modelled by Soil and Water Assessment Tool (SWAT). The data requirement for running the SWAT model are landuse, soil map, DEM, rainfall, wind velocity, relative humidity, temperature, solar radiation, potential evaporation, runoff at outlet, sediment yield outlet, runoff and sediment yield to the storage structures in the catchment and elevation-area-capacity curve of the storage structures. The inputs such as Land Use Land Cover, DEM, Soil map, Aspect map for running the SWAT 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) and NRSC. Grid based meteorological data such as daily rainfall, minimum and maximum temperatures are obtained from Indian Meteorological Department (IMD) and European Centre for Medium-Range Weather Forecasts (ECMWF) (ERA Interim data). The parameters of SWAT for the modelling discharge and sediment yield are calibrated manually (trial and error method) by considering the data from 1993 to 1996 for calibration and 1999 to 2002 for validation. The calibration and validation results of discharge and sediment yield are presented as follows:









The future scenarios of minimum and maximum temperature and rainfall for the climatic conditions such as RCP2.6, 4.5, and 8.5 are being downscaled from CanESM2 CMIP5 experiments.

10. **Expected date of completion:** 31 March 2018

11. Revised timeline

Sl. No.	Work Element	2015-16		2016-17		2017-18		2018-19	
		H1	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
1	Literature Review								
2	Collection and processing of Hydrometeorological data and purchase of satellite imagery and soil maps								
3	Data preparation for SWAT								
4	Simulation of Sediment yield by SWAT								
5	Downscaling of data from GCM Models								
6	Simulation of sediment yield with the data from future climatic scenarios								
7	Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield								
8	Preparation of interim report								
9	Preparation of final report								

12. Action to be taken during the extension period

- Downscaling of climatic scenarios from CanESM2 for RCP 4.5 and RCP 8.5
- Application of downscaled data to simulate the future sediment yield
- Revision of elevation-area-capacity for the future sediment yield

<u>Study–4 (2018-19)</u>
Internal Study (Ongoing)

1. Title of the study: Effect of climate change on evaporation at point scale

2. Study Group:

Sh. Digambar Singh, Sc B
Dr. A. R. Senthil kumar, Sc E
Dr. Manohar Arora, Sc D

3. Date of start: 1 June 2014

4. Duration of the study: 3 Years

5. Whether externally funded or not: No

6. Objectives of the study:

a. To develop evaporation model by empirical and soft computing techniques
b. To downscale the data of temperature, rainfall and humidity from GCM model
c. To determine the effect of climate variables on evaporation by using the downscaled data

7. State of the problem

Crop water requirement is the depth of water needed to meet the water loss through evapotranspiration. Computation of crop water requirement is very important in planning, design and operation of irrigation projects. Evapotranspiration comprises of both evaporation and transpiration from the crops/plants and surface of the land. Computation of evaporation and evapotranspiration requires climatic factors such as minimum and maximum temperature, relative humidity, radiation, solar radiation and wind speed, etc. Variability of evaporation and evapotranspiration depends on the local condition of climatic factors. IPPC predicts increase in mean temperature till 2100 due to the anthropogenic activities. So the Prediction of evaporation and evapotranspiration is very much important under this condition to plan the cropping pattern in future.

8. Brief methodology:

Evaporation model

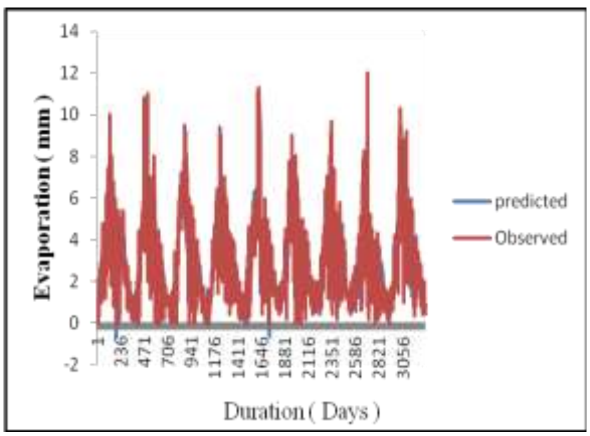
Empirical models such as Penman Method, Meyer Model, Multiple Linear regression (MLR) and soft computing techniques are applied to model the evaporation with rainfall, temperature and humidity as input vectors.

Development of climate scenarios

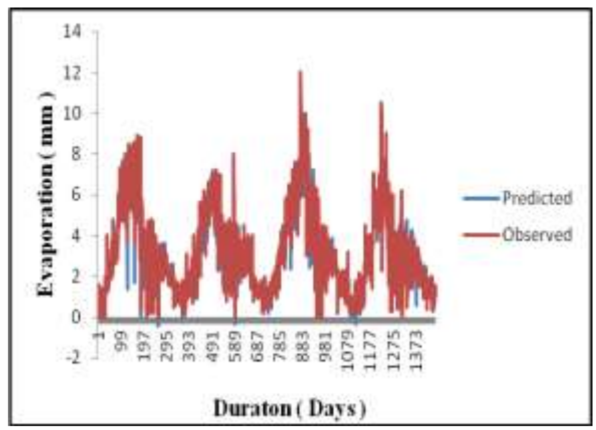
The rainfall, minimum and maximum temperature and humidity for future can be generated by GCM models. The different scenarios of climatic conditions such as RCP2.6 4.5, 6 and 8.5 are obtained from CMIP5 models available from different institutes. The historical data used for the downscaling and the bias correction are maximum and minimum temperature, rainfall, wind speed and solar radiation computed from extra terrestrial radiation. The empirical and the best model developed by soft computing techniques are applied to simulate the evaporation from the downscaled values of rainfall, maximum and minimum temperature and humidity for different climatic scenarios as mentioned above.

9. Results achieved with progress/present status

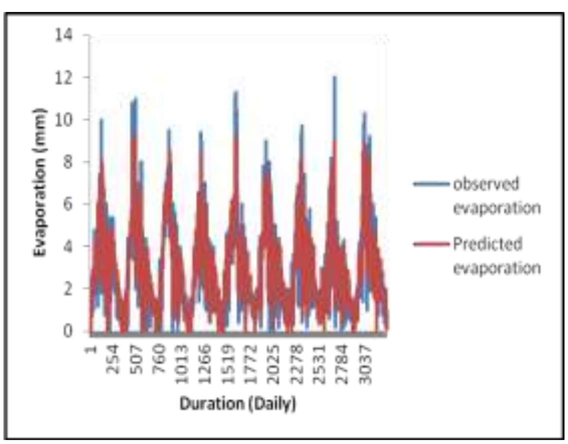
The evaporation for the period from 1987 to 2013 has been computed with the available data by different methods such as Penman method, Meyer method and other empirical equations based on saturated vapour pressure and the results are compared by statistical parameters such as coefficient of correlation and root mean squared error. The empirical equation for the condition of air and water surface temperature different is the best method among all. The evapotranspiration for the period from 1987 to 2013 has been computed with the available data by different methods such as Turc method, Hargreaves method and Thornthwaite method and the estimates by Hargreaves method is best among all. The ANN model for simulating the evaporation has been developed with the input data derived from the statistical parameters such as ACF, PACF of evaporation and CCF of evaporation with rainfall, minimum temperature, maximum temperature and relative humidity and performance of the ANN models analysed statistical parameters such as coefficient of correlation, root mean squared error and Nash-Sutcliffe model efficiency. A Multiple Linear Regression (MLR) model has been developed using the inputs considered in the development of ANN model for the simulation of Evaporation. The inputs considered in the modelling are the observed data from NIH observatory from 1987 to 2013. A comparison between the MLR and ANN models is carried out by performance indices such as coefficient of correlation, root mean squared error, Nash-Sutcliffe Model efficiency. It is found that ANN model has performed better than MLR during calibration and validation.The results of ANN and MLR are given as follows:



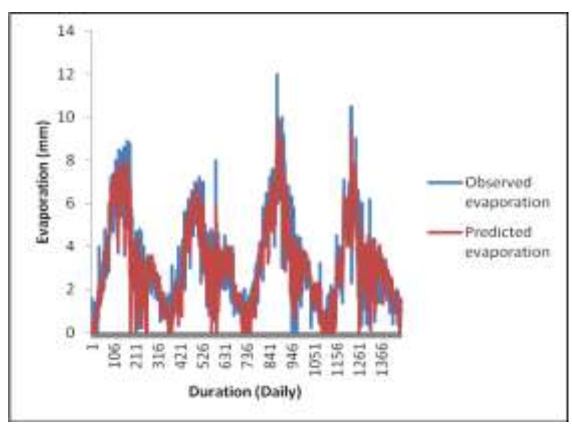
Plot of observed *Vs* modelled evaporation for ANN calibration



Plot of observed *Vs* modelled evaporation for ANN validation



Plot of observed *Vs* modelled evaporation for MLR calibration



Plot of observed *Vs* modelled evaporation for MLR validation

The future scenarios of temperature and humidity are downscaled from COordinated Regional Downscaling Experiment (CORDEX) (IITM Pune) and CanESM2. This generated output will be used for the estimation of evaporation and evapotranspiration for the future periods. The data of downscaled scenarios will be used in the empirical and ANN models to simulate the evaporation for the period.

10. Expected date of completion:
The project was to be completed by October 31, 2017. But an extension of 6 months up to June 2018 is required.

11. Revised Timeline

Sl. No.	Work Element	2014-15		2015-16		2016-17		2017-18		2018-19	
		H1	**H2**	**H1**	**H1**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
1	Literature Review										
2	Data collection, compilation and processing										
3	Development of model for evaporation by empirical and soft computing techniques										
4	Development of model for evaporation by multiple linear regression models										
5	Downscaling of data from COordinated Regional Downscaling Experiment (CORDEX) (IITM Pune) and CanESM2 (GCM Model)										
6	Simulation of evaporation by considering the climate scenarios										
7	Preparation of interim report										
8	Preparation of final report										

12. Action to be taken during the extension period

- Downscaling of climatic scenarios from CORDEX and CanESM2
- Application of downscaled data to simulate the future evaporation and evapotranspiration .
- Comparison of evaporation and evapotranspiration for the data from DOH, IIT Roorkee with the data of NIH observatory.
- Revision of elevation-area-capacity for the future sediment yield

<u>Study-5 (2018-19)</u>
Internal Study (New)

1. Title of the study:
Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of water management plan.

2. Study Group:
Digambar Singh, Sc C
Er. Omkar Singh, Sc F
Shri Subhash Kichlu, PRA
Shri N R Allaka, RA

3. Date of start: 1, April 2018

4. Duration of the study: 2 Years

5. Whether externally funded or not: No

6. Objectives of the Study:

a. Development of water management plan for identified ponds in the districts of Tikamgarh and Chhatarpur of M.P. and Jhansi and Lalitpur of U.P. through estimation of water storage capacity and water quality of ponds.

7. Statement of the Problem

Ponds and reservoirs are the life line of Bundelkhand region. Agriculture and fisheries are the main occupation of the people living in this region. These occupations are totally depending on the ponds and reservoirs. The Bundelkhand region is facing frequent droughts due to regular shortfall of rainfall in the region. The average rainfall of the study area is 800–900 mm. (Ramesh et al. 2002), But, during the last six years Bundelkhand region received only 400–**450 mm** annual rainfall and more over the lithological condition are also not favorable to develop good aquifer . Therefore, available rainwater is only viable option to be harvested for meeting various demands viz. agriculture, cattle, fisheries etc. The most of the ponds become dry by the end of March/April due to high evaporation loss and different uses. Therefore assessment of availability of water from surface water bodies is very important to sustain irrigation, fisheries and other water needs as well as to provide security to farmers. This study aims to estimate the quantity and quality of available water in the selected water bodies to know the present status and plan a strategy for the future by carrying out bathymetric survey and water quality investigations.

8. Brief methodology:

(a) **Remote/Pedal boat (using sonding weight) will be used for bathymetric survey**.
The Echo Boat is a hand portable remote controlled catamaran platform developed for bathymetric survey applications. The light weight, wide profile and water tight connection provide stability, ruggedness and portability.

(b) Assessment of water quality

The water quality parameters, viz. temp., pH, electrical conductivity, total dissolved solids, dissolved oxygen, turbidity, chlorophyll and blue green algae are to be monitored using multi-parameter Sonde (YSI, 2014) The water quality of different ponds is to be assessed based on above mentioned limited water quality parameters as monitored in field for fishery (Bhatnagar & Devi, 2013), irrigation (CPCB, 1978/2007-8), and drinking (IS: 10500, 2012), respectively and the apparatus available at water quality laboratory at NIH, Roorkee.

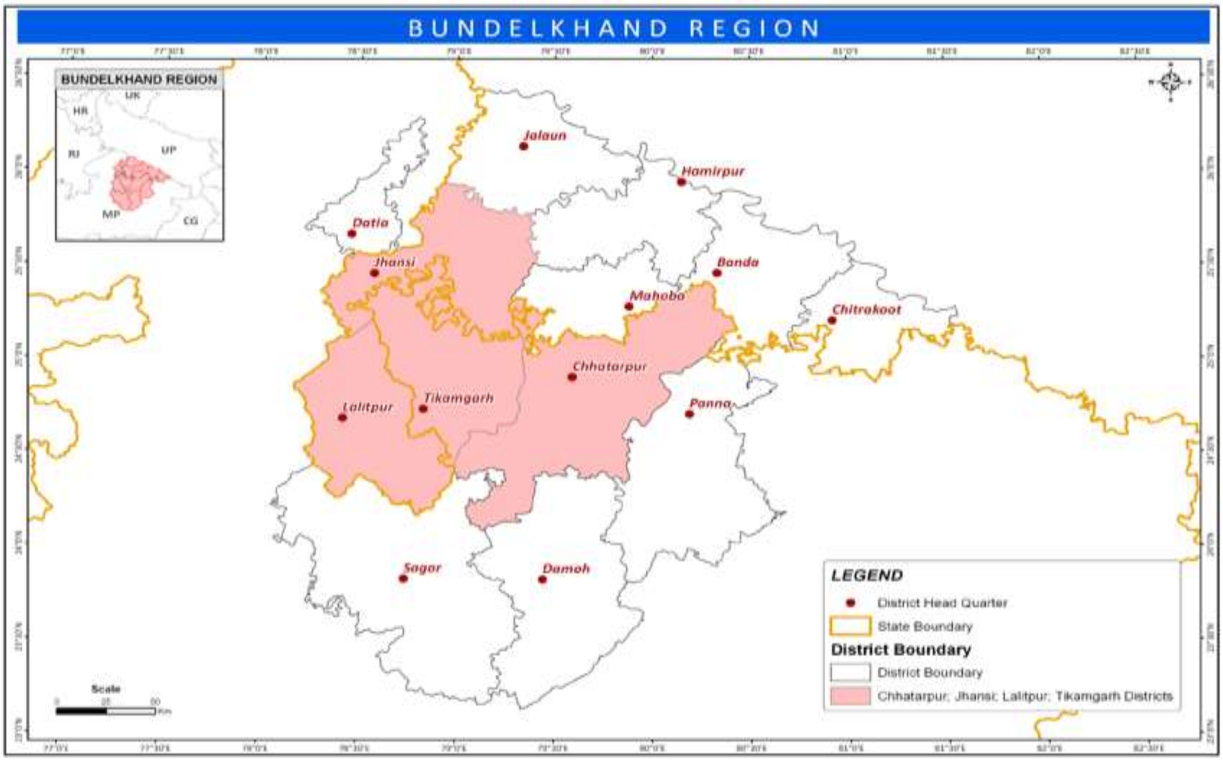
(c) Determining the Water quality index

Water Quality Index (WQI) is a standard index created and designed by The National Sanitation Foundation (NSF). The WQI is one of the most widely used tools of all existing water quality procedures. The overall results of nine separate tests can be used to determine WQ index of any water body. Water quality index is a 100 point scale that summarizes results from a total of nine parameters given below. Temperature, pH, Dissolved Oxygen, Turbidity, Fecal Coliform, Biochemical Oxygen demand, Total Phosphates, Nitrates, Total Suspended Solids.

9. Study area

The study area covers the following districts.

1. Jhansi (U.P.)
2. Lalitpur (U.P.)
3. Tikamgarh (M.P.)
4. Chhatarpur (M.P.)



10. Action plan and timeline

Sl. No.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Literature review								
2	Collection of water sample and measurement of water quality parameters by SONDE								
3	Bathymetric Survey of the ponds								
4	Water Quality Analysis								
5	Computation of the volume of the ponds								
6	Analysis of the suitability of water for irrigation and fisheries								
7	Report writing								

11. Data requirements

Dissolved oxygen, Ph, EC, TDS, Chlorophyll, Temperature, Depth, Conductivity, Salinity, ORP, BGA, FDIM, Phosphate etc.

12. Deliverables:

i) Water management plan
ii) Bathymetric map
iii) Water quality status and evaluation report for different uses
iv) Research papers

13. Adopters of the results of the study and their feedback: **Agriculture and fisheries department of the concerned region**

<u>Study-6 (2018-19)</u>
Internal Study (New)

1. Title of the study:
Conservation of ponds in Ibrahimpur-Masahi Village and performance evaluation of natural treatment system

2. Study Group:

NIH Team: Sh. Omkar Singh, Sc “F”
Dr. V.C. Goyal, Sc “G”
Sh. Digambar Singh, Sc “C’
Sh. Subhash Kichlu, PRA
Sh. N.R. Allaka, RA

CEH (UK): Dr Laurence Carvalho,
Er. Mike Clark
Centre for Ecology & Hydrology, Edinburgh, United Kingdom

3. Nature of Study: A Case-Control/Observational Study

4. Date of start: April, 2018

5. Expected date of completion: March, 2020

6. Weather externally funded or not:
No, However, in addition to technical input, CEH (Edinburgh, U.K.) may provide DO monitoring sensors for installation at pond sites in this study.

7. Objectives:

a. Water quality investigations of ponds, wastewater and groundwater for evaluating performance of CW based natural treatment system
b. Assessment of water quality for fisheries, irrigation, etc.
c. Mass Awareness Activities.

8. Statement of the Problem

In our country, most of the traditional sources of water (i.e. ponds) in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and face severe eutrophication mainly due to untreated input of wastewater in the ponds. In this context, the Institute has developed a pond (Village: Ibrahimpur Masahi, Tehsil-Bhagwanpur, Dist. Haridwar) by establishing CW based Natural Treatment System (NTS), which is to be commissioned in Feb/March 2018. The rejuvenated ponds with treated wastewater shall then be used for groundwater recharge, limited agricultural use, as well as for livelihood activities such as fishery. The performance evaluation of this system which is an important aspect to establish its feasibility and replicability in other village ponds receiving continuously input of domestic wastewater in the ponds. Therefore, in this study it proposed to regularly monitor key water quality parameters at two ponds, namely Ibrahimpur (pond with control) and Masahi Kala (pond without control) lying under Ibrahimpur-Masahi revenue village (Tehsil-Bhagwanpur, Dist. Haridwar) in collaboration with Centre for Ecology & Hydrology (Edinburgh, United Kingdom).

The NTS developed for rejuvenation of village ponds, which will facilitate the practice of water conservation and management of the village in totality for water security and sustainability, which is also expected to be a role model for the Gram Panchayat/s leading towards attaining objectives of “Ideal Village Concept” of the GOI.

9. Study Area

The study area (i.e. Ibrahimpur Masahi revenue village) is falling under Shipla Nadi-Halzora Nadi watershed, District Haridwar (Uttarakhand). The location map of the study area is given in **Figure 1**. The Shipla Nadi-Halzora Nadi watershed lies from $29^0 56'$ to $30^0 05'$ North latitude and $77^0 48'$ to $77^0 55'$ East longitude under SOI Toposheet Nos. 53 F/16 and 53 G/13 (1:50,000). The geographical area of the Shipla Nadi-Halzora Nadi watershed is 101.5 km^2 upto river bridge at village Imlikhera. The area of Ibrahimpur Masahi revenue village is 14.26 km^2 which represents about $1/7^{th}$ of the watershed area upto Imlikhera bridge. The Ibrahimpur Masahi revenue village consists of the following five sub-villages (Ibrahimpur Masahi, Masahi Kala, Belki Masahi, Inayatpur, Halzora) under its jurisdiction:

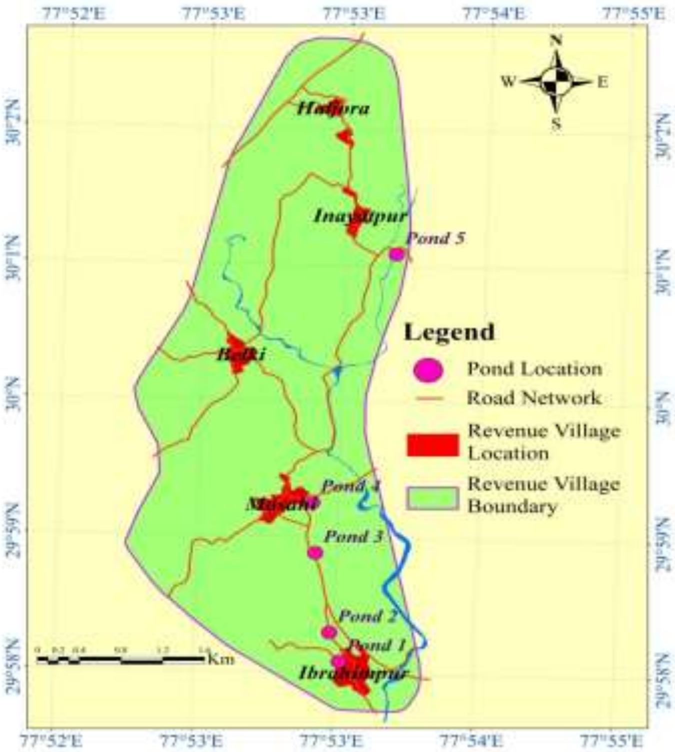


Figure: Location map of the village Ponds in the Study Area

10. Brief methodology:

In this study, the necessary surface water (ponds) and groundwater (hand-pumps) quality data will monitored per procedures (APHA 1989; Jain and Bhatia, 1987) as well as using WQ monitoring Sonde (YSI). Apart from gaining benefits of CW-NTS, its performance would be assessed using key water quality parameters (viz. DO) in collaboration with CEH-UK. The DO in both ponds (with control and without control) would be measured over seasonal cycles to assess effectiveness of the constructed wetland over different seasons using waterproof and self cleaning DO sensors with data loggers being provided by CEH-UK for permanently installing in the ponds.

The water quality assessment for agriculture purposes (BIS-1987/2001; USDA 1954) and Fishery would be performed as per recommended procedures including development of WQ Indices. Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977).

11. Timeline:

S. N.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

1	Review of Literature								
2	Procurement/arrangement of DO sensors for installing in ponds and regularly monitoring of DO data								
3	Field Investigations (WQ, WL, etc.) and maintenace of NTS/Pond sites								
4	Data Compilation & Analysis								
5	Mass awareness activities, Interaction with Gram Panchyat								
6	Report Preparation								

12. Expected Outcome/Output:

- Performance Evaluation Report of CW-NTS
- WQ Indices for Fishery/Irrigation and Eutrophication Trends of Ponds

<u>Study-7 (2018-19)</u>
Sponsored Project (Ongoing)

1. Title of the Study:
Vulnerability assessment of identified watersheds in Neeranchal Project States

2. Study group:
Dr Jyoti P Patil and nodal scientists from Regional centres (Bhopal, Patna, Kakinada, Belgaum)

3. Type of Study: Sponsored- Neeranchal National Watershed Programme (NNWP)

4. Date of start: 01.07.2017

5. Scheduled date of completion: 30.06.2019

6. Duration of the Study: Two years

7. Study Objectives:
The aim of the study is to assess the vulnerability to climate change for the identified watersheds of 9 Neeranchal Project States.

8. Statement of the Problem:
Assessing vulnerabilities is the process of identifying, quantifying, and prioritising the vulnerabilities in a system. Vulnerabilities from the perspective of climate change means assessing the threats from potential hazards to population, infrastructure, development goals etc. VAs can help to improve adaptation-planning, allocation of resources and raising awareness about climate change at different levels. Vulnerabilities cannot be measured directly; it has to be inferred with the help of various variables.

9. Brief methodology
Focus of this study has been on generating Livelihood Vulnerability Index (LVI) by IPCC approach for watersheds under NNWP. The IPCC-LVI approach would facilitate the identification of areas, which are vulnerable to climate change and need special attention towards adaptation. The socio-economic, environmental, agriculture, water resource, health, climate and forest indicators of vulnerability will employed and classified into adaptive capacity (A), sensitivity (S), and exposure (E). Identification and classification of indicators for vulnerability assessment is always subjective keeping in view the importance of indicators in the spatial context, availability of quantitative/measurable data, time series availability of data and to some extent any indicator having proxy representation. They will be classified manually as it is not possible to carry out such a classification statistically. Statistics is based on numbers and do not take into account the physical nature of the indicator.

10. Timeline:

S. N.	Work Element/ Milestone	2017-18		2018-19	
		H1	H2	H1	H2
1	Select a set of indicators to assess the vulnerability of people, livelihoods and ecosystem				
2	Collection of data from secondary sources				
3	Calculate Livelihood Vulnerability Index using the IPCC approach				
4	Highlight areas that are most vulnerable and need to be protected as well as the areas that need improvement				
5	Suggest measures/ strategies to cope up with climate change events in future				

11. **Objective and achievement during last six months**:

Work Element as per timeline	Achievement
Select a set of indicators to assess the vulnerability of people, livelihoods and ecosystem	The IPCC-LVI methodology was discussed with Neeranchal states officials during first stakeholders' workshops. The scale of the analysis is set on district/ block level. Set of indicators was also discussed with SLNAs.
Collection of data from secondary sources	Data are being collected from secondary sources like census (population/ livestock), state department sites, district statistical handbooks etc.
Calculate Livelihood Vulnerability Index using the IPCC approach	The pilot set of data is prepared for input to DSS-H of Neeranchal project. The LVI-IPCC methodology results will be made available through DSS-H.

12. Recommendation / Suggestion: **NA**

13. Analysis & Results: **NA**

14. End Users / Beneficiaries of the study**: Integrated Watershed Management Programme**

15. Deliverables: **Areas which are most vulnerable to climate change and need further attention will be highlighted**

16. Major items of equipment procured: **Nil**

17. Lab facilities used during the study: **Nil**

18. Data procured or generated during the study: **-**

19. Study Benefits / Impacts: **Outputs of the study will be used in the development of DSS(Hydrology), and later on for preparation of DIP/ DPR by the respective line departments**

20. Involvement of end users/beneficiaries: **IWMP**

21. Specific linkage with Institution and /or end users/beneficiaries: **Various line departments (KVKs, Irrigation, WRD, Agriculture, Industry)**

Study-8 (2018-19)
Sponsored Project (Ongoing)

1. Title of the study:

Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact

2. Study Group:

Dr. A. R. Senthil kumar Sc E
Dr. J. V. Tyagi, Scientist 'G'
Dr. M. K. Goel, Scientist 'G'
Dr. S. D. Khobragade, Scientist 'F'
Dr. P. C. Nayak, Scientist 'D' (DRC Kakinada)
Dr. Manohar Arora, Scientist 'D'

3. Date of start: 1 January 2016

4. Duration of the study: 5 Years

5. Whether externally funded or not: DST

6. Objectives of the study:

a. To model stream flow/snow melt runoff in Bhagirathi Basin up to Tehri dam.
b. To model sediment yield at Tehri dam.
c. To investigate the impact of likely future changes in climate on stream flow and sediment yield up to Tehri dam using future climate scenarios.
d. To assess impact of afforestation/deforestation on sediment yield in the basin.
e. To assess the operation policy of the Tehri dam in light of the climate change impact.

7. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Tehri reservoir. The study on impact of afforestation/deforestation on sediment yield in the basin is also important for effective watershed management.

8. Brief methodology:

Sediment yield model

The sediment yield up to Tehri reservoir is modeled by Soil and Water Assessment Tool (SWAT) with the information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed.

Streamflow simulation

The streamflow up to Tehri reservoir is modeled by SNOWMOD with the input data of elevation, rainfall, aspect, temperature and snow cover area. The performance of SWAT is compared with SNOWMOD in simulating the discharge.

Climate Scenarios

The different scenarios of climatic conditions such as RCP2.6, 4.5 and RCP8.5 are obtained from CMIP5 models available from different institutes.

Computation of streamflow and sediment yield under different scenarios

The parameters of the SWAT are calibrated using the historical hydro-meteorological data. The future streamflow and sediment yield are simulated using SWAT and SNOWMOD with the data of different climatic scenarios. The impact of likely future changes in climate on streamflow and sediment yield up to Tehri is analyzed by the output of SWAT and SNOWMOD for future climate scenarios.

Revision of elevation-area-capacity table

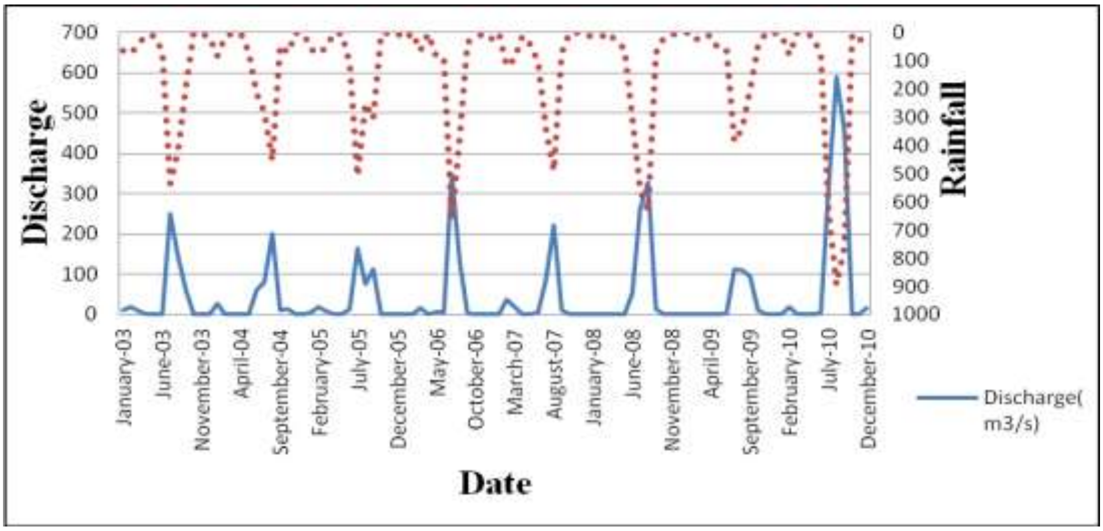
The projected sediment volume for future periods is distributed in the reservoir by empirical-area reduction method to find out the revised elevation-area-capacity table.

The impact of afforestation/deforestation on sediment yield is analyzed by the simulation of sediment yield using SWAT by increasing/decreasing the LULC.

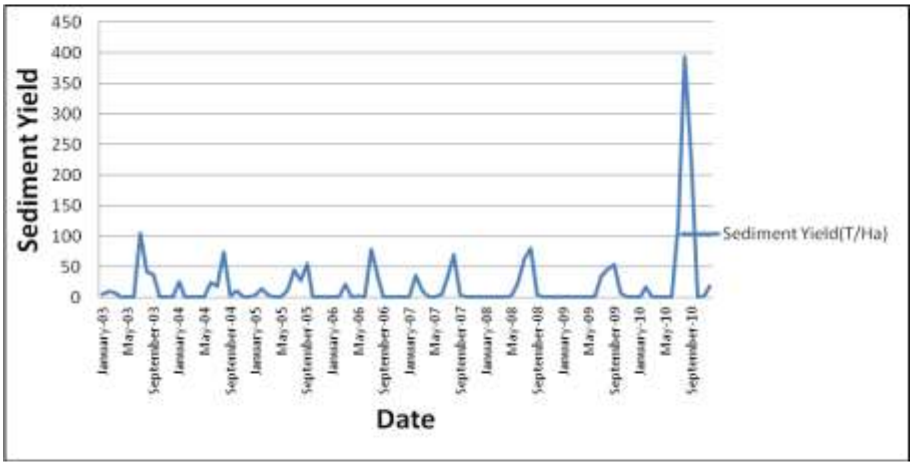
The rule curves for operating the reservoir are modified by considering the revised elevation-area-capacity curve in light of increased/increased sediment yield.

9. Results achieved with progress/present status:

The sediment yield at Tehri reservoir is modelled by Soil and Water Assessment Tool (SWAT). The inputs such as DEM, LULC and Soil map for running the ARCSWAT have been generated using different sources available in the web sites of different organisations such as NASA, National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Indian Council of Agricultural Research, Harmonized World Soil Database (HWSD) International Institute for Applied Systems Analysis **(**IIASA) and National Remote Sensing Centre (NRSC). The daily rainfall, maximum temperature, minimum temperature, Solar radiation, wind speed, relative humidity (from surface pressure, mean temperature and dew point temperature) have been obtained from **ERA INTERIM, European Centre for Medium Range Weather Forecasts (ECMWF).**The discharge and sediment yield at Tehri dam has been simulated using the gird based input data by taking the parameters randomly with SWAT and the results are given below:



Simulated discharge for the period from Jan 2003 to September 2010



Simulated sediment for the period from Jan 2003 to September 2010

Ten daily silt data from 2002 to 2011and daily discharge from 2001 to 2013 at Tehri reservoir have been collected. The parameters of the SWAT is being calibrated by considering the discharge and sediment yield data

10. Outcome of the study

The output of the study will give an idea of increased sediment yield and streamflow from the future climatic scenarios to the state department officials for managing the various demands based on the available the storage in the reservoir on priority basis. The impact of afforestation/deforestation on sediment yield will be used for planning cropping pattern to reduce the sediment yield

11. Expected date of completion: 31 January 2021

12. Timeline

Activity	2016-17		2017-18		2018-19		2019-20		2020-21	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
Collection and processing of Hydrometeorological data and purchase of satellite imagery	■	■	■	■	■	■	■	■		
Data preparation for SNOWMOD and SWAT		■	■	■						
Simulation of streamflow by SNOWMOD			■	■	■	■				
Simulation of Sediment yield by SWAT			■	■	■	■				
Downscaling of data from GCM Models			■	■	■	■				
Simulation of streamflow and 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					■	■			■	■

<u>Study-9 (2018-19)</u>
Sponsored Project (Ongoing)

1. Title: Rejuvenation of Village Ponds for Identified Villages in Muzaffarnagar and Meerut Districts of western U.P.

2. Study Group:

Investigators: V.C. Goyal, Omkar Singh, Digamber Singh
Scientific/Technical Staff Subhash Kichlu
Project Team N .G.Shrivastava, Nihal Singh, Kalzang, Sandeep Yadav, Subhash Vyas

3. Nature of Study: Action research

4. Date of start: April, 2017

5. Expected date of completion: March, 2020

6. Weather externally funded or not: MoWR sponsored project

7. Objectives:
- Rejuvenation of identified village ponds by carrying out de-weeding, de-silting and strengthening of the embankments,
- Establishment of appropriate Natural Treatment System (NTS) technology for treatment of wastewater entering into these ponds,
- Pilot demonstrations on the use of treated wastewater from ponds for agricultural purposes,
- Assessment of the impact of the rejuvenation of ponds by monitoring relevant water quality parameters and groundwater levels,
- Mass Awareness Activities.

8. Statement of the Problem

Presently, ponds in the villages of western UP are in a very bad shape. Ponds are generally used as sink for all wastewater as well as for solid waste generated in the villagesleading to the deposition of solid wastes and growth of weeds. Capacity of these ponds has been reduced drastically as removal of silt is not taken up on regular basis. Encroachment of the catchment area has added to the dismal state of such ponds in the rural and per-urban areas.

Through the proposed action research study, it is proposed to rejuvenate the identified ponds in a retrofitting mode by carrying out de-weeding, de-silting, Waste Water Treatment and strengthening of the embankments. Also, it is proposed to establish an appropriate Natural Treatment System (NTS) technology, such as Floating Wetlands (FW), for treatment of the wastewater entering into these ponds. The rejuvenated ponds with treated wastewater shall then be used for groundwater recharge through rejuvenated pond, limited agricultural use, as well as for livelihood activities such as fishery.

The project aims to develop a model for rejuvenation of village ponds, which will facilitatethe practice of water conservation and management in the selected villages in totality for water security and sustainability, which is also expected to be a role model for the Gram Panchayats in other part of the UP/country.

9. Study Area

The study area is a part of western Uttar Pradesh. In consultation with the respective Gram Pradhans, twelve ponds have been selected in ten identified villages of Muzaffarnagar and Meerut Districts.

Table 1: Details of Identified Villages and Ponds selected in the project area

S. N.	Name of Village & Pond	Pond Area (ha)	Perimeter (m)	Depth (m)	Capacity (m^3)	Catchment Area (m^2)	Total No. of Inlets
1.	Bhora Kalan (Block Sahpur, Dist. Muzaffarnagar)	0.78	348	4.0	23,710	463,727	04
2.	Bhora Khurd Pond-1 (Block Sahpur, Dist. Muzaffarnagar)	0.64	417	3.5	15,787	474,836	04
3	Antwara (Block Khatauli, Dist. Muzaffarnagar)	0.29	222	3.5	6,062	335,336	02
4	Siwaya Jamalullapur (Block Daurala, Dist. Meerut)	0.62	354	3.5	17,242	325,030	03
5	Pavli Khas (Block Daurala, Dist. Meerut)	1.15	445	3.5	30,655	924,785	02
6	Itawa Pond-1 (Block Budhana, Dist. Muzaffarnagar)	0.42	306	3.5	10,065	159,207	02
7	Itawa Pond-2 (Block Budhana, Dist. Muzaffarnagar)	0.77	482	3.5	17,830	337,895	04
8	Mohammadpur Madan -2,(Block Baghara, Dist. Muzaffarnagar)	0.55	355	3.5	14053	366866	02
9	Munnawarpur Kalan (Block Khatauli, Dist. Muzaffarnagar)	0.43	265	3.5	10,727	324,648	02
10	Roni Hazipur (Block Charthawal, Dist. Muzaffarnagar)	0.77	352	3.5	20,736	540,128	04
11	Biral (Block Budhana, Dist. Muzaffarnagar)	2.74	935	3.5	80,208	616,818	06
12	Bhora Khurd Pond-2 (Block Sahpur, Dist. Muzaffarnagar)	1.28	441	3.5	37,036	540,128	04

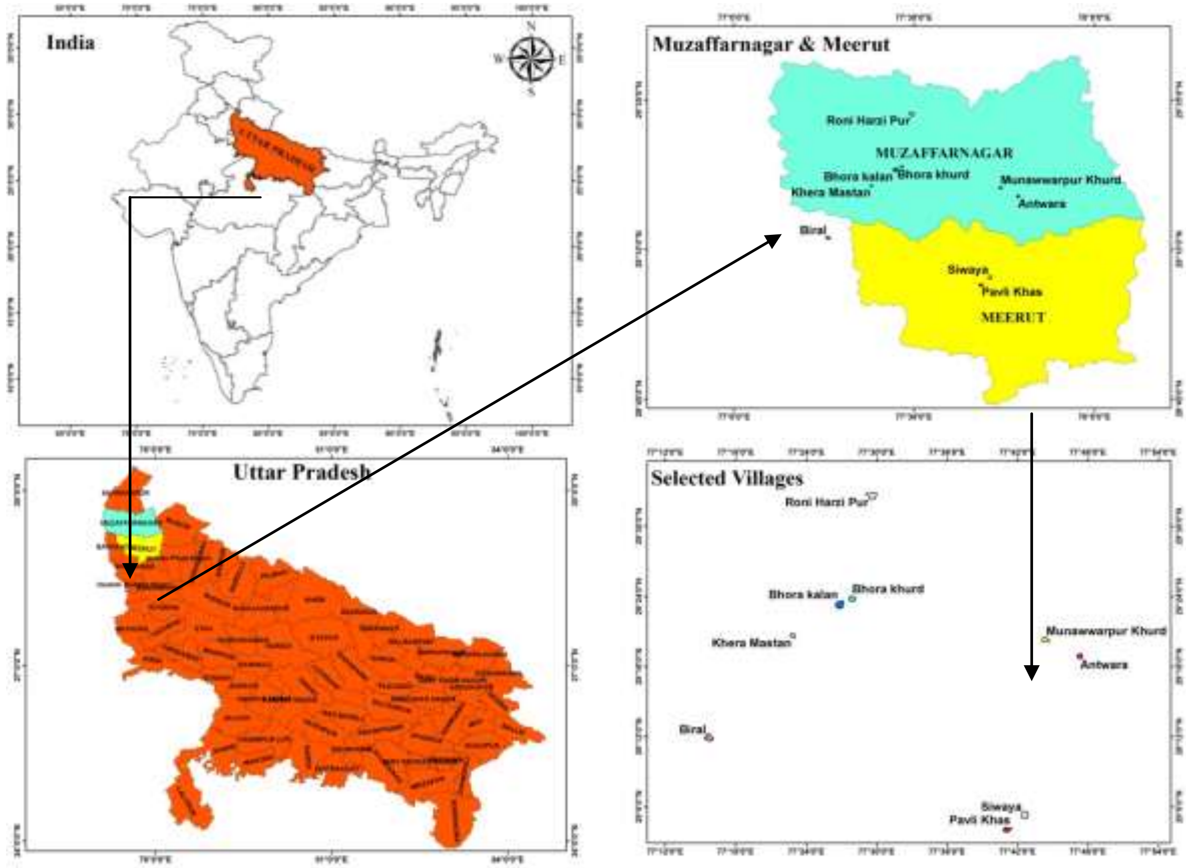


Figure 1: Selected area for action research on IWRM plan for water security in identified villages of western Uttar Pradesh

10. Brief methodology:

After field measurement of the dimensions of the ponds, DPRs will be prepared for estimation of the civil works, etc. involved in the pond rejuvenation related works. Execution of the pond rejuvenation works will be carried out by awarding contract to an identified agency.

In the next phase, an appropriate NTS technology (Floating Wetland) will be established in the identified ponds for treatment of the wastewater entering into these ponds. In order to ensure effectiveness of NTS, Screen Chamber, Grit Chamber and Sedimentation chamber will be provided at the identified locations of Inlet of waste water to the pond. Side walls/embankments of the ponds will be strengthened and a small pathway will be made on the periphery of the ponds along with periphery drain to trap household waste water in order to regulate through treatment system.

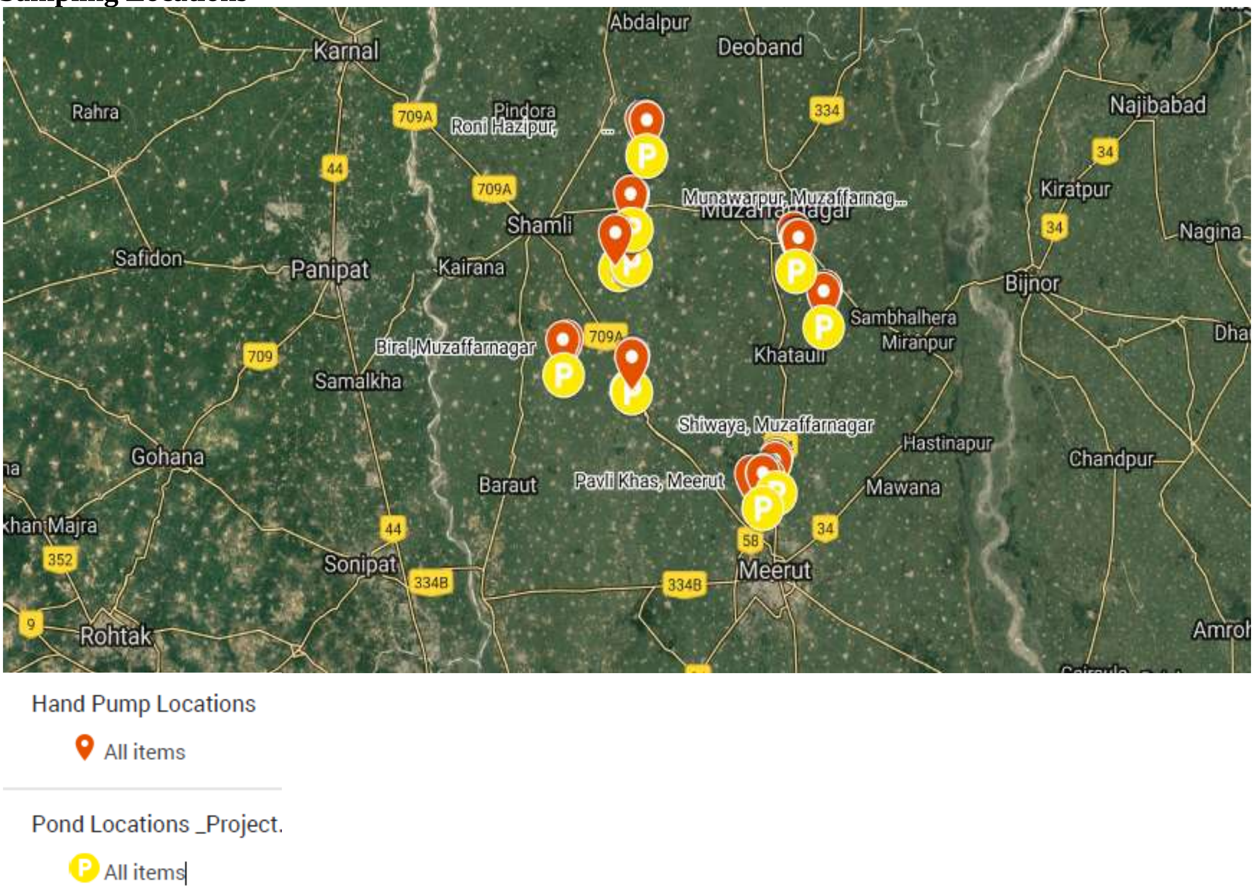
Innovative R&D Components of the Project

- Development of a cost-effective "Technology Package" for retrofitting of the existing village ponds
- Introduction of "Floating Wetland" as a Natural Treatment System (NTS) technology for treatment of the wastewater entering into ponds
- Estimation of water balance of pond, including groundwater recharge
- Impact assessment of the intervention
    - Change in groundwater level
    - Water quality assessment: Trophic State Analysis; Water Quality Index; Primary Production Capacity
- Linking with livelihood activities: reuse of treated wastewater in agricultural fields; aquaculture

S. N.	Work Element/ Milestone	2017-18				2018-19				2019-20			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Preparation of DPR												
2	Field execution of rejuvenation related works												
3	Establishment of NTS technology												
4	Pilot demonstration on use of treated wastewater for agricultural purposes												
5	Monitoring of water quality parameters and groundwater level												
6	Impact assessment of rejuvenation activities												
7	Mass awareness activities												

11. Baseline Survey & Preliminary Results (to be presented)

Sampling Locations



12. Expected Outcome/Output and Deliverables:

- Rejuvenated village ponds
- Estimated potential of fish production for the Gram Panchayats
- Standard Operating Procedures (SOP) for O&M of treatment system in village ponds
- Technical report(s) and publications

<u>Study-10 (2018-19)</u>
Sponsored Project (New)

1. Title of the Study:

Development of water allocation plan for a Neeranchal watershed in Chhattisgarh

2. Study group:

Dr A. R. Senthil kumar, Sc “E”
Dr. Jyoti P Patil, Sc “C”
Dr. T R Nayak, Sc “E”, RC, Bhopal
Sh. Rajesh Agarwal, SRA

3. Date of start: April 2018

4. Duration of the study: 2 Years

5. Whether externally funded or not: NNWP

6. Objectives:

a. To develop a water allocation plan for various uses for an identified watershed in Jashpur district of Chhatisgarh

7. Statement of the problem

The demand for water from agricultural, industrial and domestic uses is continuously increasing due to the development in their respective sectors. The fixed availability and uncertainty over the occurrence of water increases the complexity of allocation of water to the competing demands from various sectors. It is imperative to evolve management plans for the allocation of water in efficient way to achieve optimum crop yield without compromising the demands for domestic and industrial uses. Allocation of limited water resources among agricultural, domestic and industrial uses requires the integration of supply, demand, water quality and ecological considerations. The Conventional supply-oriented simulation models are not always adequate for exploring the full range of management options for water allocation. Water Evaluation And Planning (WEAP) tool integrates all tools in a robust way for integrated water resources planning.

8. Present state-of-art

SWAT is a physically based semi distributed continuous time model developed by USDA Agricultural Research Centre (ARS) of Texas A&M university, USA to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. SWAT requires specific information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling etc. are directly modeled by these inputs. The water yield is modeled by SCS Curve number method. The sediment yield is modeled by modified USLE (universal Soil Loss Equation).

WEAP simulates hydrologic pattern based on climatic input. WEAP uses precipitation, temperature, humidity, infiltration, and wind speed data to predict the amount of precipitation that falls into a particular area, discharge of streams, recharge of groundwater and/or evapotranspiration through vegetation. It allows to build a futuristic scenarios based on the baseline scenarios along with assumptions towards water demand, infrastructure and regulations. The assessment of the impact of all the anthropogenic activities on water resources management and livelihood issues could be possible in order to predict water shortage and water quality based on a model scenario. This software tool can be used to demonstrate the results of water demand quantity met during a month, the degree of potential water shortage, level of reservoir storage for future use and measurement of water quality. Further, it can be used to assess the adequacy of environmental flows, the level of hydropower generation capacity, the evaluation of soil moisture, evapotranspiration rates, volume of surface runoff, the rate of ground water recharge, agriculture water requirement, possible alternative to adapt cropping pattern to increase water use efficiency and maximize the income.

This study is undertaken to prepare water allocation plan among different uses such as agricultural, industrial and domestic uses to achieve optimum crop yield in a Neeranchal watershed in Chhattisgarh by evaluating the available water resources and management of demand and supply requirements of different socio-economic activities using WEAP model. The different components of hydrological process would be modeled by SWAT. Suitable water allocation plan would be evolved for various stress conditions by scenario analysis studies using WEAP model. Scenario analysis helps in finding out the demand and supply pattern by exploring “what if” questions such as:

- What if population growth and economic development patterns change?
- What if reservoir operating rules are altered?
- What if groundwater is more fully exploited?
- What if water conservation is introduced?
- What if ecosystem requirements are tightened?
- What if a conjunctive use program is established to store excess surface water in underground aquifers?
- What if a water recycling program is implemented?
- What if a more efficient irrigation technique is implemented?
- What if the mix of agricultural crops changes?
- What if climate change alters demand and supplies?
- How does pollution upstream affect downstream water quality?
- How will land use changes affect runoff?

9. Methodology

The water allocation plan among different uses in a Neeranchal Watershed in Chhattisgarh is evolved by setting up of WEAP tool. The inputs to WEAP tool such as water demand from various sectors, priority of the demand, catchment details, hydrologic conditions and inflows, catchment hydrology (river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc), supply preference (operating rules/policy), return flows, minimum flow requirements, economic variables such as cost water transmission etc are prepared from the data obtained from various sources such as irrigation department, IMD, CWC, census department. The hydrological processes occurring in the catchment will be modeled and will be compared with the measured discharge time series. After the proper calibration of the model, the demand sites will be added into a model framework and different scenarios will be generated to assess the gaps in the water demand and supply and water availability at different locations and at the different period of time. The different water allocation plan will be evolved based on the scenario analysis to achieve optimum crop yield.

10. Research outcome from the study

Water allocation plan for different uses such as agricultural, domestic and industrial uses to achieve optimum crop yield under varying scenarios would be brought out in the form of a comprehensive report. The water allocation plans would be useful in efficient water resources management for the economic and social up-liftment of the area. SLNA can utilize the water allocation plans evolved from the study to prepare DPR for the efficient water resources management.

11. Work Plan:

Sl. No.	Work Element	2018-19				2019-20			
		Q1	Q2	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**

1	Literature review								
2	Collection of hydro meteorological data, satellite images, thematic maps etc.								
3	Compilation and verification of hydro-meteorological data, baseline survey data, census data and other qualitative data								
4	Preparation of input data for WEAP model								
5	Simulation of components of hydrological processes using SWAT model								
6	Water allocation plan for different uses by scenario analysis by WEAP model								
7	Report writing								

Study-11 (2018-19)
Sponsored Project (New)

1. Title of the Study:
Development of Innovation Centre for Eco-prudent Wastewater Solutions (IC-EcoWS)

2. Principal Investigator:
Dr V. C. Goyal, Sc "G"

3. Partner Institutions:
National Institute of Hydrology, Roorkee
Indian Institute of Technology Bombay (IITB)
Department of Civil Engineering, MNIT Jaipur
Institute of Rural Management Anand

4. **Date of start**: April 2018 (if approved)

5. **Duration of the study**: 5 Years

6. **Whether externally funded or not**: DST

7. Objectives:

a. Establishment of a state-of-art Centre to harness the potential Natural Treatment Systems (NTS) and other eco-prudent resource recovery technologies for water security and sustainability in India.
b. 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 technologies.
c. Establishment of few pilot study sites ("Live Laboratories") for detailed assessment of selected NTS in urban, peri-urban and rural settings.
d. 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.
e. 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.

8. Brief methodology:

a. Inventory of existing NTS and resource recovery approaches
b. Screening of resource recovery technologies using DST
c. Material Flow Analysis (MFA)
d. Life Cycle Assessment (LCA)
e. R&D field research component at pilot study sites ("live laboratories")
f. R&D laboratory component
g. Development/identification of technology packages
h. Development of business models
i. Cost estimation of TPs and Cost-Benefit Analysis
j. Innovation component
k. Capacity building and outreach

9. **Proposed milestones and time schedule** (M-month from the date of start) are as follows:

a. Development of Centre's portal (M12)
b. Operation of Decision Support Tool (DST) (M24)
c. Development of Technology Packages (M42)
d. Establishment of "Live Laboratories" (M18)
e. Development and application of innovative ideas on NTS (M24)

f. Organization of Users Interaction Workshops (M12, M24, M36, M48, M58)
g. Development of TOT module on NTS applications (M50)
h. Development of Indian handbook for NTS Technology Packages (M55)
i. Submission of final Project Report (M60)

Social entrepreneurs and industry will be invited at the annual Users Interaction Workshops for sharing of the Technology Packages. Also, collaborations with Water Utilities and institutions dealing with the wastewater treatment facilities will be explored for dissemination of TOT Module on NTS Applications and Indian Handbook for NTS Technology Packages.

10. Novelty and relevance of the proposed R&D:

The Centre is expected to provide a unique opportunity of exploring the vast potential of NTS in Indian conditions, and shall deliver the full spectrum of research, innovation, development of business model, capacity building, outreach and dissemination activities. The emerging concept of a Circular Economy in the field of wastewater treatment and reuse will also be explored at the Centre. It will also play a catalytic role to propagate and promote the NTS for a variety of applications in India, and help in promoting the concept of IWRM Planning in India.

HARD ROCK REGIONAL CENTRE BELGAUM

Scientific Manpower

S N	Name	Designation
1	Dr.B.Venkatesh	Scientist F & Head
2	Dr.B.K.Purandara	Scientist E
3	Dr.Chandra Mohan T.	Scientist D
4	Dr.M K Jose	Scientist D
5	Dr.N. Varadarajan	SRA
6	Mr.Chandrakumar S	SRA

WORK PROGRAMME FOR 2017-18

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
II.	**Internal Studies (New)**			
1	Climate Change Impact assessment for Jayakwadi Reservoir	B Venkatesh, (PI), & Sc. of HRRC and officers from WRD, Govt. Maharashtra)	3 years (01/18-3/21)	Internal
2	Studies on Occurrence, Distribution and Sustainability of Natural Springs for Rural Water Supply in parts of Western Ghats, India	BK Purandara (PI) & Sc. HRRC,	3 years (4/17-3/20)	NHP
3	Hydrological evaluation of existing water conservation/ harvesting structures in selected watersheds of Amaravathi and Ahamd Nagar districts, Maharashtra state	Chandramohan T (PI) M.K. Jose	One year (2017-18)	NEERANCHAL Project
4	Water balance estimation in selected watersheds of Nelagond and Mehabob nagar districts Telangana state	M.K. Jose (PI) Chandramohan T)	One year (2017-18)	NEERANCHAL Project
5	Estimation of Water Availability for ungauged Basins in Western Ghats Region	CMT& Sc. HRRC	3 years (4/17-3/20)	Internal
III.	**Sponsored Projects (Ongoing)**			
1.	Clean and safe drinking water supply to rural community using river bank filtration techniques in hard rock regions of Krishna basin, Karnataka, India.	BK Purandara (PI), Sudhir Kumar, Sc G	3 years (4/16-3/19)	DST (95 lakhs)
IV.	**Consultancy (New)**			
1	Study of R-R Co-relation and Yield series for Bembla sub basin at Nandura GD site on Bembla River	B. Venkatesh, (PI)	3 months	Govt. of Maharashtra
2	Flood Review in Kali and Sharavathy river basin, Dam Break analysis, inundation mapping and preparation of Emergency Action Plan for Dams in Kali, Sharavathi and Varahi river basin	B. Venkatesh, (PI)	2 years	Karnataka Power Corporation Limited, Govt. of Karnataka
3	Hydrological and Water Quaity Investigations in the Solar Power Project Sites in Northern Karnataka	B.K.Purandara, (PI)	2 months	Mr. Piyush Gupta, Project Manager, Rays Power Infra Private Limited, Jaipur, Rajastan
4	Estimation of Water Level in Aghanashini River for Manikatta Saline Embankment.	B. Venkatesh, (PI)	2 months	The Principal Secretary to Government, Revenue Department (D.M), Govt. of Karnataka

Progress of the Studies for the year 2017-18

1.0 Internal Studies

1.0 Climate Change Impact assessment for Jayakwadi Reservoir

This study was initiate as a collaborative study with Department of Water Resources Department, Maharshtra. In this regard, a official approval was accorded by the Chief Engineer, WRD, Govt. of Maharashtra in the month of Jan 2018, and identified some of the officers to be part of the study group.

Presently the PI has consulted the officials and the requisite maps and data are being collected.

2.0 Studies on Occurrence, Distribution and Sustainability of Natural Springs for Rural Water Supply in parts of Western Ghats, India

The Western Ghats of the Indian Peninsula is endowed with number of perennial and seasonal springs. Springs present in the head water catchments of river Krishna (in State like Maharshtra and Karnataka) are used for the local water supply and also for agriculture purposes. Therefore, as a part of the first of the project, inventory of Springs and also investigations were carried out to understand the role of spring water in regeneration of forests in the Western Ghats, once a thickly forested tract which is converted in to a degraded land.

In this connection about 21 springs were identified in parts of Malaprabha and Ghataprabha catchments. The observations revealed that their origins are highly dependent on the lithological characters of different basaltic flow units and the existing terrain physiography. Their discharges vary between 2-432 m^3/d in the winter and 1-216 m^3/d in the summer. Although rainfall, its seasonality, and areas of recharge play vital roles in the recharge of these springs, their yields are also controlled by lithological variations and hydraulic characteristics of their source-aquifers. Chemically, these springs offer a very high quality of groundwater, their chemical concentrations depending heavily on the lithological compositions of the source-aquifers and the residence time of ground water issuing as springs in these aquifers.

Springs untapped for any human use may be harnessed effectively for reforestation purposes in the hills of the Western Ghats. Even if they are in use, because they flow continuously, part of their discharges could be diverted for reforestation purposes. However, while tapping springs for reforestation/irrigation/drinking purposes, it must be remembered that they also sustain thousands of other life forms vital to a balanced eco-system. Changes in the uses of these springs may also affect other human communities downstream. Therefore, before developing spring flow, a trade-off must be made considering local needs and downstream users. Therefore, in the present study, the hydrological simulation is carried out by using Soil and Water Assessment Tool (SWAT) model, which is integrated with ARCGIS software, to estimate some of the most important parameters of hydrology, such runoff, groundwater recharge and evapotranspiration. The model was applied to Ghataprabha sub-basin, which is a right bank tributary of river Krishna. The analysis was carried out in three phases to understand the hydrological response to catchment characteristics, particularly with reference to catchment area. The calibration and validation of the model was done by using the data of adjoining basin, Malaprabha as there is a lack of rainfall data for the regions in headwaters of Ghataprabha catchment. The model was calibrated and validated by using data for a period 1991 to 1998. Long term mean hydrometeorological data and physical characteristics of the catchment such as land use/land cover, soil type, topography, groundwater level and slope are used as an input to the model. The mean annual groundwater recharge, evapotranspiration and runoff were found to be 18%, 30% and 46% for headwater catchments with a considerable decline with an increase in catchment area. Comparison of measured and predicted values demonstrated that each component of the model is quite acceptable and realistic in nature. However, it is necessary to go data intensive modeling to get an accurate view of the hydrological processes.

A Natural Spring Observed in Sindhudrug District of Maharashtra

3.0 Hydrological evaluation of existing water conservation/ harvesting structures in selected watersheds of Amravathi and Ahmed Nagar districts, Maharashtra state (NEERANCHAL Project)

Union Government has taken up a project, **Neeranchal National Watershed Project**, with World Bank to improve watershed management in rural rain fed areas. The project is implemented by the Union Ministry of Rural Development over six-year period (2016-21) to achieve objectives PMKSY. The project is being implemented in selected sites in nine states: Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha Rajasthan and Telengana. The project contributes to enhance watershed management activities in two districts in each of the participating states.

Sub-component, 2.2, of the Objectives of the program (Decision Support Systems and Data Bases for Hydrology and Watershed Management), is to develop and pilot decision-support systems (DSS) to support DoLR and project States to implement watershed management in a more comprehensive and scientific manner, particularly around hydrology. National Institute of Hydrology (NIH) is entrusted with the development of DSS (H) and to impart technical input to the project for making better water management decisions. The activities in the State of Maharashtra are looked after by the NIH Regional Centre, Belagavi, Karnataka and NIH HQ Roorkee. Few watersheds from Ahmed Nagar and Amravati Districts were selected for the project implementation in this State, as shown in the Table.

District	Block	Name of Project	Treatable Area (Ha)
Ahmednagar	Akole	IWMP-33/2014-15	3226.17
	Karjat	IWMP-34/2014-15	4458.23
	Karjat	IWMP-35/2014-15	4332.06
	Karjat	IWMP-36/2014-15	4589.30
	Shrigonda	IWMP-37/2014-15	5166.04
	Karjat	IWMP-27/2013-14	6202.69
Amravati	Dharni	IWMP-31/2014-15	3350.00
	Dharni	IWMP-32/2014-15	3105.07
	Dharni	IWMP-33/2014-15	3659.98
	Dharni	IWMP-34/2014-15	4368.59
	Bhatukali	IWMP-36/2014-15	4527.74
	Dharni	IWMP-27/2012-13	3073.07

Progress of the Project

Field trips were conducted to Neeranchal watersheds in both the Districts of the State during last week of May, 2017.

- watersheds IWMP 27, 33, 34, 35, 36 and 37 in Ahmed Nagar
- watersheds IWMP 27, 31, 32, 33, 34 and 36 in Amravathi

A Workshop was conducted on ‘DSS-H: Deliberating Modules and Database’ at Nagpur during 16-17, August, 2017

Two studies; Hydrological evaluation of existing water conservation structures and Water availability studies, were planned for selected watersheds in each of the Neeranchal Districts of Maharashtra. As of the first phase, the study on Hydrological evaluation of water conservation structures was planned for

Karjat watershed in Ahmed Nagar (AHMEDNAGAR/IWMP-36/2014-15) and Dharni watershed (AMRAVATI/IWMP-32/2014-15) in Amravati District.

Compartment Bunding, CCT, Farm Ponds, Cement and Earthen Nala Bund, Gabion Bund, Plantations on bunds, etc. are the common conservation measures implemented by the farmers and the concerned Govt. Departments. A number of studies confirm the potential of such measures to enhance infiltration and water productivity, with subsequent enhanced agricultural activities; by simultaneously reducing runoff and soil erosion.

Evaluation of such structures can be done by collecting pre and post project data on soil moisture, ground water level, water levels in local ponds and lakes and the area, type and number of sowings of crops in the watershed. However, in the absence of such data, various scenarios can be simulated by using any suitable hydrological models and the results can be compared with or without incorporating specific water conservation measures.

In the present study, the data collection activity is being pursued by the State agencies and those data has to be transferred to NIH.

4.0 Water Balance Studies in selected Watersheds of Nalgonda and Mehaboob Nagar Districts of Telangamna

As part of the Neeranchal (NNWP) project initiatives, among other activities hydrological relevant activities were also proposed. Among those include Hydrological evaluation of existing water conservation/ harvesting structures ; Hydrological assessment (Water Balance); water demand management; spatial & temporal water availability; water demand gap for different uses; water management plan; scenario development for future water availability with possible interventions etc.
In this connection a study was initiated on water balance estimates of some of the selected watersheds of the Nalgonda and Mehaboob Nagar Districts in Telangana state (Vide Fig.1). Telengana state is mostly covered by Godavari and Krishna river basins, except for a small area in the easten borders which is bound by some east flowing rivers (Vide Fig.2).

Figure- 1

Figure-2

The work has already been started and progressing with the collaboration of the Telengana state nodal agency officials.

Two mandals each in the districts of Mahboobnagar (*Mahaboobnagar & Addakal)* and Nalgonda (*Chandur & Nampally*). In Mahboobnagar and Addakal mandals there are two projects namely, Kotakadira and Peddamunigalched respectively with a treatable area of about 4200 Ha each (Fig.3). Similarly, in *Chandur & Nampally* mandals also there are two projects namely, Theretapally and Peddapur with a treatable area of 4500 Ha and 5000 Ha each respectively (Fig.4).

Some of the basic information needed for the analyses have been collected. The information sofar collected for the study include, GIS layers of administrative boundaries, aquifer parameters in the selected areas, groundwater level information, specific yields, some information/ map of soil, geomorphology, irrigated area, terrain etc. Details of agricultural / cropping information for one year could be collected. Also, thematic maps of some of the existing projects in the districts also collected. For obtaining the other information/ data, efforts are on, and it is expected to be collected at the earliest and to complete the analyses.

Figure-3 (Mahboobnagar)

Figure-4 (Nalgonda)

5.0 Assessment of Water Resources in Ungauged Catchments of West Flowing Rivers of Karnataka

The importance of estimating the water availability from limited hydrologic data for purposes of planning water resource projects was recognized by engineers even in the last century. Lack of adequate hydrological data introduces uncertainty in both the design and management of water resources systems in ungauged catchments. Consequently, there is a need to develop methods for predicting flow characteristics at ungauged sites. The flow characteristics predicted from catchment and meteorological parameters can be used to assess the water resources of the ungauged catchments.

The West Flowing Rivers Basins in the Western Ghat region consist of small independent river basins originating at higher altitude and heavy rainfall region, and flow rapidly into the Arabian Sea. Most of these rivers have not been tapped to their optimal water potentials either for irrigation or for any other uses and the flow generated in these rivers drains into sea. Therefore, for the maximum utilization of the water resources of the catchments within this region, their water potential has to be assessed and the available water resources has to be suitably stored and diverted to other water scarce regions of the State. Therefore, this study intends to recommend suitable methodologies to assess the water potentials of the rivers originates and flows through Western Ghat region.

In this study, it is proposed to estimate the stream flow characteristics of ungauged catchments of Western Ghat regions of Karnataka State using a regionalization approach based on homogeneity among the selected basins and using multiple regression analysis and modelling techniques. This approach will be used; (i) to develop relationships between catchment characteristics and flow characteristics and (ii) to regionalise the model parameters of a hydrological model so that the model can be effectively used in ungaguged catchments.

This project generates a general hydrological prediction methodology for the ungaguged catchments of Western Ghat region, wherein regionalization techniques will be used to define a) different flow properties of ungauged basins using catchment characteristics, and b) to estimate model (such as SWAT) parameters for ungauged catchments from the hydrological observations in gauged catchments.

Steps involved in the study:

1. identify catchment characteristics that can be used for predicting flow characteristics of ungauged catchments.
2. examine the feasibility of using catchment characteristics for identifying catchments with similar hydrological responses or delimiting hydrologically homogenous regions.
3. identify suitable flow characteristics, which can be used to develop multiple regression relationships for prediction in ungauged basins.
4. develop appropriate relationships between the selected flow characteristics and catchment characteristics for available gauged streams and transferring such relationships to ungauged basins.
5. conducting field measurements of discharge in few selected ungauged streams to check the developed relationships.
6. test the possibility for regionalizing parameters of selected rainfall-runoff models (such as SWAT) on the basis of catchment characteristics, and using these to estimate flow characteristics of ungauged catchments.

6 estimation of Environmental Flow Requirement for the selected rivers.

The flow data for the following catchments were collected and being analyzed. Rainfall data from few raingauges in and around the catchment areas were also collected. Preparation of maps, computation of geomorphological parameters and collection of remaining hydrometeorological data is in progress.

Sl No	Place Name	Stream	Catchment Area (Km^2)
1	Amachi	Mavinahole	87
2	Balehonnur	Bhadra	809

3	Dusgi	Dusginala	502
4	Jadkal	Jadkalhole	90
5	Kakkattuhole Bridge	Kakkatuhole	98
6	Kateel	Kalluhole	78
7	Kokkarne	Sitanadi	343
8	Nagagundi	Konganahole	83
9	Polali	Gurpur	688
10	Surve Bridge	Gowrihole	126
11	Barchi	Barchinala	20

2.0 Sponosored Studies

1.0 Clean and safe Drinking Water supply to rural community using River Bank Filtration technique in Hard Rock Regions of Krishna Basin, Karnataka, India" (DST Sponsored Project)

Tungabhadra River is the main source for drinking water and agriculture developments in Davangere and adjoining district in Karnataka. Due to the main river around or on the bank of the river Tungabhadra River many industries were developed. Lands were totally irrigated by the river water itself, the development of the Industries like Paper and Pulps and the direct damping the effluents in to the river water at Harihar belt, totally the river water polluted by the direct/indirect effluent discharges in the river water. Public facing maximum problems for causing adverse effect on their health, and on the hazards effect on the health of the animal beings. A number of studies have already been carried out on the effluents of fibre industries. The effluent generates from the conventional pulp and rayon Industries, the poly fibre manufacturing Industries are one of the major sources of water pollution for Tungabhadra River at Harihar, Karnataka state. The industries generally contain more lignin compounds, organic matters, organic halides, total organic chloride which even after treatment have much more BOD, COD, TDS and other effluent parameters. During literature survey it was seen that more detail study has to be performed on the two major wood based industry units namely, Harihar Polyfibre Factory (HPF) and Grasilence Fibre Factory (GRF) on the bank of Tungabhadra River at Kumarapatnam near Harihar, Karnataka state. These units account for more than 90%of the rayon produced in India. The raw materials used for manufacturing the polyfibre not only polluting the water but, also poisoning environment by cutting trees. Therefore, in the present proposed project, an attempt will be made to demonstrate the applicability of the RBF technology and its implications in solving the community problems related to water supply and public health. In this connection, villages in the riparian areas of Tungabhadra river covering parts of Davangere and Shimoga districts were studied for the feasibility of drilling RBF wells. Geophysical and hydrogeological investigations were carried out. Detailed investigations with regard to water quality issues and resulting health hazard will be taken up in the neighboring villages located along the banks of selected stretches of river Tungabhadra. This is to identify the most appropriate community based village where they lack water supply facilities and good quality water for drinking. Accordingly, based on the geophysical and hydrogeological analysis bore wells were drilled in Ranebennur taluk of Davangere district. Regular monitoring of water quality in the selected locations of the Tungabhadra river and also in the RBF wells is in progress.
wells is in progress.


Fishing by local resident in contaminated River Thungabhadra


Discussion with local resident by project leader and staff


Washing cloth by village women on bank of River Thungabhadra


Soil layer study by Dr Thomas Boving URI, USA, along Thungabhadra river bank

2.0 Impact of Land use/Land cover Changes on Ground water – A Case Study

Progress

Sustainable management of land and water resources of a catchment requires the information on water availability which is in turn depends upon the loss of water in the various phases of hydrological cycle. The runoff response of watershed is essentially influenced by the geomorphology and type of land use, vegetation type and its density. Several researchers around the world have reported that, any changes in the land use may influence the hydrological responses. However, no clear evidences reported in the scientific literature relating to reduction in land cover leading to increase in water yield and increases in the higher flow volumes. The paired catchment experiments elsewhere suggested that the increase or decrease in the stream flow is much depended on the local conditions and more of the location specific. Review of literature showed that, there is an increase in the higher flow volume due to degradation of forest cover either through the selective harvesting or complete harvesting. Further, few studies indicated a significant role of tree physiognomy such as tree density, leaf litter, canopy cover and presence of grass partition into the various components of the hydrological cycle. However, such types of studies are limited in India and especially in the Western Ghats region of India. Recent studies have reported that there is an increase in the frequency of quick and higher flow as the percentage of degradation of forest increases. However, relationship between tree densities under different land use system on runoff was poorly understood and needs a thorough comprehensive analysis to evaluate the impact of tree density on the hydrologic regime of a watershed. Thus current study is aimed to understand the land-use changes under 2 rainfall regimes namely, Coastal and Mid-ghat zones. But out of five watersheds, selected in Uttara Kannada District, Karnataka, India, 3 watersheds, one each under homogenous land covers of *Acacia auriculiformis* plantation (AaP) (7 ha), Degraded forest (DF-C) (7 ha) and Natural forest (NF-C) (23 ha) lies in Areangadi village of Honnavar taluka and 2 watersheds namely Natural forest (NF-M) (14.1 ha) and degraded forest (DF-M) (4.45 ha) is located in Barchi village of Haliyal/Supa taluka. The field experiments were taken up to address the following issues, (i) to derive rainfall-runoff response of land use land cover change particularly with reference to change in the tree density, (ii) to understand the effect of tree density on peak flow and quick flow under selected land covers and (iii) to estimate event wise suspended sediment in the stream under various land use system.

3.0 Consultancy Project

1.0 Study of R-R Co-relation and Yield series for Bembla sub basin at Nandura GD site on Bembla River

Watershed yield, or water yield, is useful in some planning and design activities. Long-term averages provide sufficient information to determine representative conditions without any knowledge of the expected variation in the record. Without estimates of variability, these average values are of fairly restricted usage. For some planning and design purposes, the flows for certain exceeding probabilities, such as 10 percent or 90 percent, may be more important to know.

The official of the project had approached National Institute of Hydrology Belagavi to undertake a study on "Estimation of Water Availability of Bembla Project". After the thorough discussion with the officials and upon receiving requisite data, a comprehensive study was initiated to estimate the dependable yield at the dam site. During the discussion, the project officials informed the scientist of NIH that the water yield at the dam site should be estimated using both the available data and as well as by developing the rainfall-runoff relationships.

The Bembla project is situated on Bembla river in Godavari basin near Khadaksawanga village in Babhulgaon tehsil of Yevatmal in Maharashtra. The project is envisage to irrigate an area of about 53,968 hectares in Yavatmal. Of this, 47,000 hectares was proposed to be irrigated by the canal system and 6,968 hectares by atomised drip irrigation.

The dependable water yield at dam site was estimated using the available data and as well as by developing rainfall-runoff relationships for monsoon months. The result show a large difference in magnitude between the estimates done using observed discharge values and the one obtained through the rainfall runoff relationship. The dependable yield values estimated through the rainfall-runoff relationship has been recommended. The obtained estimates for 50%, 75% and 90% dependability are 249.10 MCM, 163.92 MCM and 122.96 MCM. The yield at the dam is 264.23 MCM, 179.05 MCM, 138.09 MCM respectively for 50%, 75% and 90% dependability after adding the 10% of amount of irrigation water applied upstream of the dam as return flow.

2.0 Flood Review in Kali and Sharavathy river basin, Dam Break analysis, inundation mapping and preparation of Emergency Action Plan for Dams in Kali, Sharavathi and Varahi river basin

The officials being contacted for obtaining the required data for the study. Meanwhile, the following works are being undertaken

1. Ordering for PMP from IMD
2. Ordering of Finer resolution DEM from NRSA
3. Estimating geo-morphological characteristics of the basin such as Kali, Tattihalla river to estimate the PMF
4. Development of EAP for dams of Sharavathi and Varahi river valley

Proposed Work Program for 2018-2019

Sl No.	Title of the Study	Study Group	Duration	Funding
INTERNAL STUDIES				
1	Assessment of Water Resources in Ungauged Catchments of West Flowing Rivers of Karnataka	CMT(PI) & Sc. HRRC	3 years (4/17-3/20)	Internal
2	Climate Change Impact assessment for Jayakwadi Reservoir	BV (PI), and officers from WRD, Govt. Maharashtra)	3 years (01/18-3/21)	Internal
3	Analysis of Spatio-temporal Characteristics of Sediment Carrying Capacity of Rivers of Karnataka State	M K J (PI)	2 Years (4/2018-3/'20)	Internal
SPONOSRED PROJECTS				
4	Clean and safe drinking water supply to rural community using river bank filtration techniques in hard rock regions of Krishna basin, Karnataka, India.	BKP (PI) & SK	Apr 2016 – Mar 2019	DST Sponsored
5	Studies on Occurrence, Distribution and Sustainability of Natural Springs for Rural Water Supply in parts of Western Ghats, India	BKP (PI) & Sc. HRRC,	3 years (4/17-3/20)	NHP
6	Hydrological evaluation of existing water conservation/ harvesting structures in selected watersheds of Amravathi and Ahmed Nagar districts, Maharashtra state	CMT (PI)	1 year	NEERANCHAL Proj
7	Water Balance Studies in selected Watersheds of Nalgonda and Mehaboob Nagar Districts of Telangana	M K J (PI)	1 year	NEERANCHAL Proj
8	Impact of Land use/Land cover Changes on Ground water – A Case Study (*submitted for sponsorship from MoES, and is approve in principal and sanction letter awaited*)	BKP & BV	3 years (April 16-March 19)	MoES
CONSULTANCY				
9	Flood Review in Kali and Sharavathy river basin, Dam Break analysis, inundation mapping and preparation of Emergency Action Plan for Dams in Kali, Sharavathi and Varahi river basin	BV (PI)	2 years	Karnataka Power Corporation Limited, Govt. of Karnataka

WESTERN HIMALAYAN REGIONAL CENTRE JAMMU

Scientific Manpower

S N	Name	Designation
1	Dr. S S Rawat	Scientist D
2	Dr P G Jose	Scientist D
3	Dr. R V Kale	Scientist C

Completed studies during 2017-18

No.	Study	Team	Duration	Status
Internal Studies				
1.	National Hydrology Project: Project Implementation Plan of River Basins in Jammu Division of J&K	RV Kale PG Jose SSRawat	08 months (Jan 2017 to Aug 2017)	Completed [Requested study by IFCD]
Consultancy Projects				
1.	Technical vetting of Tawi Riverfront Development Project: Hydrology and Hydraulic (Model Study) report	MK Goel RV Kale D SRathore PC Nayak PG Jose SSRawat	03 months (Nov 2017 to Jan 2018)	Completed

Proposed Work Program for 2018-19

No.	Study	Team	Duration	Status
Internal Studies				
1.	Hydrological Investigation of Natural Water Springs of Baan Ganga watershed in Jammu & Kashmir State	SSRawat P Kumar SP Rai RV Kale*	02 years 11 months (May 2015 to Mar 2018)	Ongoing/ Extension requested for 06months
2.	Performance evaluation of 2D-VPMM and 2D-explicit schemes for two-dimensional overland flow simulation.	RV Kale MK Goel M. Perumal	12 months (Apr 2017 to Mar 2018)	Likely to complete by April 2018
3	Hydrologic and hydraulic modeling for floodplain inundation mapping under future climate change scenarios: A case study of Tawi River, India.	RV Kale MK Goel PG Jose SSRawat R Sharma	03 years (Apr 2018 to Mar 2021)	New proposal
4.	Estimation and Assessment of Hydrological Characteristic of a Western Himalayan river	D Khurana MK Goel PG Jose SSRawat RV Kale	12 months (Apr 2018 to Mar 2019)	New proposal

PDS under National Hydrology Project (NHP)				
1.	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"	SSRawat PG Jose SP Rai RV Kale	04 years (Apr 2017 to Mar 2021)	Ongoing PDS under NHP
2.	Study of cryospheric processes in Budhil catchment for water resource management in Ravi Basin [New Studyunder PDS]	PG Jose SSRawat RV Kale SP Rai RJ Thayyen	03 years (Apr 2018 to Mar 2021)	Yet to start [proposal under review]
3.	Hydrological Modeling study to assess the impact of climate change on the hydrological regime of the Ravi River basin in India [New Studyunder PDS]	RV Kale AA Ranade PG Jose SS Rawat PC Nayak MK Goel SK Jain	04 years (Apr 2017 to Mar 2021)	Yet to start [proposal under review]
Externally funded Studies				
1.	Integrated Studies of Himalayan Cryosphere using Space Based Inputs (ISHC)	PG Jose RJ Thayyen	02 years Sept 2017 to Sept 2019	Ongoing Funded by SAC/ISRO
2.	Dynamics and associated processes in a Benchmark glacier in Ravi Basin, Himachal Pradesh, NW Himalaya and its Glaciohydrological response to climate variability	A Linda (CUHP) PG Jose P Sharma (NCAOR)	03 years (Apr 2018 to Mar 2021)	Yet to start [proposal under review]
Consultancy Projects				
1.	Establishment of Silt Observation Post (SOP) in the Baglihar HEP catchment	P Kumar PG Jose SSRawat	06 months (Mar 2016 to Oct 2016)	Ongoing/ Extension uptoJune 2018

III. Progress of ongoing studies for 2017-18

1. Hydrological Investigation of Natural Water Springs of Baanganga watershed in Jammu & Kashmir State

Baanganga is a small tributary of Chenab river, the legendary river associated with the miracles and legends of *Mata Vaishno Devi*. It is considered sacred and as is normal Hindu tradition, devotees like to bathe in it before preceding the journey of the holy shrine *Mata VaishnoDevi.*This river is originated from the Trikuta hills and passes from the side of Katra town. Since, there is no glacier presented in the Baanganga catchment, hence springs are the only available sources to fulfill the water demand of the livelihood of the surrounding people and also to maintain the flow of the river Baanganga. However, due to ecological degradation in Trikuta mountain range, the discharge of theses springs has significantly reduced and some of the springs have dried-up. Consequently, people of the area are facing acute shortage of water for their livelihood and there is hardly any water flowing in Baanganga. Keeping in view the above points, a study related to natural water springs of Baanganga watershed has been approved in 20^{th} RCC meeting of WHRC held during May, 2015.

Total 15 springs have been identified based on a comprehensive survey conducted in the Baanganaga watershed. Five springs were selected for detailed study. The daily discharges of these five springs are being monitored daily basis since July, 2015. Water samples are being collected for isotopic and chemical analysis during monsoon period since 2015.Based on isotopic analysis of rainwater at three different altitudes, the local meteoric water line (LMWL) was developed for Baanganga river catchment.Local geology (Lithology, Dip, Strike etc.) have been mapped for spring near *Bhumika Devi*. Possible recharge area of the springnearBhumika Devi has been identified by cross-examine the results of isotopic analysis, chemistry of springs and rain waters andhydo-geological setting prevailing in the area. Identification of recharge areas of remaining 04 springs are under the process.

2. Performance evaluation of 2D-VPMM and 2D-explicit schemes for two-dimensional overland flow simulation.

Many hydrological problems such as overland flow modelling, flood routing, soil erosion prediction, river management and civil protection work due to occurrence of meteorological event requires prediction of water levels and discharges at particular locations. To solve these hydrological problems overland flow is the one of the important component. Modeling of overland flow can be done using the governing equation of continuity and motion known as Saint-Venant equations and its various simplified variants. Mostly the literature replete with one dimensional description of the overland flow, but it has shortfall in case of the overland flow generation on the land surfaces characterized by irregular slopes. Two-dimensional overland flow modeling is the appropriate choice to overcome this circumstance. Further, due to highly non-linear nature of these governing equations, the global analytical solutions are not available except for limited simplified situations. This situation warrants the use of the numerical models for flood predictions and to decide on policies for minimization of the flood hazards. Therefore, over last decades several numerical schemes are proposed to solve Saint-Venant equations and its different simplified variants viz., kinematic wave and diffusion wave models using finite difference, finite element or finite volume methods. For these three methods, it is necessary to choose the numerical schemes either implicit or explicit. The implicit scheme although unconditionally stable as compared to the explicit schemes, but their use implies solving big systems and hence the explicit scheme is widely preferred numerical scheme in case of overland flow modelling. For example, the widely used rain-runoff model such as CASC2D and GASSHA models employs the explicit finite difference scheme for solving diffusion wave equations for two-dimensional overland flow simulation. However, explicit numerical scheme is posses a longer execution time, numerical stability and the mass conservation problem in the overland flow modelling. To overcome these problems, recently, Perumal and co-researchers have developed two-dimensional Variable Parameter Muskingum McCarthy method named as 2D-VPMM method for the simulation of two-dimensional overland flow. However, there is no any attempt to scientifically evaluate the performance of thesetwo schemes for the two-dimensional overland flow modelling in the literature. Therefore, in the present study, an attempt has been made tocompare the predictive abilities of these two computational schemes using different experimental data from two-dimensional overland flow runoff cases available in the literature to emphasize the main strengths and weaknesses. The data collected from the rainfall-runoff study of laboratory catchment of the University of Illinois, Urbana Champaign is used to verify the performance of explicit numerical scheme for the solution of the two-dimensional diffusive wave (2D DW_Explicit Model) and 2D-VPMM method. The simulation results obtained with both the methods and their comparison with the observed data for event 6 are shown in Figure 1.

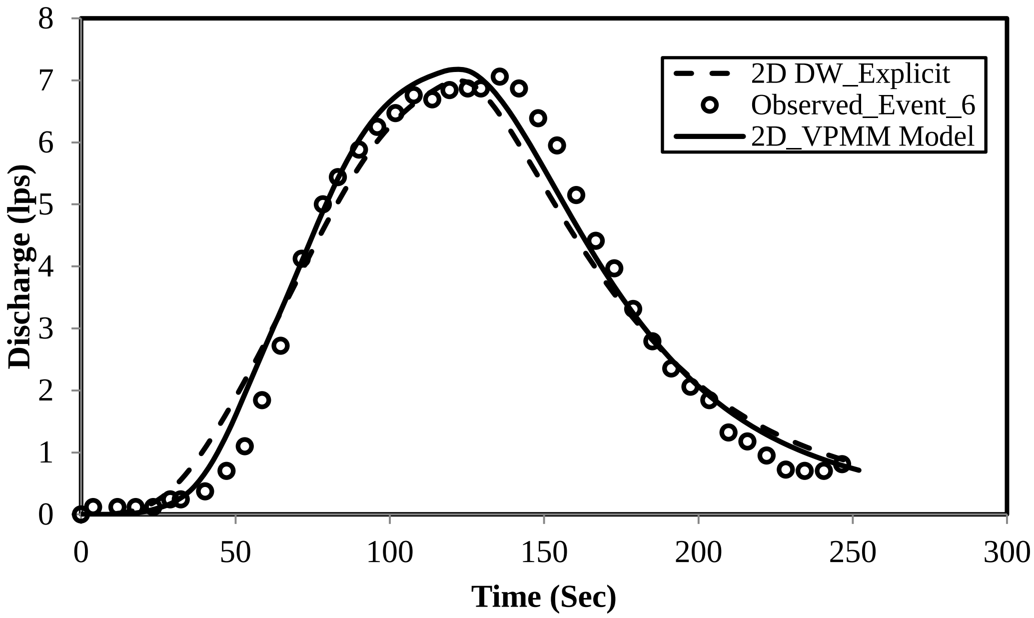


Figure 1. Comparison of the simulated hydrographs with the observed hydrograph for the laboratory catchment, University of Illinois, Event 6.

3. 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”

In compliance of the Objectives of the study, the following activities have been carried-out as per the proposed work plan of the PDS during last six months:

a. Recruitment of project staff

In the approved proposal of the project, 04 field assistants for first two years of the project was proposed for conducting survey and mapping of the springs emerging in the Ravi catchment (drainage area 3100 sq. km up to Chamba town). By following the standard procedure of recruitment of project staff, 04 field assistants have been selected through interview conducted on 04/01/2018 at WHRC, Jammu. All field assistants have joined their duty in the forenoon of 29.01.2018. These 04 field assistants have been posted at 04 different parts of the catchment (i.e. Bharmour, Holi, Saho and Mehla) so that mapping of springs can be done effectively and timely.

b. Field visits for optimization of instruments sites

A 03 days’ comprehensive field visit was conducted in the study catchment during December 07-09, 2017. The purpose of visit was to find suitable locations for instruments and staff to be recruited under the project. The information regarding existing and proposed network of Irrigation & Public Health (IPH) (supporting agency in this PDS/nodal agency in Himachal Pradesh for NHP) has been collected from the concerned department during the field visit. Further, visited the existing meteorological stations of IPH department located at Chamba, Mehla, Gehra and Bharmour to check their suitability for our study.

c. Digitization of Springs from SOI toposheets

Eleven (11) Survey of India (SOI) toposheets (52D2, 52D3, 52D6, 52D7, 52D10, 52D11, 52D12, 52D14 52D15, 52D16, 52H3) were collected from different sources and mosaiced them to obtain the base map of the study area. Springs marked in the SOI toposheets have been digitized and spring map has been generated to be used by the field assistants as a guide map for mapping of the springs. About, 180 springs have been identified and digitized from SOI toposheets and depicted in Fig. 1.

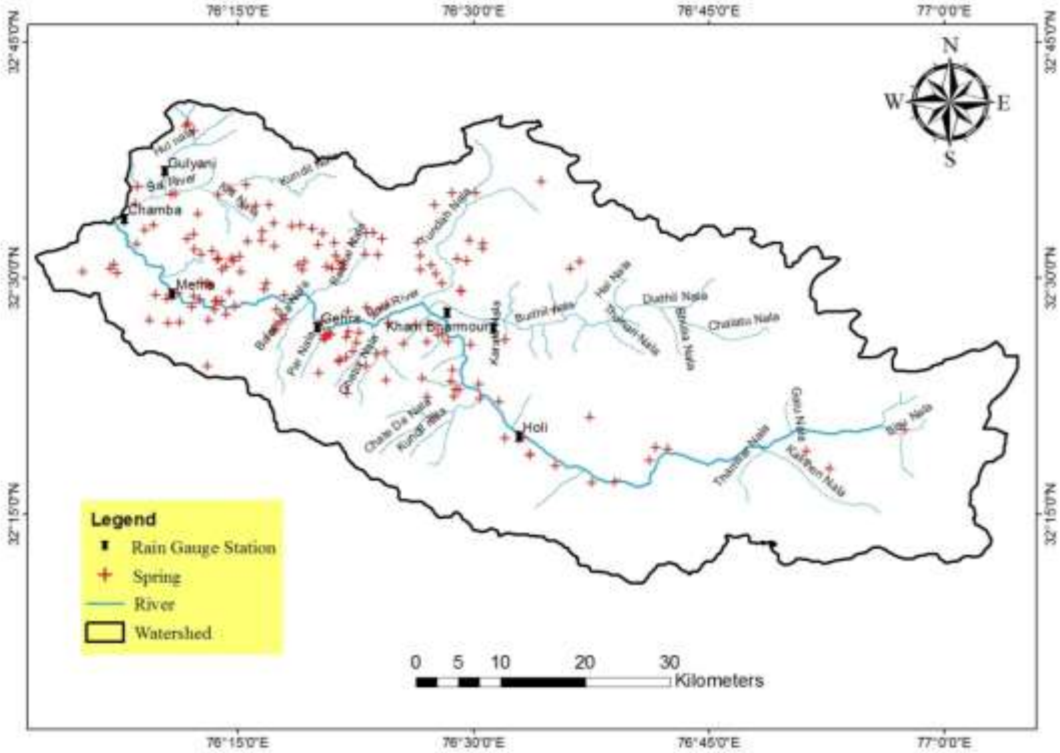


Figure 1. Springs digitized from SOI toposheets. Site of Rainguage stations to be used in the PDS is also shown in the map.

d. Procurement of equipments

Procurement of 04 Handheld GPS, 04 pH and EC meters, Laptop and Water purification system is in final stage and expected to be purchased by the end of this month i.e. March, 2018.

e. Conducted Training Programme

Two days' training programme for field assistants recruited under PDS as well as data collectors from the supporting department (I&PH, HP) organized at Chamba during 23-24 March, 2018.

4. Integrated Studies of Himalayan Cryosphere using Space Based Inputs (ISHC)

a. Field work to DrangDrung Glacier, Zanskar Valley, Ladakh (17-25.09.2017)

Field Conducted reconnaissance survey of Penzi La area and the observed a few glaciers and took photographs of their snouts along with Dr. R. J. Thayyen, Sc. D and Mr. JaydevDharpure, RA. Conducted reconnaissance survey of DrangDrung Glacier catchment upto about 5 Km downstream of glacier terminus were the proglacier stream meets with another stream.No suitable site for discharge station upto that point as channel is not well defined with intense braiding. Mapped DrangDrung glacier terminus.Conducted survey of the lower ablation zone of the DrangDrung glacier and installed six stakes and geotagged them for the purpose of ablation and surface velocity measurements.Explored the possibility of getting skilled field assistants at the nearest village; got positive results. Also visited glacier field station in South Pullu, Leh district. GPS points downloaded and overlaid on the DEM of the glacier catchment for further analysis of glacier surface velocity, etc.

Photo: Fieldwork team on DrangDrung Glacier, Zanskar Valley, Ladakh

b. Presentation of progress of project at SAC (ISRO) Ahmedabad (14.11.2017)

Participated in the meeting and presented the report of the progress of the project including the field work in DrangDrung Glacier, Zanskar Valley, Ladakh and held discussion with SAC scientists regarding future direction for the project.

GANGA PLAINS SOUTH REGIONAL CENTRE BHOPAL

Scientific Manpower

S N	Name	Designation
1	Mr. Tej Ram Nayak	Scientist E
2	Mr. R V Galkate	Scientist D
3	Mr. T. Thomas	Scientist C
4	Mr. R K Jaiswal	Scientist C
5	Mrs. Shashi P.Indwar	Scientist C

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

The studies proposed the year 2017-18

Sl. No	Name of the project	Duration	Status
1.	Development of DSS for Bina river basin in Bundelkand region in M.P. using WEAP Model	2 years	Completed in June, 2017
2.	Estimation of revised capacities of reservoirs in Chhattisgarh state using Digital Image Processing technique	2 Years	Completed, Report writing in progress
3.	IWRM based development plan for water security in four districts of Bundelkhand region in India (Sponsored by MoWR, RD &GR)	1 year	Completed, Final deliverable by P.I. at H.Q. in Apr,18.
4.	Groundwater flow modeling in lower Bina river watershed in Bina block	1 ½ year	(Sept. 2017) **Ongoing**
5.	"Neeranchal project" (The responsibility of four states, i.e. Chhattisgarh, Madhya Pradesh, Rajasthan and Gujarat)	5 years	May,2017 to Mar, 2022 **(DoLR)**
6.	Evaluation of impact of Rabi irrigation in Ganga River sub-basin of Madhya Pradesh	3 years	Started in Nov. 2017 **(NHP)**
7.	Evaluation of the Impacts of Upcoming Irrigation Projects on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh	4 years	Started in Dec. 2017 **(NHP)**
8.	Dam-Break Analysis & Preparation of Emergency Action Plan for Tawa Reservoir in Madhya Pradesh	4 years	**(NHP) Changed**
9.	Modeling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy under Climate Change	3 Years	Started in Sept. 2017 **(NHP)**
10.	Integrated Reservoir Operation Studies for Mahanadi Reservoir Complex in Chhattisgarh	4 years	**(NHP) Changed**
11.	Integrated Assessment of the Impacts of Climate Change and Land use Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches	5 years	Started in Feb. 2018 (Co-PI) **Ongoing**
12.	Modelling of Narmada using GWAVA. (International Collaborative Project with CEH Wallingford, UK)	4 Years	Started in Apr, 2015, (Co-PI) **Ongoing**

The studies proposed under NHP-PDS were subjected to approval from the expert committee of the World Bank Projects. DST, New Delhi funded one R&D project, in addition to that four consultancy projects have been awarded to at RC Bhopal after the 15th RCC meeting held on 28th April 2017. The committee may take note of these projects given below

Additional Projects taken up during the year 2017-18

Sl. No.	Name of the project	Duration	Budget
1.	Revival of Village Ponds through Scientific Interventions in Sagar District (Sponsored R&D Project by DST New Delhi)	2 years	28.82 lakh
2.	Preparation of Emergency Action Plan for Six projects of M.P. WRD (CP-119/2017-18/RC-BH)	1 year	53.10 lakh
3.	Preparation of Emergency Action Plan for Three projects of M.P. WRD (CS-122/2017-18/RC-BH)	1 year	26.55 lakh
4.	Preparation of Working Table for Multiple Reservoirs of Bina Complex (CS-129/2018-18/RC-BH)	2 months	10.03 lakh
5.	Preparation of DPR for Building Climate Resilence through participatory GWM in Burhanpur and Ratlam distt of MP	5 months	10.00 lakh

The details of the study, viz. objectives, methodology, progress made so far and outcomes are given at **Annexure-I.**

Studies Proposed for the Year 2018-19

S.No.	Name of the project	Duration	Status
1.	"Neeranchal Project" (The responsibility of four states, i.e. Chhattisgarh, Madhya Pradesh, Rajasthan and Gujarat)	5 years	Started in May, 2017
2.	Modeling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy under Climate Change	3 Years	Started in Sept. 2017
3.	Evaluation of impact of Rabi irrigation in Ganga River sub-basin of Madhya Pradesh	3 years	Started in Nov. 2017
4.	Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh	4 years	Started in Dec. 2017
5.	Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Thanwar Irrigation Project in Madhya Pradesh.	4 years	Under Process
6.	Rejuvenation of Arpa River in Upper Mahanadi Basin	4 years	Under Process
7*	Modelling of Narmada using GWAVA. (International Collaborative Project with CEH Wallingford, UK)	2 years	Started in April, 2015
8*	Revival of Village Ponds through Scientific Interventions in Sagar District (Sponsored R&D Project by DST New Delhi)	2 years	Started in Sept, 2017
9*	Development of water allocation plan of a Neeranchal watershed in Chhattisgarh	2 years	Apr.2018 to Mar.2020

* Association as Co P.I.

The brief descriptions of the studies are given at **Annexure-II.**

PROGRESS OF PROJECTS/STUDIES CONDUCTED DURING THE YEAR 2017-18

Study – 1

1. **Thrust area under XII five year plan:** Pilot Basin Studies

2. **Title of the project:**

Development of DSS for Bina River Basin in Bundelkand Region in M.P. using WEAP Model (PBS: IWRM in Bina River Basin in Bundelkhand Region of M.P.)

3. **Study Group:**

Principal Investigator -	Dr. T.R. Nayak, Scientist E	
Co-P.I. –	R.K. Jaiswal, Scientist D	Dr. T. Thomas, Scientist D
	R.V. Galkate, Scientist E	Shashi P. Indwar, Scientist C

4. **Objectives:**

The objectives of the study have been framed as:

1. To develop the Water Evaluation And Planning (WEAP) applications for the watershed management in Bina river sub-basin for Reference year.
2. Formulation and evaluation of the following scenarios:
   - Population growth
   - Groundwater recharge
   - Incorporating Water Storage Structure (Dam) in the study area

5. **Methodology:**

WEAP is designed as a comparative analysis tool. A base case is developed, and then alternative scenarios are created and compared to this base case. Developmental activities in water sector, changes in operating policies, and implications of changing supplies and demands can be economically evaluated. This project will develop a comprehensive list of external drivers based on the studies carried out by the researches, literature review and interaction with the major stakeholders. This list will then be put under a well designed priority and ranking criteria for identification of the key drivers contributing to the anticipated changes. On the basis of performance and field validation, appropriate parameters will be selected for studying the baseline conditions and effects of external drivers on water availability (supply), demand, groundwater fluctuation. Unmet demands and predictions under various scenarios.

6. **Results:**

As per the suggested methodology, the required data was fed into data view of the model and results for the 'Reference accounts year (2011)' were calculated. The values for annual water use rate, population, and supply capacity of the sources were input; and WEAP thus gave the results for Total Water Demand, Available Supply and Unmet Demand of the watershed. Water Demand here is the total amount of water that is required in the region for use of various domestic and industrial purposes. The Bina sub-basin has a major agricultural area and the irrigation demands are complex, therefore these demands have been computed separately. Unmet Demands are the unsatisfied water demands that require great concern and alternatives to cope up with them. The database available on human population, live stocks, agricultural area under different crops, irrigation supply from surface water and groundwater, etc. for the study pertains to the year 2011, therefore this year has been chosen as the base year or 'Reference accounts year' to compare the future years with different scenarios with interventions, such as population growth, decrease or increase in rainfall/runoff, etc.

The unmet water demand may be taken as difference between the Supply Requirement (including losses and reuse) of all sites and the supply delivered. The annual unmet water demands for all administrative blocks and catchment sites have been worked out through WEAP modelling under the Reference Scenarios from the year 2011 to 2025. The Annual Variation in Unmet Demands for the year 2011, 2015, 2020 and 2025 for all administrative Blocks and for the Catchments have been shown in Table I-1.

Table I-1: Unmet Water Demands (all Administrative Blocks)

Demand Site	**2011**	**2015**	**2020**	**2025**
Begamgunj	1.044	1.114	1.196	1.266
Bina	0.428	0.456	0.488	0.522
Gairatganj	0.915	0.976	1.045	1.106
Gyaraspur	0.168	0.184	0.203	0.220
Industries	0.000	0.000	0.004	0.008
Khurai	0.712	0.756	0.805	0.849
Korwai	0.105	0.123	0.144	0.163
Rahatgarh	0.914	0.973	1.043	1.104
Tyonda	0.000	0.000	0.002	0.013
Sum	**4.285**	**4.582**	**4.931**	**5.250**

The Unmet Demands for all four scenarios, viz. Reference, High Population Growth, Ground Water Recharge and Water Storage Structure are given at Table I-2. This figure gives an overall outlook of the effect of different scenarios together. The figure also represent the relative effects of all scenarios, viz. unmet demands increases in case of High Population Growth Rate scenario and it decreases in case of Ground Water Recharge and Water Storage Structure scenarios. Thus the WEAP predicts the future demands under different scenarios.

Table I-2: Annual Variation in Unmet Demand (MCM), All Demand Sites

Year	Reference	Population Growth	Groundwater Recharge	Water Storage Structures
2011	32.55	32.55	32.55	32.55
2012	33.32	33.83	29.64	33.34
2013	32.74	33.84	25.65	32.76
2014	32.81	34.55	22.45	32.83
2015	32.87	35.33	18.94	32.89
2016	33.58	36.83	15.91	33.60
2017	34.01	38.14	13.05	34.03
2018	33.08	38.17	12.11	33.10
2019	33.15	39.31	10.58	33.17
2020	34.09	41.45	8.43	34.11
2021	33.29	41.95	7.05	21.33
2022	33.36	43.48	5.02	19.58
2023	33.44	45.15	2.79	19.62
2024	34.40	47.88	0.31	19.02
2025	33.59	49.01	0.18	19.69

Study – 2

1. **Thrust Area under XII five year Plan:** Reservoir Sedimentation

2. **Title of the Project:**
   Estimation of Revised Capacities in Reservoirs of Chhattisgarh State using Digital Image Processing technique

3. **Project team:**

PI	Sh. Rahul kumar Jaiswal, Sc-D	
Co-PI	Dr. T. R Nayak, Sc-E Sh. Ravi Galkate, Sc-E	Dr. T. Thomas, Sc-D Dr. A. K. Lohani, Scientist-G

WRD, Chhattisgarh, Raipur

PI	Sh. Akhilesh Verma, Dy Dir, SWDC, Raipur	
Co-PI	Sh. Rishi Chandrakar, Sh. J. N. Vishwakarma	Sh. S. K. Verma, Sh. S. K. Shukla, Sh. T. L. Chandrakar, WRD Raipur

4. **Objectives:**

- Preparation of GIS based database for the study area
- Collection and analysis of reservoir details and other information
- Selection and digital image processing of remote sensing data
- Estimation of revised capacities of reservoirs and trend assessment in selected reservoirs
- Knowledge dissemination and development of awareness

5. **Methodology:**

The basic principle of remote sensing based assessment of estimation of revised capacities in reservoir is lying in the fact that deposition of sediment brought down by river and tributaries reduces water spread when compared with original water spread. The revised water spreads at different levels in the live storage zone of reservoir can be determine with the help of digital image classification technique of remote sensing data in GIS platform. The synoptic viewing of large areas at regular intervals by different satellites makes it possible to select and determine revised water spreads at different levels. The revised water spreads computed from image processing are used to compute revised capacities which in turn give revised cumulative storages that can be compared with original capacities to determine loss in storages. The different steps used for determination of revised capacities with digital image processing of remote sensing data are given below:

Development of GIS Based data base of reservoirs

- Collection of reservoir details including reservoir levels
- Selection and procurement of remote sensing data
- Digital image processing in GIS for determination of revised water spread
- Estimation of revised capacities using digital image processing technique
- Estimation of average rate and trend of sedimentation in selected reservoir

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

The revised capacities of reservoirs estimated from the study will be helpful for efficient reservoir operation and modifying the releases considering present status of sedimentation. The average rate of sedimentation determined from the study can be used for selection of dead storages and gross capacities during design of future projects in the state.

The process of sedimentation in reservoir embodies the sequential processes of erosion, entrainment, transportation, deposition and compaction of sediment. The estimation of revised capacities at regular interval is necessary to formulate efficient operation plan under available capacity of reservoir, irrigation management and estimation of useful life and economic benefits of water resource project. During the period, the draft report containing the estimation of revised capacity for Ravishankar Sagar, Maramsilli, Tandula, Dudhawa and Gondli reservoirs were prepared and sent for review to experts and user agencies. The sediment in Dudhawa reservoir was determined using digital image classification technique of multi spectral data of nine different dates to cover whole range of live storage zone. The revised bed from the analysis was computed as 406.10 m with respect to original bed of 404.2 m and nearly 6.8% of cumulative storage (265.2 Mm^3) was lost in 50 years of its operation.

Conventionally, the sediment pattern for known sediment is computed with the help of empirical area reduction method suggested by Borland and Miller, 1960 is based on limited data from reservoirs in USA and some time give erroneous results. In the present study, an attempt has been made to optimize the parameters C, m and n of Borland & Miller method for sediment deposits in Ravishankar Sagar reservoir using Latin Hypercube, one parameter at time (LH-OAT) technique and compared with the results obtained from remote sensing technique. A program in FORTRAN language has been written to optimize the parameters. The C, m and n of empirical area reduction method was optimized and found as 2.1, 2.4 and 1.8 respectively. It has been concluded that the remote sensing technique coupled with optimization of Borland & Miller technique can be used to determine sediment pattern in dead and live storage zones of reservoir. The study may need six more months subjected to financial support for completing sedimentation analysis of other reservoirs.

Study-3

1. **Title of the project:**

   Groundwater Flow Modeling in Lower Bina river basin

2. **Project Team:**

PI	Er. Shashi Poonam Indwar, Scientist-C	
Co-PI	Dr. T.R. Nayak, Scientist-E Dr. T. Thomas, Scientist-D Sh. R.V. Galkate, Scientist-E	Sh. R.K. Jaiswal, Scientist-D Dr. N.C. Ghosh, Scientist-G

3. **Objectives of the study:**

- To analyse and model the groundwater flow paths in Lower Bina river basin
- To determine in detail the groundwater movement and assess the interaction between the groundwater aquifer and the lower Bina River using Visual Modflow Flex /Visual Modflow Software/Tool.

A finite difference model would be generated for groundwater flow analysis of lower Bina river watershed in Bina block. The conceptual model would be calibrated for steady state condition and validated for steady state conditon through USGS 3D Finite Difference code, Visual Modflow Flex. Various applications would be tried out on the calibrated model such as recharge to the aquifer, reasons for drying out of wells and water logging, river-drain influencing the aquifer and well design strategies. This study outcome would be helpful for groundwater development activity in lower Bina river watershed in Bina block.

4. **Action plan for forthcoming one year (2017-2018)**

Review Literature	Completed
Reconnaissance Survey of study sites	Completed
Data collection and base data analysis	Completed
Analysis of field data(Conceptualization of the problem, model setup, model data preparation)	Completed
Flow Model Calibration and Validation	Under progress
Report Writing	Under progress

5. **Objectives and Achievements:**

• To analyse and model the groundwater flow paths in lower Bina river watershed.	• The baseline data for groundwater flow modeling has been collected and assimilation of various other data related to flow modeling is completed. • The Conceptual framework for the flow model has been prepared.
• To determine in detail the groundwater movement and assess the interaction between the groundwater aquifer and the lower Bina River using Visual Modflow Flex/VM Software/Tool.	Under progress

6. Progress/Results Achieved during 2017-18

Data collection and base data computerization: The baseline data such as groundwater level measurements, river stage at different locations of the Bina River for flow modeling have been collected from CGWB and CWC respectively. Daily meteorological data for 16 years from 2000 to 2016 have been collected, graphs have been plotted to show the trends of groundwater levels. Bore log data for 3 locations, topographic information through SRTM data and generation of DEM is completed. Geological map, groundwater potential map, soil map, land use and land cover map have been generated using Geological Survey of India maps in GIS platform. Drainage map has been generated using DEM and Watershed delineation technique of ARC Hydro tool.

Analysis of field data (Conceptualization of the problem, model setup, model data preparation): The Conceptualization of the flow model has been completed.DEM (Digital Elevation Model) for the study area using SRTM data has been generated. Aquifer characterization is completed using Rockworks. Various hydrogeological and hydraulic data for setting up the flow model is in progress. Groundwater flow model calibration and validation is under progress.

Study-4

1. **Title of the Project:**

Evaluation of Impacts of Rabi Irrigation in Ganga River Sub Basin of Madhya Pradesh

2. **Study Group:**

Lead Research Institution: National Institute of Hydrology, Regional Centre, Bhopal

PI	Mr. Ravi Galkate, Scientst-E
Co-PI	Mr. R.K. Jaiswal, Scientist-D Dr. T.R. Nayak, Scientist-E Dr. T. Thomas, Scientist-D Mrs. Shashi Indwar, Scientist C

Partner Institution: Water Resources Department (WRD), Madhya Pradesh, Bhopal

PI	Director, Hydrometeorology
Co-PI	Dy. Director & DBA, Bhoapl Dy. Director, Hydromet Div No. 3 Rewa

3. **Study area:**

- The evaluation of impacts of Rabi irrigation on hydrology, agricultural growth, socio-economy and health will be conducted for three irrigation projects of MP namely, Samrat Ashok Sagar, Jajon dam on Betwa river in Vidisha district and Kotwal dam on Asan river in Morena district.
- Performance evaluation will be carried out of eight medium irrigation projects located in the major tributaries of Ganga and Yamuna basin such as Betwa, Chambal, Dhasan, Ken, Son, tone and Sindh. These irrigation schemes are Naren Dam, Mala dam, Rajendra sagar dam, Kotwal dam, Lilgi dam, Mehroi and Jajon.

4. **Objectives:**

- ✓ Evaluation of impacts of Rabi irrigation on hydrology, agricultural growth, economy and public health for selected irrigation projects in Ganga basin. Performance evaluation of medium/minor irrigation projects.
- ✓ Development of web based dynamic application for performance evaluation of irrigation project.
- ✓ Recommendation of strategies to improve the performance of irrigation projects, dissemination of knowledge and findings through trainings and workshops.

5. **Progress/Results Achieved during 2017-18**

The project proposal was presented before the NHP Review Committee at NIH Roorkee and few modifications were suggested to add new on development of dynamic web application, to add new aspect of health impact in objectives and to increase budget, which were incorporated in the proposal. Then the approval was accorded by the Committee in September, 2017. Correspondence has been made to WRD for seeking hydrological and meteorological data of study area and dam details. The process and formalities of appointment of JRF has been completed. As per the provision in PDS proposal the process of purchase of laptop and computer is under progress. An one day stakeholders workshop has been planned in the month April, 2018 at Bhopal. Detail data of dam and command area, crop type, etc of Kotwal dam has been collected from WRD. Review work of the study is under progress.

6. **Duration: 3 years**

7. **Budget: Total Cost of Project (Rs.): 54.512 lakh**

a) Lead Institution- NIH, RC, Bhopal: 44.512 lakh
b) Partner Institution- WRD, Bhopal: 10.000 lakh

Study- 5

1. Title of the Project:

Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh

2. **Study Group**:

Lead Research Institution: National Institute of Hydrology

PI	**Dr. T. Thomas, Scientist-D**	
Co-PI	Dr. P.C. Nayak, Sc-D Dr. Surjeet Singh, Sc-E Dr. B. Venkatesh, Sc-F	Er. R.V. Galkate, Sc-E Er. R. K. Jaiswal, Sc-D Ms.ShashiPoonam Indwar, Sc-C

Partner Institution: Water Resources Department (WRD), Madhya Pradesh

PI	Director, Hydrometeorology, WRD, Bhopal.	
Co-PI	Sh. M.K.Paliwal, Dy.Director, WRD, Bhopal Er.SanjivDas,Dy.Dir.& DBA, WRD, Bhopal	Mr. Sunil Vyas,Dy. Director Mr.Girish Sharma, SDO

3. Study area:

Chambal basin in Madhya Pradesh comprising of its right bank tributaries including Parvati river, Kalisindh river, Newaj river and Chambal river covering the districts of Mandsaur, Ratlam, Rajgarh, Guna etc. in Madhya Pradesh

4. Objectives:

- ✓ Assessment of climate change signals in Chambal basin.
- ✓ Evaluation of drought characteristics and investigation of the desertification.
- ✓ Hydrologic modelling for simulation of the hydrological processes in the basin.
- ✓ Assessment the impact of climate change under alternate climate scenarios on the future water availability, drought and desertification.
- ✓ Evaluation of the impacts of upcoming irrigation projects on the drought and desertification.
- ✓ Integrated assessment of vulnerability to drought, desertification and climate change.

6. Progress/Results Achieved during 2017-18

The project proposal was presented before the NHP Review Committee at NIH Roorkee and minor modification was suggested to reduce the cost of the GPS which was incorporated and submitted. The approval was accorded by the Committee in December 2017. Letters of request seeking the hydrometeorological and hydrological data have been sent to CWC, Yamuna basin; CGWB, Bhopal; Data Centre, MP WRD; and MPCST Bhopal. The approval has been accorded for the recruitment of a JRF. Also approval for the procurement of the computers, software and other equipments is under process. A visit was made to the Mohanpura dam site, which is under constructed and the pressurized irrigation system being adopted there was studied in detail with the project authorities. The catchment area has been delineated for the various sub-basins falling under the Chambal river system in Madhya Pradesh.

Study - 6

1. Title of the project:

Modeling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy

2. Project Team: National Institute of Hydrology

PI	Er. Shashi Poonam Indwar, Scientist C	
Co-PI	Dr. T. Thomas, Scientist D Dr. T.R. Nayak, Scientist E Sh. R.V. Galkate, Scientist E	Sh. R.K. Jaiswal, Scientist D Dr. N.C. Ghosh, Scientist G Er. Sumant Kumar, Scientist C

3. Objectives

- ✓ Assessment of the present supply-demand scenario for Tawa reservoir.
- ✓ Establishment of a comprehensive hydrological model for Tawa river basin upto Tawa reservoir.
- ✓ Assessment of climate change signals based on the historical hydro-meteorological and hydrological datasets.
- ✓ Evaluation of future supply-demand scenario in the light of climate change.
- ✓ Reservoir operation for optimal utilisation of future water resources.

4. Origin of the Proposal & Problem Definition

A number of reservoirs have been planned and constructed in India for the conservation and utilization of the water resources for deriving various benefits. The Tawa River is one of the important left bank tributary of Narmada River and the Tawa dam a major irrigation project, is located on it. The management of any reservoir system from planning to operation is quite challenging as it deals with diverse complex variables and uncertainties viz., inflows, return flows, storages, diversions, inter/intra-basin water transfers, irrigation demands, hydropower demands, industrial demands and municipal water supply demands (Rani & Moreira, 2010). The reservoir management strategies should be based on the hydrological response of the catchment as well as the water utilization pattern in the command areas.

Both the left bank canal (LBC) and right bank canal (RBC) of the Tawa dam caters to large command area, which is largely located outside the extent of the confluence of Tawa River with the Narmada River. The Tawa river basin is however considered to be a water deficit basin and the water allocation to the competing water users is quite challenging. Looking into the climate change related impacts and uncertainties in future, the management of the available water resources including the management and operation of the Tawa reservoir should be challenging as well as an interesting case study for devising targeted adaptation plans for the various stakeholders. In such an uncertain futuristic scenario, the assessment of the impacts of climate change on the water availability in the reservoir and the subsequent impacts on meeting the committed demands for the domestic, industrial and agricultural sector is necessary. The study shall cater to these issues and will explore the possibilities of formulating revised reservoir operation policies to address the altered future supply-demand scenario in the basin.

5. Total Budget: **NIH: Rs. 25, 46,000**

6. Administrative progress-

Under the study titled," Modeling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy",

(i) JRF recruitment was undertaken through interview dated 16/1/18 and 1 JRF (Er Ankit Kumar, M.Tech in Water Resources) recruited for the project dated 2/2/18.

(ii) Purchase of items bearing expenditure of Rs 2.30 Lakh under the head Infrastructure/Equipment note sheet forwarded to Nodal Officer Project Management Unit NHP.

(iii) Budget Plan of above mentioned PDS study for current year 2017-2018 sent for sanctioning of funds amounting to Rs 13.20 Lakh.

7. Technical progress-

Work Component to be achieved during 6 months (September, 2017-Febuary, 2018) and current status:

1.Field trip undertaken on 29/11/17-1/12/17 –Had meeting with SE (Tawa Project Circle) and EE(Itarsi Office) ,informed about the NHP_PDS study under which Inception Workshop has to be conducted. It was decided that the 1Day Workshop can be conducted at Itarsi Tawa Office to benefit the officials of Tawa and other related stakeholders (Irrigation Department, Agriculture Department, Fisheries, and Hydro-power etc)

2. Database generated and obtained for the Tawa Catchment and Tawa Catchment Command

Study-7

(under Centre for Excellence in Hydrologic Modelling)

1. Title of the Project:

Integrated Assessment of the Impacts of Climate Change and Land use Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches – NIH under Centre for Excellence in Hydrologic Modelling.

2. Project team:

Lead Research Institution: National Institute of Hydrology

PI	Dr. T. Thomas, Scientist-D	
Co-PI	Dr. Surjeet Singh, Scientist-E Dr. B. Venkatesh, Scientist-F Dr. P. C. Nayak, Scientist-D Dr. ArchanaSarkar, Scientist-D Er. Manish Nema, Scientist-C Dr. Prabhash Mishra, Scientist-C Er. Shashi P. Indwar, Scientist-C	*Dr. Sharad Jain, Scientist-G* *Dr. N.C. Ghosh, Scientist-G* *Dr. J. V. Tyagi, Scientist-G* *Dr. Sanjay K. Jain, Scientist-G* *Dr. M. K. Goel, Scientist-G*

Partner Institution: Water Resources Department (WRD), Madhya Pradesh.
M. P. Council of Science & Technology, Bhopal.

PI	Director, Hydrometeorology, WRD, Bhopal.
	Dr.SandeepGoyal,Sr. Principal Scientist, MPCST
Co-PI	Sh.Sanjiv Das,Dy. Director & DBA, WRD,MP Sh. M. K.Paliwal, Dy.Director, WRD,MP

3. Objectives:

- ✓ Application of hydrological models for simulating the present and future water availability under climate and land use change scenarios.
- ✓ Assessment of future water availability under alternate scenarios of climate change and land use change for the near-term (2006-40), mid-term (2041-70) and end term (2071-99).
- ✓ Water allocation planning and optimal water use based on future water availability scenario.
- ✓ Assessment of Environmental Flow Requirements (EFR) for various river reaches in the study area.
- ✓ Characterization of extreme events including droughts and floods.

4. Progress/Results Achieved during 2017-18

The project has been awarded very recently in February 2018. The study area has been delineated and the data collection is in progress. Efforts are being made to collect the hydrometeorological and hydrological data from CWC, CGWB, MP-WRD and IMD. It is also proposed to carry out a comprehensive soil sampling and testing for various crop-soil combinations in the basin. 85 sampling sites have been identified in the study area based on the grid size of 25 km x 25 km and also comprising of various types of soil-land use combinations, which area also easily approachable. The soil sampling exercise will be taken up once the rabi crop is harvested from the fields. Also the approvals for the computer hardware, software and project staff have been sought, which is under consideration. A meeting is proposed to be held shortly wherein all the investigators shall be involved and it shall be presented how to carry forward this project in a planned manner with specific work assignments, so as to meet the desired objectives of the Centre for Excellence in Hydrological Modelling.

Study-8

1. Thrust Area: Hydrology for sustainability of water resources

2. Title of the Project: Modelling of Narmada using GWAVA.

3. Study Group:

PI	Dr. Sanjay Jain,Sc G, NIH Roorkee.	
Co-PI	**Dr. T. Thomas, Sc-D, NIH-RC Bhopal.** Dr. P K Mishra, Sc-C, NIH Roorkee. Er. Manish Nema, Sc-C, NIH Roorkee. Dr. Sharad Jain, Director, NIH.	Dr. Gwyn Rees, Science Head WR, CEH Wallingford, UK. Ms. Helen Houghton-Carr, Senior Hydrologist, CEH Wallingford, UK. Mr. Nathan Rickards, Hydrologic Modeller, CEH Wallingford, UK.

Project Partners: Centre for Ecology & Hydrology, Wallingford, UK.

4. Study area: Narmada river basin up to Hoshangabad in Madhya Pradesh.

5. Objectives:

- Collection and processing of historical data
- Modelling of rainfall runoff.
- Future climate change and land use change projections.
- Impact of changes on the water availability.

6. Progress/Results Achieved during 2017-18

The GWAVA hydrological model developed by CEH Wallingford, UK has been setup for the Narmada basin up to Hoshangabad GD site. GWAVA is a gridded model and the inputs comprising of climate data have been provided at a finer resolution of 0.125^o x 0.125^o. All the other mandatory input data including DEM, land use/land cover, soil type, population density map, livestock density map, season-wise cropping patternetc. were prepared in GIS environment and data input extracted in ASCII format and fed to the model at the same resolution. The initial calibration runs on a daily time scale were giving poor performance indicator values, which was mainly due to the application of the Thornthwaite method for computation of evapotranspiration, which gave the same ET value for all the days in a month. Therefore the Hargreaves method was included in the source code and the model runs thereafter gave encouraging results. The land use map was revised based on the fine resolution (500 m) data from the USGS and converted into the four types of GWAVA land use format. To capture the real picture of the water transfers from Narmada basin to other cities, as well as transfers out of the basin was incorporated in the model viz., water transfer to the command area of Tawa basin which falls completely outside the study area; transfer of drinking water to Bhopal city from main river near Hoshangabad. This further improved the calibration results to a good extent. The future watertransfer to Ganga basin through the right bank canal from Bargi dam has been incorporated in future developmental scenarios. The model has been use to study the impact of climate change, land use change and planned developmental activities on the hydrology of the basin including the water availability, for the future time horizon from 2028-2060. All the model runs have been completed and the future streamflow data has beenanalyzed to derive the matrix depicting the standalone impacts of climate change, land use change, developmental aspects as well as the integrated impacts. The report will be completed and submitted by June 2018.

A one-day Brainstorming Session on “Capabilities of Hydrological Modelling in Decision Making” was organized jointly by NIH and CEH at PICU, WRD Bhopal on 9th March 2018, to disseminate the findings and outcomes of this modelling exercise to the various stakeholders and policy makers. The brainstorming session was attended by 47 participants from various organizations who appreciated the efforts being carried out by NIH in promoting the use of modelling in decision making. It was decided by Director NIH and CEH to extend the study to cover the the full Narmada basin during the current year 2018-19.

New Studies Proposed for the Year 2018-19

Study-1
(New PDS)
REMARKS: (UNDER CONSIDERATION BY NHP-PDS)

1. Thrust Area under XII five year Plan:

Irrigation management

2. Title of the PDS

Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Thanwar Irrigation Project in Madhya Pradesh

3. Project team:

PI	Sh. Rahul kumar Jaiswal, Sc-D	
Co-PI	Sh. Ravi Galkate, Sc-E Dr. T. Thomas, Sc-D Dr. D. S. Rathor, Scientist-F	Dr. T. R Nayak, Sc-E Smt. Shashi P. Indwar, Sc-C

MP WRD, Bhopal

PI	Director, DRIP, O/o Chief Engineer (BODHI), WRD Bhopal	
Co-PI	Director, Hydrometeorology, State Water Data Centre, Bhopal (M.P.) Deputy Director (Data Base Administrator), : State Water Data Centre, WRD Bhopal (M.P.)	Superintendent Engineer, Thanwar Irrigation Project (M.P.) Executive Engineer, Astt Engineers, Sub Engineers, Thanwar Irrigation Project (M.P.)

4. Objectives

- Assessment of different components of hydrological cycle for computation of irrigation return flow coefficients in the command
- Spatially distributed modeling of hydrological processes at the level of canal command area
- Investigation of various scenarios including conjunctive use, irrigation water management, cropping pattern changes, variable climate etc. for irrigation planning and reservoir operation in command
- Development of web/mobile application for WR managers and farmers for optimal release and management of water resources
- Capacity building and development of public awareness through workshop, conference, seminars and preparation of manual, leaflets etc.

5. Methodology

In India, irrigation has gain substantial importance due to erratic behaviour of monsoon and more crop production to feed increasing population. The loss of water through conveyance and application are emerged as irrigation return flow that can be reused to increase efficiency of irrigation system. The quantification of return flow from irrigation system is usually done through thumb rule without considering important criterions including soil properties, topography, crops, condition of distribution system, application methods etc. Very little efforts have been made to quantify irrigation return flow and still considered as grey area in irrigation management. Proper and equitable distribution of irrigation water is another area where scientific knowledge with management skill can play important role for optimum utilization of water resource in the command. The methodology for attaining the objectives of the PDS includes survey of the command, development of GIS data base, evaluation of hydrological soil properties, groundwater monitoring and measurement of different components of hydrological cycle in the command, pump tests for determination of specific yield and transmissivity, water balance for computation of return flow, application of spatially distributed hydrological model, development of MIKE HYDRO management model and development of mobile based application for planning irrigation releases

6. Research outcome from the project

Very limited studies have been carried out on irrigation return flow in India and abroad because of considerable effort and scientific inputs. The irrigation return flow can be used to design irrigation projects and downstream water availability. The scenarios based assessment of irrigation planning can be used by water resource managers to operate reservoir for optimal production under climate change, conjunctive use, efficiencies conditions. The mobile based application developed under this PDS can be used to transfer information and issuing advice and suggestion to farmers for efficient management of existing water resources. The scientific community can use the results of this study to other water resource projects for modeling and computation of return flows in other projects.

7. Budget

NIH: Rs. 63.00 Lakh
WRD MP: Nil

Study-2

(New PDS)

REMARKS: (UNDER CONSIDERATION BY NHP-PDS)

1. **Project Title:** Rejuvenation of Arpa River in Upper Mahanadi Basin

2. **Duration of the project:** 4 Years

3. **Study Group:**

Lead Organization: Water Resources Department, Govt. of C.G., Raipur

PI	**Er. Akhilesh Verma, Dy. Director (Hydromet)**	
Co-PI	1.	Er. S. K. Saraf, Sub Divisional Officer
	2.	Er. J.N. Vishwakarma, Assistant Engineer
	3.	Er. J.K. Dass, Sub Engineer

Partner Organization: National Institute of Hydrology

PI	**Dr. T. R. Nayak, Scientist-E**	
Co-PI	1.	Mr. R. K. Jaiswal, Scientst-D
	2.	Mr. R. V. Galkate, Scientist-E
	3.	Mrs. Shashi P. Indwar, Scientist-C

4. **Project Summary (Max. 200 words)**

Bilaspur district in Chhattisgarh receives an average rainfall of about 1220 mm that is amongst the good range in the country. Yet as summer approaches all lakes and rivulets go dry. As a part of National Hydrograph Network Observation Stations (NHS), 43 no of dug wells and 17 no of piezometers are established to monitor water levels four times in a year. The average depth to water level in the district during pre-monsoon period is 8.30 m bgl. The water level varies between 5 to 16.5 m in the area. The average depth to water level in the district during post-monsoon period is 4.34m bgl. From the figure it is clear that the water levels during the post-monsoon period are mostly varying from 0 to 5 m. The maximum falling trend is observed in the monitoring well at Bilaspur followed by Pathriya and Sipat. The rising trend has been observed in Lormi, Kota, Saragaon and Belgahana wells. The rising trend is observed in the canal command area and the hilly tracts and the falling trend is more significant in the Chhattisgarh plain area in the southern half of the district. The pre-monsoon long-term water level fall suggests an increase in ground water abstraction over the years (Source: CGWB, NCCR, Raipur). Nearly 30% of the bore wells of Bilaspur and Sipat area in Arpa River Basin become dry during the summer months due to over exploitation. The river that once used to flow throughout the year is restricted to few months of monsoon.

In the first phase, a status report will be prepared to assess the present supply and demand. The water balance of the Arpa river basin will be prepared including surface water inflows and outflows; groundwater recharge, withdrawal and fall/rise; effect of developmental activities in the water resources viz. growth in water demands/supply due to population growth, industrialization, construction of irrigation projects, etc. Long term trend analysis will be carried out to identify the significant changes in rainfall, stream flow and groundwater levels. More importance will be given to harvest the rain water for groundwater recharge to inverse the declining trend of groundwater table and increase the base flow in the river Arpa. Finally, a comprehensive river basin management plan will be prepared to rejuvenate the Arpa river, which once used to flow throughout the year in this area. Also, the water quality of Arpa river will be monitored and corrective measures will be suggested to improve the water quality as per the requirements.

In phase II, a pilot sub-basin will be selected for implementation of the suggested river basin management plan through various government schemes. We anticipate that by the end of the fourth year groundwater level would rise to such levels that the streams in the pilot sub-basin would start gushing again in post monsoon months.

5. Total Cost of Project: Rs.68 Lakh

a) MP-WRD: Rs.35 Lakh

b) NIH: Rs.33 Lakh

Study-3

(Sponsored project under R&D programme of DST)

1. **Title of Project:**

Revival of Village Ponds through Scientific Interventions in Sagar District (Sponsored R&D Project by Department of Science & Technology, Govt. of India).

2. **Study Group:**

PI	**Dr. T. Thomas, Sc D, NIH Bhopal.**
Co-PI	Dr. SandeepGoyal, Sr. Principal Scientist, MPCST, Bhopal. Dr. Vivek Bhatt, Associate Professor & Head WRM&E, WALMI, Bhopal. Dr. JyotiPatil, Sc C, NIH, Delhi Office, New Delhi.

3. **Study area:** Two village ponds in Banda block of Sagar District in Bundelkhand region of Central India.

4. **Objectives:**

- Creation of an inventory of ponds and preparation of present status of selected ponds.
- Assessment and documentation of construction, management and use of village ponds.
- Analysis for identifying the causes for the dysfunction of the selected ponds.
- Identification of possible scientific interventions and involvement of community participation for revival of the selected ponds.
- Capacity building initiatives for knowledge dissemination to the stakeholders.

5. **Progress/Results Achieved during 2017-18**

The project has been initiated under the R&D programme of Department of Science and Technology, Govt. of India with an aim to harvest the rainwater through surface storage in existing but dysfunctional village ponds and tanks. These measures involving the local communities under the participatory management approach may prove to be an effective method in facing the challenges of water scarcity in rainfed regions under the impending impacts of climate change. The Bundelkhand region in Central India (Agro-ecological zone 10) has been selected for the study as the region is under regular droughts and faces severe water scarcity during in summers. The local population, particularly women have to travel far distances to fetch the much required drinking water. Moreover the agricultural productivity is very low due to non-availability of assured water for irrigation.

The methodology and the proposed schedule of activities was presented at the DST Take-ff meeting held at Punjab Agricultural University, Ludhiana which was reviewed by Dr. Bhoop Singh, DST and Prof. S. Kukkal, Programme Coordinator. Few field visits were carried out to the Bundelkhand region by the team of Scientists from NIH, WALMI and MPCST and many village ponds visited to identify the issues facing the people vis-à-vis the village ponds and their use. Two village ponds have been identified in the Banda block of Sagar district viz., i) village pond in Sahawan village and ii) village pond in Cheelpahadi village. Both these ponds are situated in the water stressed areas and the water quality is very poor due to the domestic animals and people bathing in the lake and due to inflows from households located in the vicinity of these ponds. Since both these villages have very limited groundwater potential, people have to travel several kilometers to fetch the water for drinking. The catchment area and the water spread area of these village ponds have been delineated using SRTM digital elevation model. However, the field survey is being planned to demarcate the actual catchment area of these village ponds. Interactions were held with the local administration and efforts are being to channelize some of their departmental funds for the activities that shall be suggested to enhance the storage capacity as well as improve the water quality of these ponds. Meetings were held with the village Sarpanch of both these villages to ensure their participation and mobilize the local communities in the conservation efforts. The water quality sample has been collected and analyzed at the laboratory of MP Pollution Control Board at Sagar. The progress report during the period July – December 2017 was presented at the DST Progress Review Committee Meeting held at IARI, New Delhi during January 2018. The analysis pertaining to the rainfall variability, and evaluation of drought characteristics have been completed for the study area. One JRF and one Field Assistant have been appointed under the project in November & December 2017 respectively. The approvals for the procurement of the instruments for the monitoring network have been obtained from the competent authority and are in the processing stage.

DELTAIC REGIONAL CENTRE
KAKINADA

Scientific Manpower

S N	Name	Designation
1	Dr. YRS Rao	Scientist F & Head
2	Mr. S V Vijayakumar	Scientist F
3	Dr. V S Jayakanthan	Scientist E
4	Dr. P C Nayak	Scientist D
5	Mr. R. Venkata Ramana	Scientist D
6	Mr.T.Vijay	Scientist B

Work Program for 2017-18

S.N.	Title of the Project	Team	Duration (Start date and End date)	Funding
I.	**Internal Studies**			
1	Sedimentation Study of Hirakud Reservoir, Odisha using Optic and Microwave Remote Sensing Technology	V.S. Jeyakanthan(PI) J.V. Tyagi Y.R. Satyaji Rao S.V. Vijaya Kumar R. Venkata Ramana P.C. Nayak	July 2017-March 2020	Approved by NHP PDS Rs.51.19lakhs (SP-28/2017-18/PDS-3)
2	Groundwater salinity source identification in Godavari delta, Andhra Pradesh	Y R Satyaji Rao (PI) T Vijay J.V. Tyagi S V Vijaya Kumar V S Jeyakanthan P C Nayak R V Ramana	Dec., 2017-March 2020	Approved by NHP PDS Rs 61.09 lakhs (SP-28/2017-18/PDS-13)
3	Forecasting of Flash flood and Management of East Flowing Rivers of India's sub Zone 4 (A)	R. V. Ramana (PI) Y.R. Satyaji Rao V.S. Jeyakanthan S.V. Vijaya Kumar P.C. Nayak T.Vijay	Dec., 2017-March 2020	Internal (Yet to be approved by RCC)
II.	**Sponsored Projects (Ongoing)**			
1.	Hydrological evaluation of existing water conservation/ harvesting structures in identified IWMP watersheds in Chitturu and Ananthapur district (AP)	Y. R. Satyaji Rao R. Venkata Ramana V.S.Jeyakanthan	April 2017-March 2019	DoLR (under NNWP)
2	Hydrological evaluation of existing water conservation/ harvesting structures in identified IWMP watersheds in Pulbani and Khandamal district (Odisha)	Y. R. Satyaji Rao V.S.Jeyakanthan R. Venkata Ramana	April 2017-March 2019	DoLR (under NNWP)
3	River bank Filtration (RBF) studies in coastal alluvium of Andhra Pradesh	Y R Satyaji Rao (Co-PI) T Vijay	April 2016 - March 2019	Under Peya Jal Suraksha Project

Progress of ongoing studies of 2017-18:

Title : Sedimentation study of Hirakud Reservoir, Odisha using Optic and Microwave Remote Sensing Technology

Objectives:

- To assess the best approach between per-pixel, sub-pixel and super resolution classifier for the reservoir sedimentation estimation of Hirakud reservoir

- To evaluate the feasibility of Microwave satellite data for reservoir water-spread area estimation.

- To estimate sediment yield and prepare watershed wise soil erosion maps of the Hirakud basin using soil erosion modeling approach.

Progress of the study:

SOI topographical maps and soil maps of the study area were procured and georeferenced in GIS framework. The DEM map of the study area is prepared for the study area. Further study area catchment map, DEM map, drainage map and sub-watershed map pertaining to Hirakud catchment area have been prepared. The location of Hirakud reservoir is shown in Figure 1 and DEM of the catchment area is shown in Figure 2. Hirakud catchment area soil map pertaining to the study area and water-spread area estimation of Hirakud reservoir from microwave data (Sentinal-1A-SAR) is in progress.

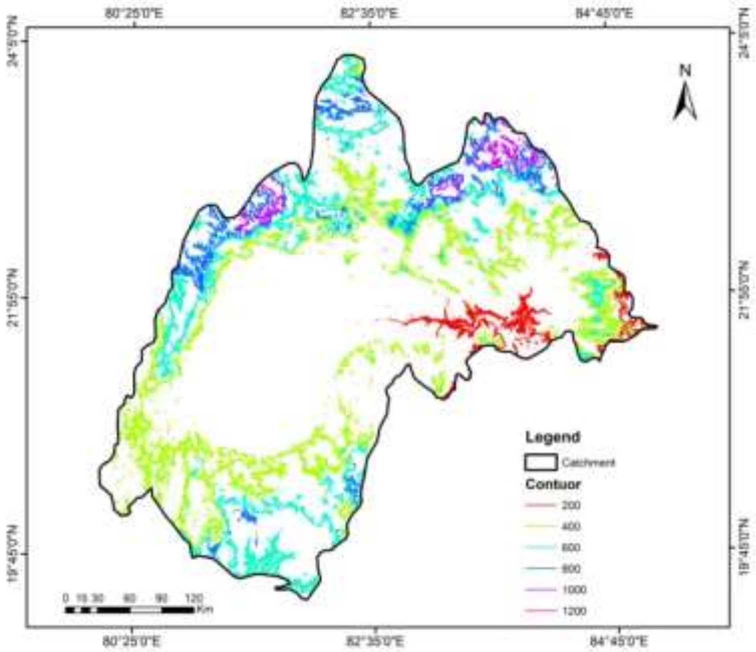


Figure 1. Location of Hirakud reservoir and its catchment area with topographical contours

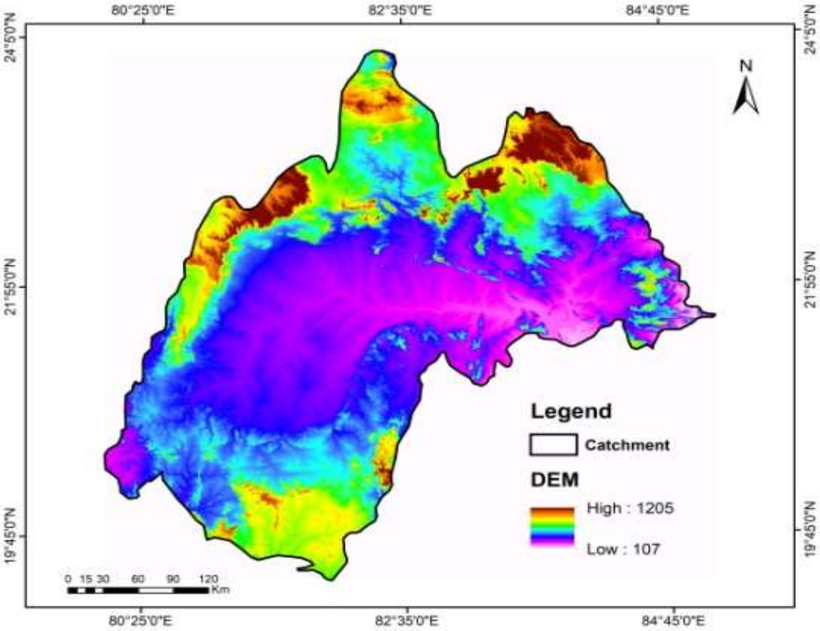


Figure 2. DEM of the Hirakud reservoir catchment area

Title: Groundwater salinity source identification in Godavari delta, Andhra Pradesh

Objectives:

- Identification of groundwater salinity zones within the Godavari Delta
- Salinity Source identification using integrated approach
- Remedial measures to control groundwater salinization in Godavari delta

Progress of the study:

The Godavari Delta has been covered by East Godavari and West Godavari District in Andhra Pradesh. Most of the thematic layers are available in the form of Administrative boundaries (Districts) and all statistical data is available on Mandalwise administrative boundaries. The relevant SOI topographical sheets on 1: 50000 scale has been obtained (23 Nos) and base map has been prepared in GIS frame work. The soil map and its details are collected for the study area. Groundwater levels and water quality network has been integrated from State Groundwater Department and CGWB for identifying gaps for further monitoring of ground water quality. Godavari delta, its river mouth and important locations are shown in Figure 1. The present water quality analysis indicates that groundwater in coastal areas is susceptible to salinization by natural developments and anthropogenic factors. In addition to this, many harmful pollutants, such as agricultural fertilizer, pesticides, waste deposits, industrial effluents and aquaculture altering the chemical composition of groundwater. The shallow water quality data indicated that there is significant increase of TDS from the year 2005 to 2016 and decease in the paddy grown area from 2007 to 2016. The detailed analysis is under progress.

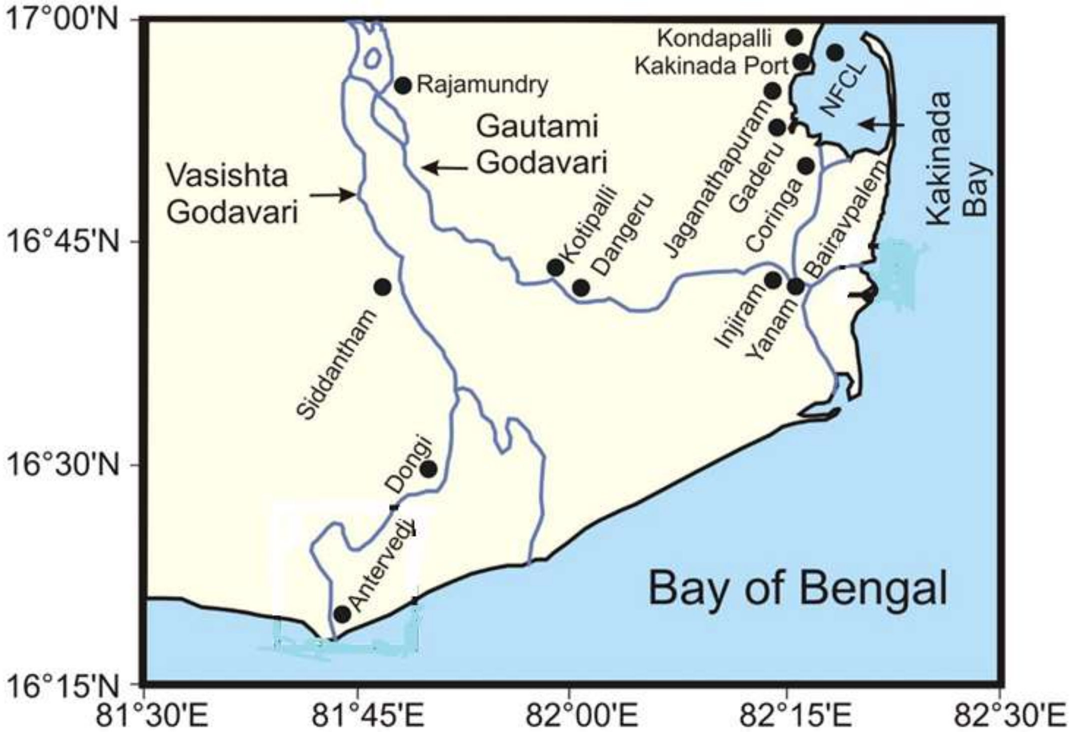


Figure 1. Location of Godavari delta and its river mouths

Title : Forecasting of Flash flood and management for east flowing rivers of India's Sub-zone 4(A).

Objectives:

- Study on flash flood for east flowing rivers of sub zone 4(A)
- Analyze historical precipitation data and precipitation forecast estimates from IMD as input to such rainfall-runoff model for flood forecasting.
- Assessment of flood pattern in the region of sub zone 4(A) due to climate change.

Progress:

In the proposed study hydrological model HEC HMS (the Hydraulic Engineering Center hydrological model System) with hydrodynamic model HEC-RAS (the Hydraulic Engineering Center River Analysis System) model would be integrated by employing IMD forecast rainfall as input. As per CWC report three basins lies in flood prone area in the sub zone 4(A) of the Andhra region namely Vamsadhara, Nagavali and Sarada river bains. Accordingly ASTER 30 m resolution digital elevation model (DEM) downloaded from Earth Explorer (USGS WEB site) and delineation study basin, sub-catchments and drainage network using with terrain processing in HEC-GeoHMS environmental. Basin, sub-catchments and stream characteristics was determined in basin processing. Land use and landcover (LU/LC) were performed with January 2018 landsat 8 image downloaded from USGS web site. Daily gauge discharge data downloaded from India-WRIS and IMD 0.5 degree gridded daily rainfall of three basins has been analyzed. The preliminary model setup is shown in Figure 1. The detailed data collection and preparation of thematic maps and preparation of model inputs are under progress.

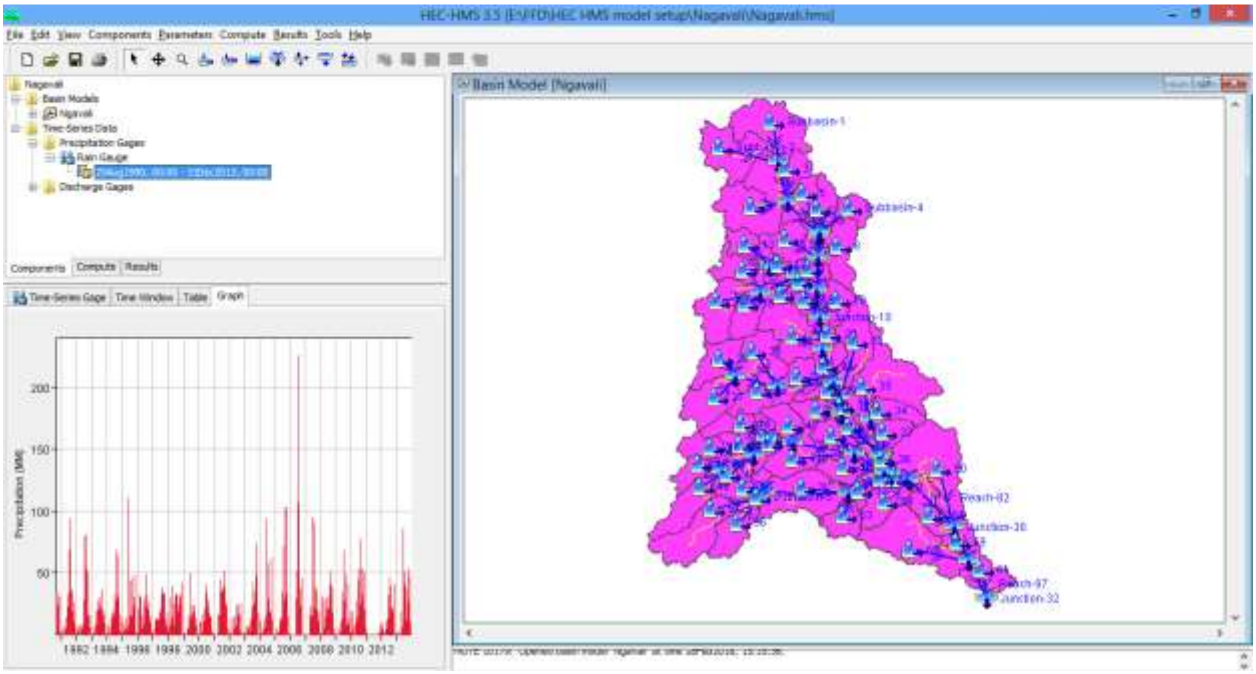


Figure 1. HEC HMS model setup of the Nagavali river basin in the sub zone 4(a) in A.P

Title : Hydrological evaluation of existing water conservation/ harvesting structures in identified IWMP watersheds in Chittoor and Ananthapur districts (AP) under NNWP

Progress of the study:

Conducted field visit in Mudivedu and Maddinayunipalli watershed projects and collected the preliminary data from local community and user groups. Organised two day workshop on “DSS- (H) Deliberating Modules and Database” for different user organizations and NGOs at Tirupati, Chittoor District, AP during 28-29 Aug., 2017. Total 10 watershed projects, 5 each in Chittoor and Anantapur, AP have been identified under NNWP. The Mudivedu watershed area is about 3706 ha and Maddinayunipalli is about 4000 ha. Since identified watersheds are new, no hydrological data is available. AP State SLNA papered the DPR for procuring the instruments and installation in the identified watershed for data generation. ASTER 30 m resolution DEM has been downloaded from EarthExplorer and delineated drainage network and sub catchment areas using terrain processing in ArcGIS for two watersheds in Chittoor districts, AP and the same is shown in Figure 1. Rainfall and runoff modeling is under progress.

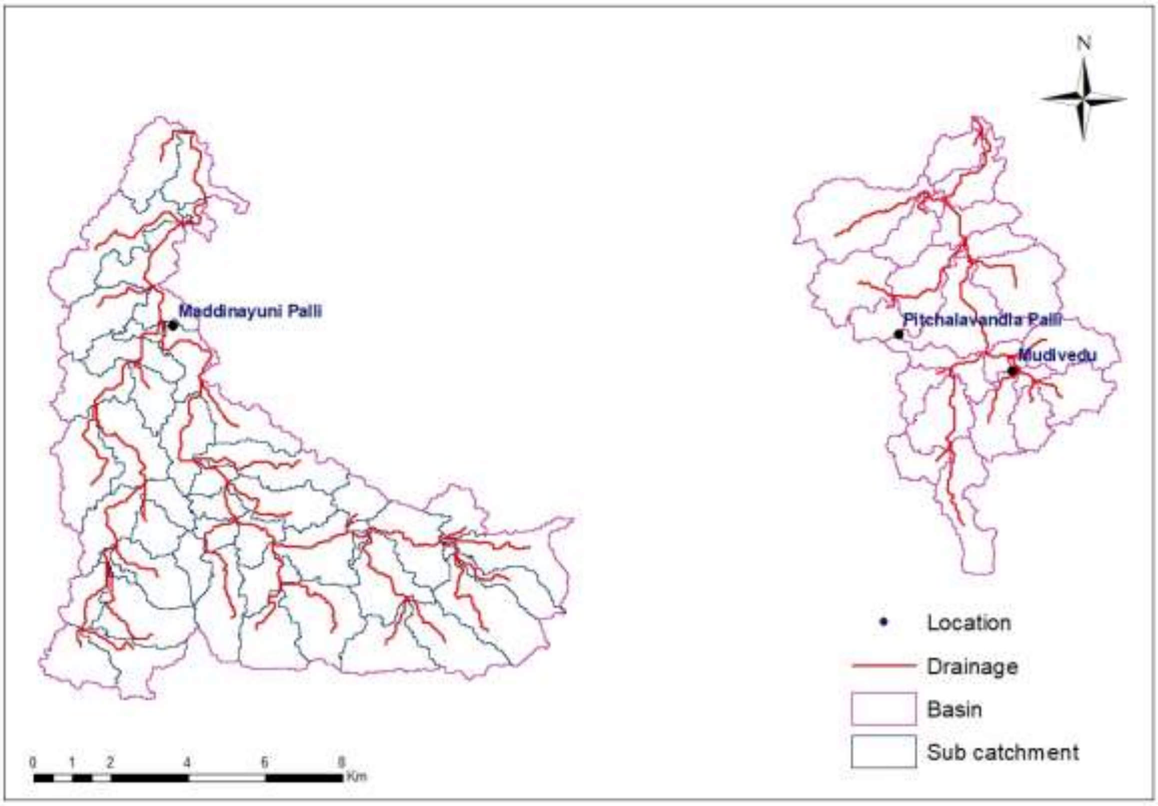


Figure 1. Mudivedu and Maddinayunipalli watershed projects in Andhra Pradesh.

Title: Hydrological evaluation of existing water conservation/ harvesting structures in identified IWMP watersheds in Pulbani and Khandamal district (Odisha)

Progress of the study:

Visited Kandhamal watershed project area and ground truth information has been collected from four villages namely Pendipadar, Bandudi, Nahudumaha and Balmargan. Further interacted with farmers and obtained information on crop production, available irrigation facilities, alternative livelihood opportunities, availability of facilities- drinking water, sanitation, electricity etc. During filed visit GPS points were collected at water conservation structures and also for different types of crops grown. Organized two day workshop on 'DSS (H) Deliberating Modules and Database' with different user organizations and NGOs at Phulbani, Kandhamal District, Odisha during 6th to 7th September 2017. Watershed delineation and model setup is under progress at NIH, Roorkee.

Title : River bank Filtration (RBF) studies in coastal alluvium of Andhra Pradesh under Peya Jal_ Suraksha Project

Objectives:

- Identification of Drinking water gaps in coastal areas in consultation with RWS and Sanitation Department of Andhra Pradesh
- Selection of RBF site by geophysical investigations and satellite imageries
- Drilling and design of groundwater pumping schemes through RBF
- Finalization of pumping schemes and handing over to state department for further use

Progress of the study:
Conducted field investigations and found a village in S. Rayavaram mandal of Visakhapatnam district on Varaha river for supply of fresh drinking water to the nearby village people, who do not have access to fresh groundwater, as the villages are affected by salinity. The present groundwater TDS varies from 1350 to 5000 mg/l. Most of the drinking water needs for this village is met from the limited supply from protected water supply schemes of Govt., of Andhra Pradesh. Several thematic maps of Varaha river basin (Geology, geomorphology, soils, lineaments) has been prepared and analyzed. Using these maps the locations for ERT profiling are identified and are shown in Figure 2. The tomography profiling has been carried out along and across the Varaha river covering a total length of 500 m. The detailed analysis of profiling data for drilling of bore well location is under progress.

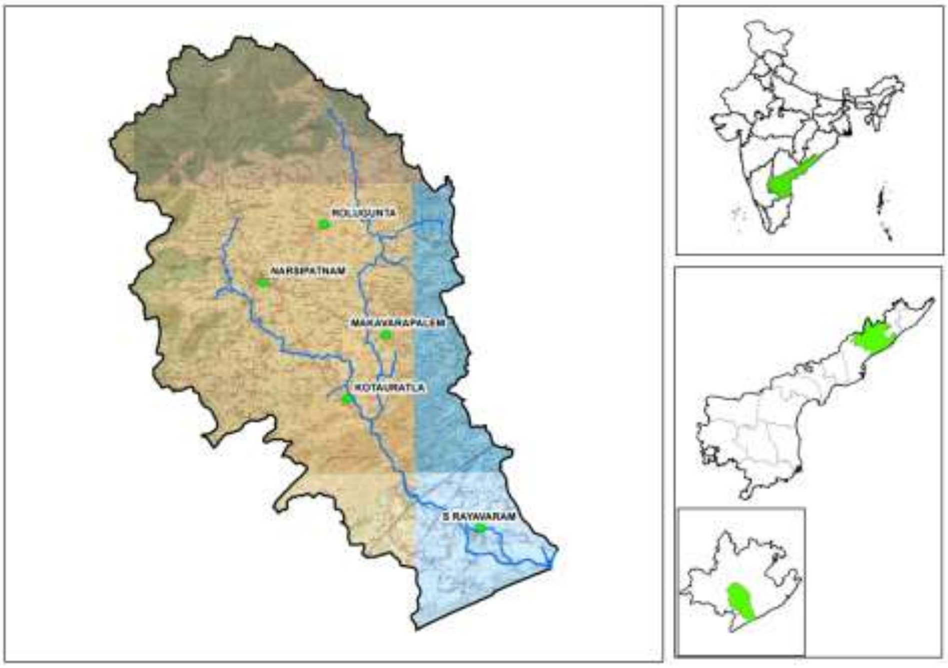


Figure 1. Location of Varaha river basin identified for RBF investigations at S.Rayavaram, Visakhapatnam District, Andhra Pradesh

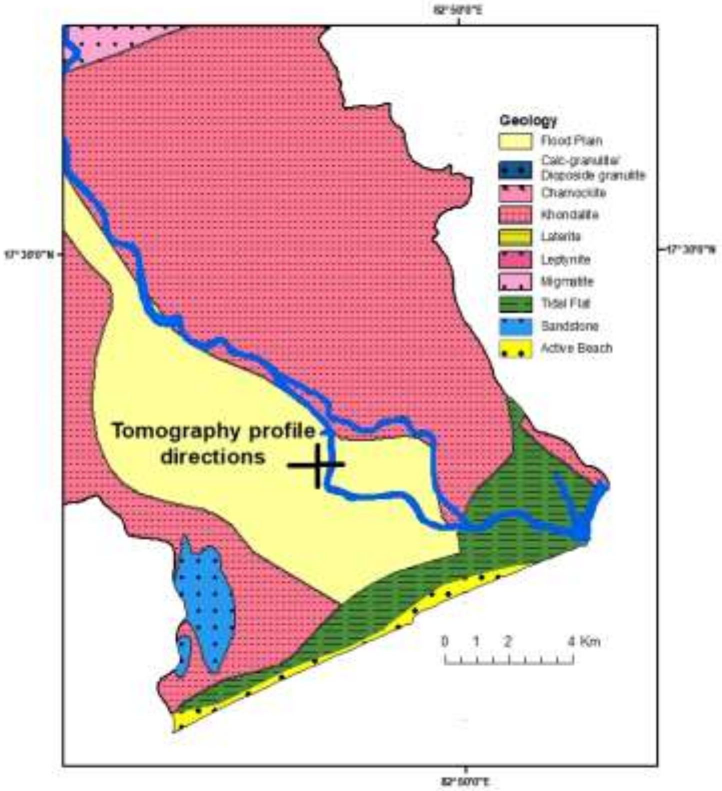


Figure 2. Location of ERT profiling nearby Varaha river bank

Proposed Work Programme for 2018-19 (yet to be finalized by RCC of Kakinada)

S.N.	Title of the Project	Team	Duration (Start date and End date)	Funding
III.	**Internal Studies**			
1	Sedimentation Study of Hirakud Reservoir, Odisha using Optic and Microwave Remote Sensing Technology	V.S. Jeyakanthan(PI) J.V. Tyagi Y.R. Satyaji Rao S.V. Vijaya Kumar R. Venkata Ramana P.C. Nayak	July 2017-March 2020	Approved by NHP PDS (Rs.51.19 lakhs) (SP-28/2017-18/PDS-3)
2	Groundwater salinity source identification in Godavari delta, Andhra Pradesh	Y R Satyaji Rao(PI) T Vijay JV Tyagi S V Vijaya Kumar V S Jeyakanthan P C Nayak R V Ramana	Dec.,2017-March 2020	Approved by NHP PDS (Rs 61.09 lakhs) (SP-28/2017-2018/PDS-13)
3	Forecasting of Flash flood and Management of East Flowing Rivers of India's sub Zone 4 (A)	R. V. Ramana (PI) Y.R. Satyaji Rao V.S. Jeyakanthan S.V. Vijaya Kumar P.C. Nayak T.Vijaya	Dec.,2017-March 2020	Internal
4	Hydrological Evaluation and Modeling for Water Resources Management in Baitarani basin in Odisha State	Dr. P C Nayak (PI) J.V. Tyagi Y.R. Satyaji Rao S.V. Vijaya Kumar R. Venkata Ramana P.C. Nayak	2018-2023	*under* NHP PDS Total Cost of Project: Rs 2,43,98,352.00
IV.	**Sponsored Projects (Ongoing)**			
1.	Hydrological evaluation of existing water conservation/ harvesting structures in identified IWMP watersheds in Chitturu and Ananthapur district (AP)	Y. R. Satyaji Rao R. Venkata Ramana V.S.Jeyakanthan	April 2017-March 2019	DoLR (under NNWP)
2	Hydrological evaluation of existing water conservation/ harvesting structures in identified IWMP watersheds in Pulbani and Khandamal district (Odisha)	Y. R. Satyaji Rao V.S.Jeyakanthan R. Venkata Ramana	April 2017-March 2019	DoLR (under NNWP)
3	River bank Filtration (RBF) studies in coastal alluvium of Andhra Pradesh	Y R Satyaji Rao (Co-PI) T Vijay	April 2016 - March 2019	Under Peya Jal Suraksha Project

CENTRE FOR FLOOD MANAGEMENT STUDIES GUWAHATI

Scientific Manpower

S N	Name	Designation
1	Dr. S K Sharma	Scientist B
2	Mr. Gulshan Tirkey	Scientist B

WORK PROGRAMME FOR 2017-18

Ref. Code	Title	Study Team	Duration
INTERNAL STUDIES			
1.NIH/CFMS-G/17-18	Evaluation of Ground Water Quality with More Emphasis on Arsenic Contamination in Barpeta District of Assam	C. K. Jain S. K. Sharma Babita Sharma	Completed, 1 year (April 2017 to March 2018)
2.NIH/CFMS-G/17-19	Evaluation of Ground Water Quality in Shillong – the Capital City of Meghalaya	C. K. Jain M. B. Ritshong S. K. Sharma Babita Sharma	Completed, 1 year (April 2017 to March 2019)
3.NIH/CFMS-G/17-18	Distribution and Risk Assessment of Heavy Metal Pollution in Surface Soils of Guwahati (Assam)	C. K. Jain S. K. Sharma Upma Vats	Completed, 1 year (April 2017 to March 2018)
4.NIH/CFMS-G/17-19	Estimation of Runoff for Kulsi River Basin using NRCS Curve Number and Geographic Information System	S. K. Sharma GulshanTirkey G. Arun	Ongoing, 1 year (April 2017 to March 2019)
5.NIH/CFMS-G/17-19	Morphometric Analysis of Kulsi Basin using different Digital Elevation Models (DEMs)	GulshanTirkey S. K. Sharma	Ongoing, 1 year (April 2017 to March 2019)

1. PROJECT REFERENCE CODE: NIH/CFMS-G/17-18

a. Title of Study:	Evaluation of Ground Water Quality with More Emphasis on Arsenic Contamination in Barpeta District of Assam.
b. Study Group:	C. K. Jain, S. K. Sharma and Babita Sharma
c. Date of Start:	April 2017
d. Duration of the Study:	One years (April 2017 to March 2018)
e. Funding:	NIH

f. Objectives:

To examine the quality of ground water in Barpeta District of Assam with special reference to arsenic contamination and suggesting remedial measures.

g. Brief Description/Methodology:

In the North Eastern Region of India, natural springs and dug wells are the most cost effectiveand viable means of fulfilling the needs of freshwater for present population. In hilly areas,most of the drinking water is used to be harnessed from rivers, ponds and natural springs.Many springs are reportedly becoming seasonal. In valleys, most of the domestic water isharnessed from groundwater through shallow tubewells and dug wells. Availability ofdrinking water in summers is severely marred and the overall quality is questionable.

Information on groundwater quality of North Eastern India is scanty. Recently, arsenic contamination has been reported in many parts of North East Region including Barpeta District of Assam. Thealarming pictures of the water quality in the region and continuousconsumption of this water has the potential of posing serious health hazard to the localpopulation. The observation warrants an extensive and exhaustive study to identify thecontamination sites both from the standpoint of protecting public health and preserving thenatural resources.Recognizing the enormity and severity of the problem, groundwater quality study was taken with special reference to arsenic contamination in Barpeta District of Assam to examine the suitability of groundwater quality for drinking purpose and remedial measures will be suggested.

h. Results achieved with Progress/Present Status:

Fifty ground water samples from various abstraction sources were collected during pre- and post-monsoon seasons and analyzed for various water quality constituents (pH, EC, TDS, Alkalinity, Hardness, Sodium, Potassium, Calcium, Magnesium, Chloride, Sulphate, Nitrate, Fluoride and metal ions (Fe, Mn, Cu, Ni, Cr, Pb, Cd, Zn, As). The hydro-chemical data is being analyzed with reference to BIS and WHO standards, ionic relationships are being studied, hydrochemical facies and water types are being identified. An attempt will also be made to classify the ground water on the basis of different classification techniques, viz., Piper trilinear, Chadha's diagram and U.S. Salinity Laboratory classifications. The report is under preparation and will be completed by April 30, 2018

2. PROJECT REFERENCE CODE: NIH/CFMS-G/17-18

a. Title of Study:	Evaluation of Ground Water Quality in Shillong – the Capital City of Meghalaya.
b. Study Group:	C. K. Jain, M. B. Ritshong(SE, WRD, Meghalaya) S. K. Sharma, Babita Sharma
c. Date of Start:	April 2017
d. Duration of the Study:	One year (April 2017 to March 2018)
e. Funding:	NIH

f. Objectives:

To examine the quality of ground water in Shilllong city of Meghalaya with special reference to arsenic contamination and suggesting remedial measures.

g. Brief Description/Methodology:

In the North Eastern Region of India, natural springs and dug wells are the most cost effectiveand viable means of fulfilling the needs of freshwater for present population. In hilly areas,most of the drinking water is used to be harnessed from rivers, ponds and natural springs.Many springs are reportedly becoming seasonal. In valleys, most of the domestic water isharnessed from groundwater through shallow tubewells and dug wells. Availability ofdrinking water in summers is severely marred and the overall quality is questionable.

Information on groundwater quality of North Eastern India is scanty. Ground Water Quality Study for Shillong to examine the quality of ground water for drinking and irrigation purposeThealarming pictures of the water quality in the region and continuousconsumption of this water has the potential of posing serious health hazard to the localpopulation. The observation warrants an extensive and exhaustive study to identify thecontamination sites both from the standpoint of protecting public health and preserving thenatural resources.Recognizing the enormity and severity of the problem, groundwater quality study was taken with special reference to arsenic contamination in Shillong City of Meghalaya to examine the suitability of groundwater quality for drinking purpose and remedial measures will be suggested.

h. Results achieved with Progress/Present Status:

Twenty ground water samples from various abstraction sources were collected during pre- and post-monsoon seasons and analyzed for various water quality constituents (pH, EC, TDS, Alkalinity, Hardness, Sodium, Potassium, Calcium, Magnesium, Chloride, Sulphate, Nitrate, Fluoride and metal ions (Fe, Mn, Cu, Ni, Cr, Pb, Cd, Zn, As). The hydro-chemical data is being analyzed with reference to BIS and WHO standards, ionic relationships are being studied, hydrochemical facies and water types are being identified. An attempt will also be made to classify the ground water on the basis of different classification techniques, viz., Piper trilinear, Chadha's diagram and U.S. Salinity Laboratory classifications. The premonsoon samples could not be processed due to repair of the equipment. The report is under preparation and will be completed by April 30, 2018

3. PROJECT REFERENCE CODE: NIH/CFMS-G/17-18

a. Title of Study:	Distribution and Risk Assessment of Heavy Metal Pollution in Surface Soils of Guwahati (Assam)
b. Study Group:	C. K. Jain, S. K. Sharma, Upma Vats
c. Date of Start:	April 2017
d. Duration of the Study:	One year (April 2017 to March 2018)
e. Funding:	NIH

The study was dropped.

4. PROJECT REFERENCE CODE: NIH/CFMS-G/17-19

a. Title of Study:	Estimation of Runoff for Kulsi River Basin using NRCS Curve Number and Geographic Information System
b. Study Group:	S. K. Sharma, GulshanTirkey
c. Date of Start:	April 2017
d. Duration of the Study:	Two years (April 2017 to March 2019)
e. Funding:	NIH

f. Objectives:

i) To estimate runoff from Kulsi River Basin using NRCS CN Method.
ii) To prepare runoff potential maps for Kulsi River Basin.

g. Brief Description/Methodology:

One of the major requirements for water resources development and management is analysis of rainfall runoff relationship and availability of water in the area, which vary with time and space. Knowing the amount of runoff from a catchment gains a vital importance particularly for planning the hydraulic structures and taking necessary erosion control measures, in catchments where there is no runoff observations. In catchments where agricultural lands are prevailing, American Soil Conservation Service (SCS) Runoff Curve Number Method is widely used for planning the structures aimed at water storage and, erosion and flood control. United States Department of Agriculture (USDA), Soil Conservation Service have developed a method to calculate runoff from agricultural catchments with different soil groups, vegetation covers and land uses by examining measured precipitation and runoff amounts, and named it as "SCS Curve Number Method". The Method has been renamed as NRCS Method.

The SCS CN method requires numeric catchment characteristics which are the basis of catchment runoff determination. The objective of the method is to determine the right curve number of the catchment of interest that defines the runoff potential. Hydrologic soil group number, land use type, vegetation cover, soil conservation measures, antecedent soil moisture conditions are the basic catchment characteristics used for curve number calculations.

Keeping in view the above points, SCS-CN method will be used along with remote sensing and GIS datasets for simulation of rainfall runoff relationship for Kulsi River Basin. The study will also generate runoff potential maps for the Basin.

h. Results achieved with Progress/Present Status:

Soil maps and landuse landcover information has been downloaded for kulsi River Basin . The maps have been reprojected for the basin and analysis is underway.

5. PROJECT REFERENCE CODE: NIH/CFMS-G/17-19

a. Title of Study:	Morphometric Analysis of Kulsi Basin using different Digital Elevation Models (DEMs)
b. Study Group:	GulshanTirkey, S. K. Sharma,
c. Date of Start:	April 2017
d. Duration of the Study:	Twoyear (April 2017 to March 2019)
e. Funding:	NIH

Since PI was on EOL since last one year the study could not be taken under progress.

ITEM 1.4: PROPOSED WORK PROGRAMME FOR 2018-19

Thefollowing new study is proposed to be taken-up during 2018-19.

I. Flood Inundation Mapping of Beki River Basin of Assam
II. Development of regional methods for design flood estimation inNorth Brahmaputra subzone 2 (a).
III. Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin

The proposed work programme for the year 2018-19 is given in Annex - IV**.**The details of the studiesaregiven below:

I. PROJECT REFERENCE CODE: NIH/CFMS-G/18-22

1 **Title of the Study:** Flood Inundation Modelling of Beki River Basin of Assam.

2 **Study Group:**

Sanjay Kumar Sharma, Scientist –'C' (PI)
Rakesh Kumar, Scientist –'G'
Pankaj Mani, Scientist –'E'
Jagadish Prasad Patra, Scientist –'C'

3 **Type of Study:** Internal

4 **Date of Start:** 1 April 2018

5 **Scheduled date of completion:** 31 March 2022 (Four years)

6 **Objectives:**

a. To calibrate and validate Rainfall-Runoff-Inundation (RRI) model for the Beki river basin.
b. To model rainfall-runoff process in for the Beki river basin using HEC-HMS/ NAM model.
c. To model the flood inundation in lower reach of Beki River using HEC-RAS / Mike Flood.
d. To compare the flood inundation simulations from RRI Model and HEC-RAS/ Mike Flood.

7 **Present state-of-art**

Flood is one of the most destructive events happening around the world.Accurate and current floodplain maps are most valuable tools for avoiding severe social and economic losses due floods.Early identification of flood-prone properties during emergencies allows public safety organizations to establish warning and evacuation priorities. Armed with definitive information, government agencies can initiate corrective and remedial efforts before disaster strikes. This study is undertaken based on the recommendation by Chief Engineer, WRD Assam.

8 **Brief Description/Methodology:**

Rainfall-Runoff-Inundation (RRI) model is a two-dimensional model capable of simulating rainfall-runoff and flood inundation simultaneously. The model deals with slopes and river channels separately. At a grid cell in which a river channel is located, the model assumes that both slope and river are positioned within the same grid cell. The channel is discretized as a single line along its centerline of the overlying slope grid cell. The flow on the slope grid cells is calculated with the 2D diffusive wave model, while the channel flow is calculated with the 1D diffusive wave model. For better representations of rainfall-runoff-inundation processes, the RRI model simulates also lateral subsurface flow, vertical infiltration flow and surface flow. The lateral subsurface flow, which is typically more important in mountainous regions, is treated in terms of the discharge-hydraulic gradient relationship, which takes into account both saturated subsurface and surface flows. On the other hand, the vertical infiltration flow is estimated by using the Green-Ampt model. Various models like HEC-RAS and MIKE FLOOD are generally applied for hydrodynamic routing of flood and preparation of flood inundation maps in India. These models can be used both for 1-D and 2-D routing of flood. In this study the RRI model will be model flood inundation maps by simulating rainfall runoff process and river routing. Further, the rainfall runoff process will be simulated using HEC-HMS/NAM model and the flood routing will be carried out using HEC-RAS/ Mike Flood to generated flood inundation maps. The generated flood inundation maps from RRI model will be compared with that of HEC-RAS/ Mike FLOOD results. Moreover, simulated flood inundation maps for historical flood events will also be compared with satellite images.

9 Expected Outcome:

- Assessment of usefulness and limitation of RRI model for flood inundation modelling in Indian basin.
- Flood Inundation maps for Beki river basin
- Research papers and reports.

10 Work Schedule:

S.N.	Work Element	Year			
		1	2	3	4
17	Collection of hydro meteorological data, satellite images, thematic maps etc.				
18	Compilation, statistical analysis of rainfall and river discharge				
19	RRI Model setup, calibration and validation				
20	Rainfall runoff modelling using HEC-RAS/ NAM				
21	Flood inundation modelling using HEC-RAS/ Mike Flood				
22	Model comparison				
23	Workshop/ Training				
24	Report				

II. PROJECT REFERENCE CODE: NIH/CFMS-G/18-22

1 **Title of the Study:** Development of regional methods for design flood estimation inNorth Brahmaputra subzone 2 (a).

2 **Study Group:**

Sanjay Kumar Sharma, Scientist –'C' (PI)
Rakesh Kumar, Scientist –'G'
Pankaj Mani, Scientist –'E'
Jagadish Prasad Patra, Scientist –'C'

3 **Type of Study:** Internal

4 **Date of Start:** 1 April 2018

5 **Scheduled date of completion:** 31 March 2022 (Four years)

6 **Objectives:**

a. Development of at-site and regional flood frequency relationships using L-moments.
b. Development of regional relationships between mean annual peak floods and physiographic and climatic characteristics.
c. Development of at-site and regional rainfall frequency relationships using L-moments.
d. Development of flood frequency relationships under climate change scenarios.
e. Estimation of floods of various return periods for North Brahmaputra subzone 2 (a).

7 **Present state-of-art**

The commonly used design floods estimation approaches can be categorized as: flood formulae, flood frequency analysis and hydrometeorological approach (CWC, 2010). Various empirical flood formulae have been developed for regions. These include Dicken's, Ryve's, Nawab Jung Bahadur, W P Creager's, Jarvis f, Modified Myer's etc. When long term and short term rainfall and runoff records are not available the design flood is obtained using these formulae. However, the value obtained from these can only be used for preliminary estimates for small catchments and the concept of return period flood is generally not included in this approach. The flood frequency approach can be adopted in case data of peak floods series are available for a longer period of time. In, Indian generally Gumbel or Generalized Extreme Value (GEV) distributions are fitted to the peak flood series without considering other available frequency distributions. Further, there is a need to use better parameter estimation technique for estimation of parameter of candidate distribution. In India for many catchments, streamflow data are not available or the data are inadequate at the site of interest. In such cases the methods of frequency analysis using data from a single site have limited applicability because of large sampling errors, and as a result, regional flood frequency analysis is performed. The various commonly used methods of regional flood frequency analysis are: USGS method, Pooled curve method, analytical method and L-moments approach. Hosking and Wallis (1997) presented the L-Moments based regional frequency analysis approach. The authors mention that regional flood frequency analysis resolves the problem of short data records or unavailability of data by "trading space for time"; as the data from several sites are used in estimating flood frequencies at any site. Kumar et al. (2003, 2005, 2015) applied L-moments approach for development of regional flood frequency relationships for some of the regions of India. Considerable work has been done to estimate flood characteristics and long-term mean annual flow using regression relationships with catchment parameters in Indian, but most of these methods were developed a long time ago and may need to be revisited Jha and Smakhtin (2008).The Central Water Commission in association with the India Meteorological Department and Research Design and Standard Organization unit of the Indian Railways have classified the country into 7 zones and 26 hydro-meteorologically homogeneous sub-zones, for each one of which flood estimation guidelines have been published. These reports contain ready to use chart and formulae for computing floods of 25, 50 and 100 year return period of ungauged basins in the respective regions. Recently, the PMP atlas for Brahmaputra river basin is prepared by CWC (2015). The studies carried out for regional flood frequency estimation in India are limited to a few regions, scattered as well as they are mostly based on the various types of conventional techniques. The L-moments form basis of an elegant mathematical theory for carrying out regional frequency analysis and are being used by many organizations the worldwide. The L-moments are capable of characterising a wider range of distributions, compared to the conventional moments. There arecomparison available, which demonstrates howthe standard and weighted *Bulletin 17B* quantile estimators perform relativeto alternative Log Pearson Type-III (LP3) quantile estimators that also make use ofregional information.

8 Brief Description/Methodology:

This study aims at development of at-site and regional flood frequency relationships using L-moments approach for North Brahmaputra subzone 2 (a). 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.Further, the non-stationary aspect of data series will also considered in frequency analysis for climate change aspects. Floods of various return periods for selected locations of North Brahmaputra subzone 2 (a)will be estimated.

9 Expected Outcome:

- Design floods of various return periods at river gauging locations.
- Development of relationships between mean peak floods of various return periods with catchment characteristics.
- Research papers and reports.

10 Work Schedule:

S.N.	Work Element	Year			
		1	2	3	4
1	Collection of hydro meteorological data, DEM, thematic maps etc.				
2	Compilation, statistical analysis of rainfall and river discharge				

S.N.	**Work Element**	**Year**							
		1		**2**		**3**		**4**	
3	Estimation of various catchment characteristics.								
4	At site and Regional rainfall frequency analysis								
5	At-site and regional flood frequency analysis for gauged catchments								
6	Development of regional relationships for peak floods with catchment characteristics.								
7	Workshop/ Training								
8	Report								

III. PROJECT REFERENCE CODE: NIH/CFMS-G/18-21

1. **Title of the Study:** Linear hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin.

2. **Study Group:**
   Gulshan Tirkey, Scientist –'B' **(PI)**
   Sanjay Kumar Sharma, Scientist –'C'
   Pankaj Mani, Scientist –'E'
   Arun G, Research Scientist

3. **Type of Study:** Internal

4. **Date of Start:** 1st April 2018

5. **Scheduled Date of Completion:** 31st March 2021(Three Years)

6. **Objectives:**
   1. Calibration and bias correction of satellite precipitation products (TRMM 3B42-RT, GPM IMERG & GPROF) with observed rainfall.
   2. Linear Hydrological routing of bias corrected precipitation products for runoff calculation to check the feasibility of routing using satellite precipitation products.
   3. Evaluation of IFAS (Integrated Flood Analysis System) model for satellite based precipitation data.

7. Present State of Art

Satellite rainfall observations are essential for improving our understanding of the occurrence of hazardous events and possibly in lessening their impact on local economies by reducing damageto people and property by creating reliable warning systems. The study explores the capability of NASA's TRMM 3B42 RT and newly launched GPM -IMERG and GPROF satellite rainfall products to track the continuous heavy rainfall events and associated floods in the Brahmaputra Basin. Tracking using real time satellite rainfall products and routing helps in timely forecasting of flood and issue warnings.

8. Description & Methodology

TRMM Monthly Satellite Precipitation Analysis (TMPA): The NASA/JAXA Tropical Rainfall Measuring Mission (TRMM) has been in operation since 1997. In the study TRMM Monthly Satellite Precipitation Analysis (TMPA) products will be used. It is designed to combine precipitation estimates from various satellite systems, as well as land surface precipitation gauge analyses, with the aim that the final product will have the best estimates. TRMM Daily product 3B42 RT version 7 for the period 2000-2017 will be used. It is a popular near-global (50°N to 50°S) precipitation product having a spatial resolution of 0.25°. Global Precipitation Measurement (GPM): Global Precipitation Measurement (GPM) constellation satellites are an international mission to produce subsequent era observations of rain and snow. NASA and the Japanese Aerospace Exploration Agency (JAXA) launched the GPM Core Observatory satellite on February 27th, 2014 (http://www.nasa.gov). The increased sensitivity of the Dual-frequency Precipitation Radar (DPR) and the high frequency channels on the GPM Microwave Imager (GMI) have enabled GPM to improve forecasting of extreme events that cause natural hazards and disasters. A new algorithm "Integrated Multi-Satellite Retrievals for GPM" (IMERG) has been introduced for rainfall estimates combining data from all passive-microwave instruments in the GPM Constellation (Huffman 2014). This algorithm is intended to merge and interpolate all satellite microwave precipitation estimates, together with microwave-calibrated infrared (IR) satellite estimates, precipitation gauge analyses, and potentially other precipitation estimators at fine time and space scales over the entire globe (Source: Precipitation Measurement Missions, NASA). IMERG early run daily data at 0.10° spatial resolution from March 2014 to present will be used. The Goddard Profiling Algorithm is a Bayesian approach that nominally uses the GPM Combined algorithm. GPROF V05 daily averages of 0.25° spatial resolution are also used.

Depending on the availability of hydro-meteorological data and the basin characteristic, warning time required and purpose of forecast, linear hydrological routing of satellite precipitation datasets for flood forecasting techniques will be used. To support decisions for better management and operational strategies of water resources calibration, validation and uncertainty analysis of these routing models are necessary.

Design of IFAS model involves in preparation of interfaces to get satellite-based rainfall data in addition to ground based rainfall data, to secure the worldwide availability of input data for flood forecasting/analysis system. IFAS adopts globally-available GIS databases for flood forecasting/analysis. To implement GIS analysis modules in the system and to set up the parameters for the flood forecasting/analysis model, therefore no need to depend on external GIS software.

9. Expected Outcome:

1. Effective bias correction algorithm for Satellite Precipitation products(TRMM 3B42-RT, GPM IMERG & GPROF) for Brahmaputra Basin.
2. Prototype for operational flood forecasting using Simplified Hydrological routing techniques and satellite rainfall products.

10. Work Schedule:

S.N.	**Work Element**	**Year**		
		1	**2**	**3**
1	Collection of hydro satellite images & meteorological data			
2	Comparison of Satellite and observed rainfall for development of bias correction algorithm			
3	Development reliable prototype for operational flood forecasting using satellite rainfall products			
4	Preparation of Report.			

WORK PROGRAMME for 2018-19

ONGOING STUDIES (Internal)			
1.NIH/CFMS-G/17-19	Estimation of Runoff for Kulsi River Basin using NRCS Curve Number and Geographic Information System	S. K. Sharma, GulshanTirkey G. Arun	Ongoing, 1 year (Ap 2017 to to Mar 2019)
2.NIH/CFMS-G/17-19	Evaluation of Ground Water Quality in Shillong – the Capital City of Meghalaya	C. K. Jain M. B. Ritshong S. K. Sharma Babita Sharma	Ongoing, 1 year (April 2017 to March 2019)
3.NIH/CFMS-G/17-19	Morphometric Analysis of Kulsi Basin using different Digital Elevation Models (DEMs)	GulshanTirkey S. K. Sharma	Ongoing, 1 year (April 2017 to March 2019)
NEW STUDIES (Internal)			
4.NIH/CFMS-G/18-21	Flood Inundation Modelling of Beki River Basin of Assam	S. K. Sharma Rakesh Kumar Pankaj Mani J. P. Patra G. Arun	3years (April 2018 to March 2021) Asked to be done by 3 years.
5.NIH/CFMS-G/18-21	Development of regional methods for design flood estimation for North Brahmaputra Subzone 2 (a)	S. K. Sharma Rakesh Kumar Pankaj Mani J. P. Patra G. Arun	3 years (April 2018 to March 2021)
6.NIH/CFMS-G/18-21	Linear hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin	GulshanTirkey S. K. Sharma Pankaj Mani G. Arun	3 years (April 2018 to March 2021)

CENTRE FOR FLOOD MANAGEMENT STUDIES PATNA

Scientific Manpower

S N	Name	Designation
1	Mr.Biswajit Chakravorty	Scientist F
2	Dr.Pankaj Mani	Scientist D
3	Mr. N G Pandey	Scientist D
4	Mr. S R Kumar	Scientist D
5	Mr. R Venkataraman	Scientist C

WORK PROGRAMME FOR 2017-18

S.N.	Title of the Project	Team	Duration	Funding
V.	**Internal Studies (Ongoing)**			
1.	Demonstration scheme on Riverbank Filtration in Gangetic plain of Bihar	B. Chakravorty (PI) N. G. Pandey	2 years (02/16-02/18)	NIH
2.	Development of Relationships between Reference Evapotranspiration (ETo) of Penman-Monteith and other Climatological methods	S.R. Kumar (PI)	3 years (04/16-03/19)	NIH
3.	River shifting analysis and flow modelling study of Ganga river from Rishikesh to Anupshahar	Pankaj Mani (PI) Rakesh Kumar, J. P. Patra	3 years (04/16-03/19)	NIH
VI.	**Sponsored Projects**			
1.	NEERANCHAL watershed project in Jharkhand	B. Chakravorty (PI) N. G. Pandey	2 Years (04/17-03/19)	DoLR

WORK PROGRAM FOR 2018-19

S.N.	Title of the Project	Team	Duration	Funding
I.	**Internal Studies (Ongoing)**			
1.	Demonstration scheme on Riverbank Filtration in Gangetic plain of Bihar	B. Chakravorty (PI) N. G. Pandey	3 years (02/16-03/19)	NIH
2.	Development of Relationships between Reference Evapotranspiration (ETo) of Penman-Monteith and other Climatological methods	S.R. Kumar (PI)	3 years (04/16-03/19)	NIH
3.	River shifting analysis and flow modelling study of Ganga river from Rishikesh to Anupshahar	Pankaj Mani (PI) Rakesh Kumar, J. P. Patra	3 years (04/16-03/19)	NIH
II.	**Sponsored Projects**			
1.	NEERANCHAL watershed project in Jharkhand	B. Chakravorty (PI) N. G. Pandey	5 Years (04/17-03/22)	DoLR

1. Demonstration scheme on Riverbank Filtration in Gagatic plain of Bihar

Objectives of the study:

(i) Study and improve natural water treatment systems.
(ii) Popularize them among the various stakeholders.

Statement of the problem**:** Bank Filtration is a natural pre-treatment technology, which enables the utilization of surface water sources such as lakes or rivers. The water passes through the natural porous sub-surface (aquifer) to the production well. The porous media serves as a natural filter and reduces the amount of suspended solids and pathogens. Bank filtrate from the production wells shows a significantly higher quality compared to water abstracted directly from surface or groundwater sources. BF is advantageous as a pre-treatment in order to reduce the necessary doses of chlorine prior to flocculation. Additional advantages of BF may also be seen during the monsoon season, principally in the removal of turbidity and pathogens, as well as in the removal of colour and dissolved organic carbon (DOC), UV absorbance, turbidity, and total thermo tolerant coliform counts. NIH proposes to develop pilot demonstration schemes on BF for sustainable drinking water supply.

Study area: It is proposed to develop pilot demonstration schemes on BF on the right bank of Ganga river in and around Ara locality of Bihar for sustainable drinking water supply. The area is arsenic affected and therefore it is proposed to take up R&D study to see and improve natural water treatment systems.

Present state of art:

A collaborative European Union research project on river bank filtration under 'Saph Pani' started in October 2011 with duration of 36 months involving a consortium of 20 partners from India, European Union, Switzerland, Sri Lanka and Australia. The Saph Pani project aimed to study and improve natural water treatment systems such as bank filtration (BF), managed aquifer recharge (MAR) and constructed wetlands (CW) in India building Indian and European expertise in those fields. All the above three technologies have vast potential in the Indian context.

Methodology

RBF is the influx of River water to the aquifer induced by a hydraulic gradient. Collector wells along banks in a certain distance from the river create a pressure head difference due to drawdown between the River and the well, which induces water from the river to flow through the porous media into the pumping wells. By this process, the water from the river passes through the porous material between the river and the well acting as a filtration media removing undesirable constituents from the river water. By applying this system of drinking water extraction, two different water resources are used namely surface water from the river percolating towards the well and the groundwater of the surrounding aquifer. It means the site selected for RBF is to be located where porous material is present between the River and the well to act as a filtration media to remove undesirable constituents from the River water. At the same time the yield of such well need to be reasonable high so that it caters the water supply need.

Progress: In consultation with PHED, Govt. of Bihar several prospective sites were visited in the diara area of Ganga river and a site at Barahara village in Buxar district on the bank of Ganga river has been identified. Water samples from a few wells were collected and analyzed in the laboratory. Cost estimate for exploratory tubewell upto a depth of 25 m has been prepared by PHED, Ara. Site selection has been completed and Govt. land measuring about 1000 sq ft is available very close to the bank of Ganga. Land allotment for the site from Circle office, Barhara is in progress. Panchyat Pradhan has been associated to cooperate in land allotment procedure.

Research outcome from the project: Study and improve natural water treatment systems through bank filtration and after successful implementation the effort would be to popularize them among the stakeholders and to other places.

2. Development of Relationships between Reference Evapotranspiration (ETo) of Penman-Monteith and other Climatological methods

The objective of the study is to develop regional relationships relating the ETo values of Penman-Monteith (PM) and other climatological methods for Bihar**.**

Present state-of-art: Modified Penman Method of ETo estimation is the most elaborate and rational but requires a large number of data. Often such data is very scanty forcing the use of some other empirical methods. Therefore it is necessary to develop regional relationships relating the ETo values of PM and other climatological methods.

Methodology: The main aim of this study is to find out the alternate method for finding out the ETo values which will be comparable to the estimates of FAO-56 PM. FAO-56 PM method needs large climatological data, time consuming and requires advanced computing facilities to find out the values of ETo. It is always not possible to get advanced computing facilities and all required climatological data. In such constraints we have to search other alternate method for reliable ETo estimates having ease in calculation and less dependency on large database. The most common approach in practice is the regression method other than standard and empirical methods. This regression analysis has been used in this study.

Results: The study was carried using 108 mean monthly measurements (Jan 2001 to Dec 2009) of different climatological parameters which were collected from the agroclimatic zone-I of Bihar situated at Pusa, Samastipur, North Bihar. Findings are presented in Fig-1 and Table-1.

Fig-1

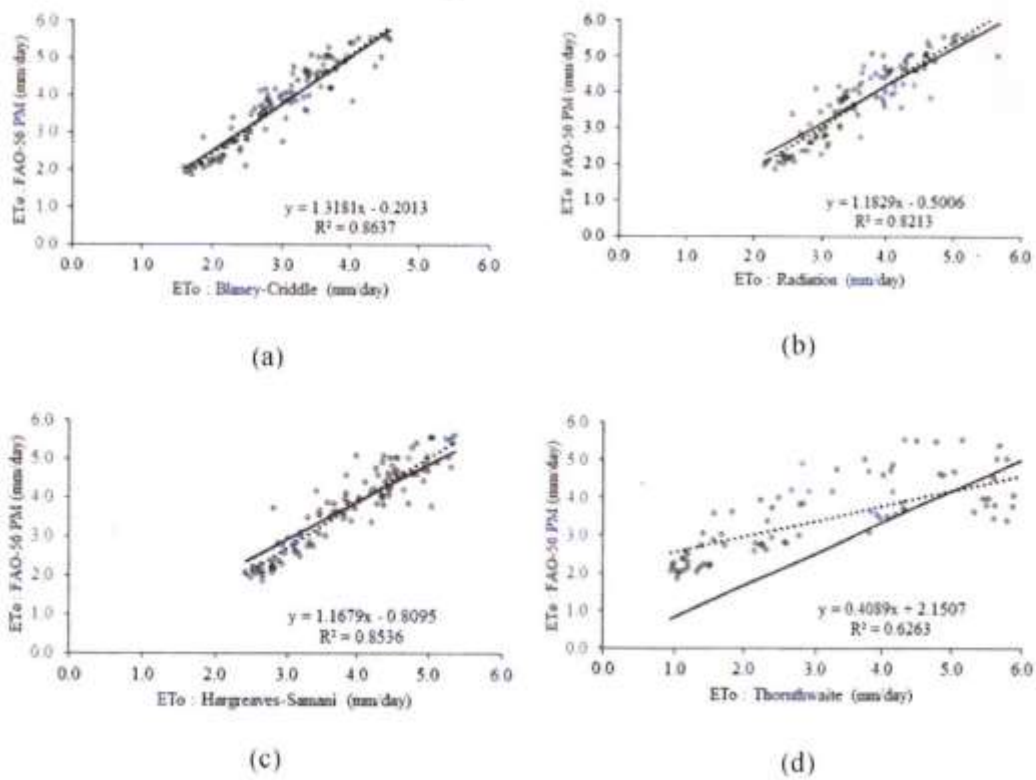


Table-1

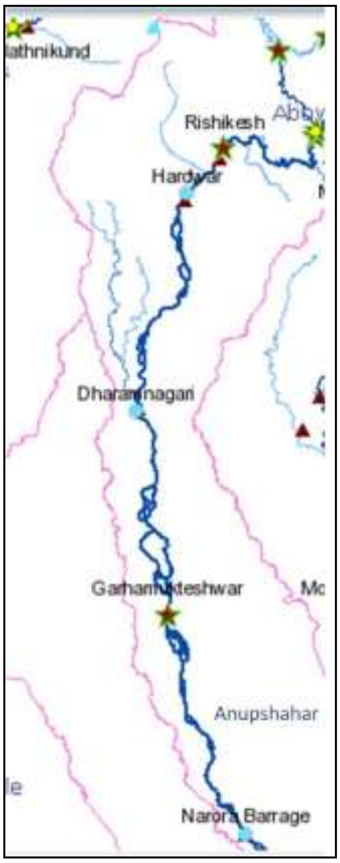
	Blaney-Criddle	Radiation	Hargreaves-Samani	Thornthwaite
R^2	0.8637	0.8213	0.8536	0.6263
SSRE	4.7026	2.9646	2.2173	12.9422
Corresponding Equation No.	(5.1)	(5.2)	(5.3)	(5.4)
Rank to use in absence of FAO-56 PM	3	2	1	not recommended

SSRE and the corresponding correlation coefficient and choice of method

Developed ranked relations as presented in Fig-1 and Table-1 can be used to find out the ETo estimates closest to FAO-56 PM.

3. River shifting analysis and flow modelling study of Ganga river from Rishikesh to Anupshahar

A study entitled "River shifting analysis, formation of sand islands and hydrodynamic flow modelling of Ganga river from Rishikesh to Anupshahar" has been taken up. River Ganga in the stretch of Rishikesh to Anupshahar is about 300 km long. Study is proposed with the following **objectives**:



- River shifting study: GIS based temporal analysis of satellite data for study of river shifting ternds, identification of erosion and sedimentation prone area.
- Development of flow model: 1D flow model for the study reach, calibration and validation with observed GD data, Inundation mapping-validation with satellite data, Inundation maps for floods of different return period.

Progress of the study:

For this reach of the river geomorphological study and identification of erosion/ siltation prone area, the IRS satellite data are being used. The entire study stretch is covered in four scenes of LISS III data. At the affected sites, detailed analysis is being carried out using high resolution satellite data (LISS IV). Over the duration of nineteen years from 1997 to 2015 data of five time periods viz. 1997, 2000, 2006, 2011 and 2015 have been procured from NRSC, Hyderabad. Further, silt balance study is also proposed to be carried out between Rishikesh to Kachhala Bridge site.

For the flow model study, 103 surveyed river cross sections between Rishikesh to Kachhalabridge (stretch of 334 km) have been used. Also, from Tehri dam site to Rishikesh (99.7 km stretch), 14 river cross-sections have been extracted from online CartoDEM (available from Bhuvan website of NRSC). In addition, 30 digital toposheets have been procured from SOI and DEM has been prepared for the river reach. Hydrological data of the four gauging sites viz. Rishikesh, Gurumukteshwar, Narora and Kachhalabridge have been procured from CWC. Flood frequency analysis has been carried out using the annual maximum flood data of the gauging sites and floods of various return periods have been estimated. A coupled 1D-2D hydrodynamic package MIKE-FLOOD is being used for modelling of river discharge, velocity, depth, duration and inundation for carrying out the study and the study is under progress.

4. Neeranchal National Watershed Project-

This project pertains to HQ and CFMS, Patna has been entrusted to deal with watershed development in Jharkhand state. 5 watersheds each from Ranchi and Dhanbad have been identified for the scheme. In this connection a workshop was organized at Ranchi during 11-12 September 2017 for the stakeholders meet. Details are available from Dr. V. C Goyal, Team Leader, NNWP.

APPENDIX 71.4.2

LIST OF PAPERS PUBLISHED/ ACCEPTED FOR PUBLICATION DURING AUGUST, 2017 – MARCH, 2018

LIST OF RESEARCH PUBLICATIONS FROM AUGUST, 2017 TO MARCH, 2018

S.No.	Item	Published
1.	International Journal	27
2.	National Journal	07
3.	International Conference/ Seminar/ Symposium	73
4.	National Conference/ Seminar/ Symposium	06
5.	Books/Chapters	07
	Total	**120**

International Journal

1.	Arora, S., Jain, C. K. and Lokhande, R. S. (2017), Review of heavy metal contamination in soils, International Journal of Environmental Sciences and Natural Resources, 3(5), 1-6.
2.	Abass Gibrilla, Dickson Adomako, Geophrey Anornu, Samuel Ganyaglo, Tibor Stigter, Joseph R. Fianko, S. P. Rai, et al. (2017) $\delta^{18}O$ and $\delta^{2}H$ characteristics of rainwater, groundwater and springs in a mountainous region of Ghana: implication with respect to groundwater recharge and circulation, Sustainable Water Resources Management, 3: 413. https://doi.org/10.1007/s40899-017-0107-6.
3.	Goyal, V C, T Thomas, S Goyal and R V Kale (2017). Water supply-demand assessment in Ur river watershed in Tikamgarh district, In: V P Singh, Shalini Yadav and R N Yadava, Water Resources Management, Springer.
4.	Gupta, Meeta, V C Goyal, Fawzia Tarannum, Jyoti P Patil (2017). Designing a watershed scorecard as a performance evaluation tool for Ur river watershed, Tikamgarh district, Madhya Pradesh, International Soil and Water Conservation Research, https://doi.org/10.1016/j.iswcr.2017.10.001
5.	Jain, C. K. and Vaid, Upma (2018), Assessment of Groundwater Quality for Drinking and Irrigation Purposes using Hydrochemical Studies in Nalbari District of Assam, India, Environmental Earth Sciences, 77, 254 (DOI: 10.1007/s12665-018-7422-6).
6.	Jaiswal, R.K., T.R. Nayak, Sanjay K Jain, A.K. Lohani "Application of RS Data for Reservoir Sediment Profiling using Latin HypercubeOne at Time (LH-OAT) Technique", International Journal of Advances in Agricultural Science and Technology, Vol.4 Issue.8, August- 2017, pg. 10-17 ISSN: 2348-1358, Impact Factor: 6.057
7.	Kasheebai,B., Shivapur, A.V., and Venkatesh, B., 2017 Application of Swat Model For Generating Surface Runoff and Estimation of Water Availability For Balehonnuru Catchment Area For Badhra River Basin, International Research Journal of Engineering and Technology (IRJET**)** 4(8)
8.	Krishan, Gopal, Singh, Surjeet, Sharma, Anupma, Sandhu, C., Kumar Sumant, Kumar, CP, Gurjar, Suman, 'Assessment of river Yamuna and groundwater interaction using Isotopes in Agra-Mathura area of UP, India', International Journal of Hydrology. 1(3): 00016. DOI: 10.15406/ijh.2017.01.00016
9.	Krishan, G, Rao, MS, Singh, RP, Chopra, RPS, Takshi, KS, 'Aquifer Characterization A Scientific Imperative in Analysis of Water Level Trend – A Case Study from Northern Punjab', Curr. World Environ. 13 (1): 2018.
10.	Kumar, Amrit, R.P. Pandey & S.K. Mishra, 'Assessment of meteorological drought characteristics over Central India. Sustain', Water Resour. Manag. Springer International Publishing, https://doi.org/10.1007/s40899-017-0205-5, Online ISSN2363-5045 (Published online on 01 November 2017)
11.	Kumar Amrit, S. K. Mishra, R. P. Pandey, (2017) Tennant Concept Coupled with Standardized Precipitation Index for Environmental Flow Prediction from Rainfall. Journal of Hydrologic Engineering, ASCE, Published online 28 November 2017 (DOI: 10.1061/(ASCE)HE.1943-5584.0001605).
12.	Malik, D. S., Jain, C. K. and Yadav, A. K. (2017), Removal of heavy metals from emerging cellulosic low cost adsorbents: A Review, Applied Water Science, 7(5), 2113-2136 (DOI: 10.1007/s13201-016-0401-8).

13.	Mudbhatkal, Amogh, R.V. Raikar, B. Venkatesh and A.Mahesha, ‘Climate change impact on varied river flow regimes of southern India’, Journal of Hydrologic Engineering, (ASCE) 2017, 22(9): 1-13, 05017017 (IF 1.69)
14.	Nuzhat Q. Qazi, L. Adrian Bruijnzeel, S. P. Rai and Chandra P. Ghimire (2017) Impact of forest degradation on streamflow regime and runoff response to rainfall in the Garhwal Himalaya, Northwest India, Hydrological Sciences Journal, DOI: 10.1080/02626667.2017.1308637
15.	Nuzhat Q. Qazi and S. P. Rai (2017) Spatio-temporal dynamics of sediment transport in lesser Himalayan catchments, India, Hydrological Sciences Journal, 63:1, 50-62, DOI: 10.1080/02626667.2017.1410280
16.	Pandey R.P. Surya Prakesh, ‘Hydrology and Drought: India’s Priorities”- A Concept Note. School Safety and Security: Reflections’, Southasiadisasters.net, Publisher All India Disaster Management Institute (IADMI). Issue No.162, September 2017, pp.4-6.
17.	P. Semwal, S. D. Khobragade and H. C. Nainwal (2017). “Modelling of Recent Erosion Rates in a Lake Catchment in the North-Western Siwalik Himalayas”. Environ. Process. (2017) 4:355–374.
18.	Pitre, Pranav, Sanjay Divekar, Pramod Hanamgond and Purandara, B. K., 2017. Surface water quality evaluation of Malaprabha river, Belagavi district, Karnataka, International Journal of Current Research Vol. 9, Issue, 09, pp.57756-57759, September, 2017
19.	Rai, S. P.,Singh, D., Rai, A. K., and Kumar, B., (2017) Application of Environmental Isotopes and Hydro-chemistry in Detection of Source of Seepage and Likely Connection with Lake Water in Lesser Himalaya, Uttarakhand, India. Journal of Earth System Sciences. Volume 126 (8).
20.	Rina Kumari, P. S. Datta, M. S. Rao, S. Mukharjee, C. Azad (2018) Anthropogenic perturbations induced groundwater vulnerability to pollution in the industrial Faridabad District, Haryana, India. Environmental Earth Sciences. 77: 187. https://doi.org/10.1007/s12665-018-7368-8
21.	Shafee-Ullah, S, B. K. Purandara and B. Venkatesh, 2018. Terrain Analysis of Malaprabha River Basin Using SAGA (System for Automated Geo-scientific Analysis). Accepted for publication in the International Journal of Hydrogeology & Hydrologic Engineering.
22.	Saranya, P., Krishan, G., Rao, M.S., Kumar, S., Kumar, B., Controls on water vapor isotopes over Roorkee, India: impact of convective activities and depression systems, Journal of Hydrology (2017), doi: https://doi.org/10.1016/j.jhydrol.2017.12.061
23.	Singh, Surjeet, N. C. Ghosh, Suman Gurjar, Gopal Krishan, Sumant Kumar and Preeti Berwal, ‘Index-based assessment of suitability of water quality for irrigation purpose under Indian conditions’, Environmental Monitoring and Assessment 190 (29), 2017.
24.	Singh, S. K. (2017). “Unified extreme value distribution.” J. Irrig. Drain. Eng., ASCE, 143(12), Dec 2017
25.	Tiwari, Kuldeep, Rohit Goyal, Archana Sarkar, “GIS-Based Spatial Distribution of Groundwater Quality and Regional Suitability Evaluation for Drinking Water”, Environmental Processes. DOI 10.1007/s40710-017-0257-4
26.	Tiwari, Kuldeep, Rohit Goyal, Archana Sarkar, “GIS-based Methodology for Identification of Suitable Locations for Rainwater Harvesting Structures”, Water Resources Management, March 2018, Volume 32, Issue 5, pp 1811–1825. https://doi.org/10.1007/s11269-018-1905-9
27.	Vaibhav R Chate, Raviraj Kulkarni, V G Desai and Purandara B K, 2018. Sea-water Washed Activated Bauxite Residue for Fluoride Removal: Waste Utilization Technique, ASCE Journal of Environmental Engineering. 144(5):04018031

National Journal

1.	कुमार, नरेश, मनोहर अरोडा जतिन मल्होत्रा (2017), ‘जलवायु परिवर्तन एवं हिमालय की नदियों को जोड़ना’, रासंगोस्ठी तकनीकी आयोजित तक **2017** अप्रेल **21-20** मे वडोदरा द्वारा .अ. व.ज..
2.	Jain, S.K. and Tyagi, J.V. (2017). Harvesting rainwater for agriculture needs. Kurukshetra journal (special issue), Ministry of Rural Development, Delhi, 66(1) pp.34-38

3.	Prabhakar, A.K., K. K. Singh, A. K. Lohani, S. K. Chandniha "Long term rainfall variability assessment using modified Mann-Kendall test over Champua watershed, Odisha (2017)", Journal of Agrometeorology, Vol. 19(3), pp. 288-89.
4.	Singh, Gaurav, Surjeet Singh, R.M. Singh, Rajesh Kumar and C.D. Mishra (2017), 'Assessment of natural groundwater recharge in Sonar sub-basin using HELP3 model: A case study', Indian Journal of Soil Conservation, Vol. 45, No. 2, pp 176-182.
5.	Satyaji Rao Y.R., K. Jyothi, K. Nanda Gopal and PRK Raju (2017), 'Assessment of Water Quality at Different Mass Bathing Ghats on River Godavari during Mahapushkar –2015 in East Godavari District, AP, India', Journal of Chemical and Pharmaceutical Sciences (JCPS). Volume 10 Issue 3. ISSN: 0974-2115.www.jchps.com.
6.	Singh, Gaurav, Surjeet Singh, R.M. Singh, Rajesh Kumar and C.D. Mishra, **'**Assessment of natural groundwater recharge in Sonar sub-basin using HELP3 model: A case study,' Indian Journal of Soil Conservation, 45(2), 176-182, 2017.
7.	Tiwari, Kuldeep , Rohit Goyal, Archana Sarkar, "Impact of Wheat and Mustard Crop Water Requirements on Water Resources Management of Development Corridor", Plant Archives Vol. 17 No. 2, 2017, pp. 1727-1733.

International Conference

1.	Ashwini, P. P, Vivekanand, H., Venkatesh.B., and Machineni, N., 2018 Isolating the Impacts of Climate Change using QSWAT model on Uguem river streamflow at Goa, India**,** Presented in International Conference on SWAT from 8-12 Jan 2018 organised by IIT Chennai at Chennai.
2.	Bardhan, Avijit, M. Rao Chintalacheruvu, J. P. Patra (2017) Application of SWAT Model for Simulating Monthly Stream flow in Upper Baitarani River Basin. Hydro-2017 , 22ndInternational Conference on Hydraulics,Water Resources and Coastal Engineering, L. D. College of Engineering, Ahmedabad, December 21-23, 2017.
3.	Behera, Ajit Kumar, Saranya P, Sudhir Kumar, Krishnakumar A, 2018, Groundwater Recharge Pattern in East and West Coast of India: Evidence of Dissimilar Moisture Sources. 20th International Conference on Isotope Hydrology and Geochemistry. Zurich, Switzerland, January 15-16, 2018.
4.	Ajit Kumar Behera, Sudhir Kumar. 2017. Submarine groundwater discharge from Mahanadi Delta coastal aquifer to Bay of Bengal, India. 7th International Groundwater Conference (IGWC-2017) "Groundwater Vision 2030: Water Security, Challenges & Climate Change Adaptation", December 11-13, 2017, New Delhi, India
5.	Choudhury, B., Kar, A.K., and Lohani, A.K. "Development of saturated raingauge network for runoff computation (2018)", International Conference on "Sustainable Technologies for Intelligent Water Management" February 16-19, 2018 at IIT Roorkee. Glaciers and glacial lake outburst flood risk mapping using geospatial techniques (2018), Tirkey, N. , Lohani, A.K., and Parhi, P.K., International Conference on "Sustainable Technologies for Intelligent Water Management" February 16-19, 2018 at IIT Roorkee.
6.	Ghosh Bobba, A., Y. R. S. Rao, Vijay P. Singh, 'Application of Finite Element Model to Predict Subsurface Water & Contaminant Discharge from Krishna-Godavari Delta to Bay of Bengal', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
7.	Gupta, Meeta, Jyoti P Patil, V C Goyal (2017). Assessment of Groundwater Quality for Drinking Purpose in a Watershed of Bundelkhand Region, Intemalyarnational Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi.
8.	Gupta, S.K., Sharma, G., Jethoo, A.S., and Tyagi, J. (2017). Mathematical Modeling of Rainfall-Runoff from Natural Watersheds. Proc. HYDRO-2017, 22nd International Conference on Hydraulics, Water Resources & Coastal Engineering, 21-23 Dec., 2017 Ahmedabad.
9.	Gunjan, P, Mishra, S.K., Lohani, A.K, Chandniha, S.K. "Changes in temporal distribution of rainfall using Precipitation Concentration Index in Rampur watershed of Mahanadi river basin (2018)", International Conference on "Sustainable Technologies for Intelligent Water Management" February 16-19, 2018 at IIT Roorkee.
10.	HailuBirara; S.K. Mishra and R.P. Pandey(2018).A comparison of methods for computation of evapotranspiration in Tana Basin in Ethiopia. Presented in International Conference on Sustainable

	Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee India, p-365
11.	Kapoor, Raksha, Rakesh Kumar and Mohit Sood "Development of regional flood frequency relationships for gauged and ungauged catchments of Upper Narmada and Tapi Subzone 3 (c)". International Conference on Sustainable Technologies for Intelligent Water Management 2018 to be organized at Indian Institute of Technology Roorkee, India during February 16-19, 2018.
12.	**Kale, R. V.**, M. G. Kale, S. M. Taley (2017) "Application of the HEC-GeoHMS Model for Dikrong River Discharge Simulation" "International conference on the Status and future of the World's Large Rivers" organized by National Institute of Hydrology, India and University of Natural Resources and Life Sciences, Vienna, Austria during 18-21 April, 2017 at New Delhi.
13.	Krishan, Gopal, Ghosh, NC, Yadav, Brijesh Sharma, Lalit Mohan, CP Kumar, Surjeet Singh, A. Das (2017), 'Groundwater conditions in Mewat, Haryana', India Water Week-2017, October 10-14, 2017 at New Delhi.
14.	Krishan, Gopal, Singh, Surjeet, Sharma, Anupma, Ghosh, NC, Tripathi, Mansi, 'Geochemical processes controlling the fluoride concentrations in the ground water of Agra-Mathura, India', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi.
15.	Krishan, Gopal, Rao, M.S., Sharma, Veenakshi and Kaushal, Ishan, 'Identification of groundwater recharge sources in deep aquifers in Punjab, India using δ^2H and δ^{18}O', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi.
16.	Krishan, Gopal, Lohani, A.K., Chandaniha, SK, 'Groundwater trend analysis using non-parametric methods in Haryana, India', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
17.	Krishan, Gopal, N.C. Ghosh, D.J. Lapworth, Alan MacDonald, Helen Bonsor, C. Sandhu, Brijesh Yadav, 'Groundwater conditions in northwest India : Few case studies for its sustainable management,' International conference on sustainable technologies for intelligent water management at IIT Roorkee during February 16-18, 2018
18.	Kumar Amrit, R.P. Pandey and S.K. Mishra, 'Meteorological Drought Characteristics in Eastern India,' Presented in International Conference on Sustainable Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee, p-171.
19.	Kumar, A., Kumar, S. S., Singh, A., Kumar, M., Kumar, J., Kumar, D., Kumar, A., Kumar, D., Fagodiya, R. K., Gupta, D. K., Malyan, S. K. and Singh, R. (2018), Greenhouse gases mitigation through industrial byproduct in rice soil. In: Proceedings of International Conference on Sustainable Technologies for Intelligent Water Management organized by IIT Roorkee and Indian Water Resources Society during Feb 16-19, 2018, Roorkee, pp. 368.
20.	Kumar Amrit S.K. Mishra and R.P. Pandey, 'SPI Based assessment of Environmental Flow Conditions,' Presented in International Conference on Sustainable Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee, p-262.
21.	Kumar, P., Nayak, J. and Ram, S. (2018), Hydro-ecological Assessment of Environmental Flows for Satluj river. In: Proceedings of International Conference on "Sustainable Technologies for Intelligent Water Management" organized by IIT Roorkee and Indian Water Resources Society during Feb 16-19, 2018, pp. 263.
22.	Lohani, A.K., S. Naha, S.K. Jain, L.N. Thakural "Snowmelt runoff modelling in a subbasin of the Ganga Basin (2017)", 3rd International conference on "Status and Future of World's Large Rivers, New Delhi India, April 18-21, 2017.
23.	Jeyakanthan, V.S., Y.R.Satyaji Rao, R. Venkata Ramana, 'Updating Elevation-Area-Capacity Table of Singur Reservoir Using Satellite Data,' 2nd International Conference on Emerging Trends in Engineering, Science and Technologies (ICETEST-18), Organised by Balaji Institute of Technology & Science (BITS), Warangal, Telangana, during 16th – 17th February 2018.
24.	Malyan S. K., Rawat M., Kumar M. and Singh R. (2018), Carcinogenic Pollutants in Groundwater of India: A Review. In: Proceedings of International Conference on Sustainable Technologies for Intelligent Water Management organized by IIT Roorkee and Indian Water Resources Society during Feb 16-19, 2018, Roorkee, pp. 349.
25.	Mani, Pankaj, Rakesh Kumar & J. P. Patra (2018) " Dam Break Flood Inundation Modelling for a Hydroelectric Dam" International Conference on Sustainable Technologies for Intelligent Water

	Management 2018 to be organised at Indian Institute of Technology Roorkee, India during February 16-19, 2018.
26.	Modi, P., M S Rao Chintalacheruvu, R V Kale (2017) Rainfall-Runoff Simulation Using HEC-HMS In Sutlej River Basin, India, Hydro-2017 International, during December 21-23,2017.
27.	Nayak, P. C., S. V. Vijaya Kumar, P. R. Rao and T. Vijay, 'Isotope analysis and groundwater flow modeling for Puri city', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
28.	Nayak, P C, B Venkatesh, T Thomas and YRS Rao, 'Assessing the impact of climate change for Mahanadi basin using SWAT model', International SWAT conference, IIT Madras, Chennai, 10-12 Jan., 2018
29.	Moktan, Sudin, R.P. Pandey, S.K. Mishra, R.B. Pokhrel, 'Study of Drought Characteristics in Ken Basin of Bundelkhand region in India,' Presented in International Conference on Sustainable Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee, p-168.
30.	Murugan G., Sakthivel, Jeyakanthan V.S., Kanmanishanmugapriya, R, 'Evapotranspiration Estimation Using Satellite Data,' 2nd International Conference on Emerging Trends in Engineering, Science and Technologies (ICETEST-18), Organised by Balaji Institute of Technology & Science (BITS), Warangal, Telangana, during 16th – 17th February 2018.
31.	Pandey, R.P., Rakesh Kumar, 'Challenge of Drought Management in India and A Way Forward. Paper Presented in Special Panel Discussion Session on "Drought Management and for Social Security", India Water Week, 10-14 Oct 2017, New Delhi.
32.	Pandey Ashish, Deen Dayal, S. S. Palmate, S.K. Mishra and R.P. Pandey, 'Long Term Historic Changes in Temperature and Potential Evapotranspiration Over Betwa River Basin,' Presented in International Conference on Sustainable Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee
33.	Pant Neeraj, Rai S.P., Saini K. R., Singh Rajesh, Kumar Manish, Mishra Sumit, "Evaluation of Hydrogeochemistry and Groundwater Quality in Lalitpur District, Bundelkhand Region, Uttar Pradesh, India. Presented in 7th International Groundwater conference on groundwater vision 2030 "WATER SECURITY, CHALLENGES & CLIMATE CHANGE ADAPTATION" 11th -13th Dec 2017 New Delhi"
34.	Pokhrel R.B., R.P. Pandey, S.K. Mishra and Sudin Moktan , 'Evaluation of Hydro-Meteorological Drought Indices in Dry Land Areas- A Case Study of Seonath River Basin,' Presented in International Conference on Sustainable Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee, p-172.
35.	Parajuli, Dinesh, J.P. Patra, S.K. Mishra (2018) Event based hydrological modelling of Babai watershed using HEC-HMS. International Conference on Sustainable Technologies for Intelligent Water Management 2018, IIT, Roorkee, February 16-19, 2018.
36.	Pottakkal, Jose George (2017) Texture and mineralogy of sediments of Hooghly River, Bengal, India, "International Conference on the Status and Future of the World's Large Rivers" organized by National Institute of Hydrology, India and University of Natural Resources and Life Sciences, Vienna, Austria during 18-21 April, 2017 at New Delhi.
37.	Patra, J.P., Rakesh Kumar, Pankaj Mani (2018) Hydrologic analysis and modelling of bridge across Chandrabhaga river. International Conference on Sustainable Technologies for Intelligent Water Management 2018, IIT, Roorkee, February 16-19, 2018
38.	Purandara, B.K.,Chandramohan T., Venkatesh.B., and Jose, M.K., 2017 Simulation of soil moisture and solute transport movement in an agriculture field – A case study, Proceedings of International Groundwater Conference, December 11-13, 2017, organsied by NIH at New Delhi
39.	Purandara, B.K., Zameerulla, M., Varandarajan, N., and Chandrakumar S., 2017 Groundwater Impact assessment using VLEACH Model, Proceedings of International Groundwater Conference, December 11-13, 2017, organsied by NIH at New Delhi
40.	Rao, Satyajit, Y.R. Sivavignesh, Venkata Ramana, R. , Shanmugam, M., 'Mapping of Groundwater Vulnerable Zones in Amaravati New Capital of Andhra Pradesh, India', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
41.	Rai,S.P., N. Pant, Y.S. Rawat, R.K. Saini, D. Singh., D. Rai., S. Kumar, and K. Pratap, 2017 Isotopic characterisation and identification of sources of groundwater of Bazada region in Tapi alluvial basin,

	District Jalgaon, Maharashtra, India. In: 7th International Groundwater Conference (IGWC-2017) "Groundwater Vision 2030: Water Security, Challenges & Climate Change Adaptation", December 11-13, 2017, New Delhi, India.
42.	Rai, S.P., Kumar, B., Kumar, S., Singh, D., Verma, S.K., Arora, M., Rawat, Y.S., Pant, N., and Pandey, N.G. Stable isotope schematics of Ganga River and its tributaries. International Conference on "Status and Future of the World's Large Rivers", April 18-21, 2017 New Delhi, National Institute of Hydrology, Roorkee.
43.	Rai, S.P., Kumar, S., Singh, D., Rathore, D.S. and Saini, R. Hydro-chemical comparison of water of Mansarovar Lake and Gangotri Glacier. International Conference on "Status and Future of the World's Large Rivers", April 18-21, 2017 New Delhi, National Institute of Hydrology, Roorkee.
44.	Rai S. P., Pant Neeraj, Rawat Y D, Saini K.R., Rai Dinesh. "Isotopic characterization and Identification of source of Groundwater of Bazada region in Tapi Alluvium basin district Jalgaon, Maharashtra" Presented in 7th International Groundwater conference on groundwater vision 2030 "WATER SECURITY, CHALLENGES & CLIMATE CHANGE ADAPTATION" 11th -13th Dec 2017 New Delhi
45.	Rai S. P., Kumar B., Kumar S., Singh D., Verma S. K., Arora M., Rawat Y. S., Pant Neeraj. and Pandey N.G. 2017. Stable Isotope Schematics of Ganga River and its tributaries. International Conference on the Status and Future of the World's Large River. April 18-21, 2017, New Delhi.
46.	Rao, YRS, RV Raman and VS Jeyakanthan, 'Management of Storm Water Flooding in Metropolitan Cities of India', International SWAT conference, IIT madras, Chennai, 10-12 Jan., 2018
47.	S S Rawat, S P Rai, P G Jose, P Kumar, R V Kale (2017) Hydrological evaluation of impact of springshed development programme: Case study of four springs from a Himalayan state of India, "7th International Groundwater Conference (IGWC-2017) on Groundwater Vision 2030" organized by National Institute of Hydrology, Roorkee at NAAS Complex, New Delhi during December 11-13, 2017.
48.	Pandey, R.P., 'Relevance of Climate Change on Characteristics of Regional Droughts and Irrigation Requirement (Key note paper),' Presented in International Conference on Sustainable Technologies for Intelligent Water Management (STIWM), Feb. 16-19, 2018, IIT Roorkee
49.	Pant, Neeraj, S.P. Rai, Saini R. K., Kumar S, Singh R., K. Pratap, Dubey R.K., Mishra S. 2017. Evaluation of Hydrogeochemistry and Groundwater Quality in Lalitpur District, Bundelkhand Region, Uttar Pradesh, India. 7th International Groundwater Conference (IGWC-2017) "Groundwater Vision 2030: Water Security, Challenges & Climate Change Adaptation", December 11-13, 2017, New Delhi, India
50.	Shafeeulla, S., Purandra, B.K and Venkatesh,B., 2017 Hydrogeological characteristics and model conceptualization of Malaprabha Catchment, Karnataka, India, Proceedings of International Groundwater Conference, December 11-13, 2017, organsied by NIH at New Delhi
51.	Saranya. P, Krishnakumar. A, Sudhir Kumar, Anoop Krishnan. 2017. Seasonal patterns of Surface water and groundwater interaction in Periyar river basin, Kerala, India. In: 7th International Groundwater Conference (IGWC-2017) "Groundwater Vision 2030: Water Security, Challenges & Climate Change Adaptation", December 11-13, 2017, New Delhi, India
52.	SaiLakshmi, V.S.Jeyakanthan, Y.R.Satyaji Rao, R. Venkata Ramana, 'Rainfall-Runoff of Modelling Using SWAT,' 2nd International Conference on Emerging Trends in Engineering, Science and Technologies (ICETEST-18), Organised by Balaji Institute of Technology & Science (BITS), Warangal, Telangana, during 16th – 17th February 2018.
53.	Saka, David, Egbi, Courage, Yevutsey, Stephen, Krishan, Gopal, 'Assessment of groundwater contamination by pit latrine in the Angaw – Lower Volta River Basin, Ghana using tracer technique', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
54.	Sahoo, Sashikanta, Sharma, Richa, Litoria, Pradeep, Krishan, Gopal and Pateriya, Brijendra, 'Groundwater quality mapping in urban groundwater using GIS and geostatistics', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
55.	Shashi Poonam Indwar, N.C.Ghosh, Anupma Sharma, Stefanie Fischer, S.Mittal, R.Goel, 'Riverbank Filtration Modelling for Haridwar case study using Visual MODFLOW', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
56.	Sharma, MK, RJ Thayyen, CK Jain, Manohar Arora, Shyamlal, 'Role of subglacial system in

	controlling the hydro-chemistry of Gangotri glacier system,' International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi, pp.102
57.	Sharma, M. K., Jain, C. K., Singh, R., Singh O. and Durbude, D.G. (2018), Contamination in Drinking Water Supply: A Case Study of Shimla City, Himachal Pradesh. In: Proceedings of International Conference on "Sustainable Technologies for Intelligent Water Management" organized by IIT Roorkee and Indian Water Resources Society during Feb 16-19, 2018, pp. 224.
58.	Singh, D., Rai, S.P., Kumar, S., Pant, N. and Swain, S.K. "Application of Stable Isotopes in Water Resource Management: A Case Study of Kaushalya Dam". 12th DGSI International Conference on "Environmental changes in south and south east Asia: Challenges and prospects," September 24-26, 2017 Raipur, School of studies in Geography, Pt. Ravishankar Shukla University, Raipur Chhattisgarh.
59.	Singh, D., Rai, S.P., Kumar, S., Pant, Neeraj. and Swain, S.K. "Application of Stable Isotopes in Water Resource Management: A Case Study of Kaushalya Dam". 12th DGSI International Conference on "Environmental changes in south and south east Asia: Challenges and prospects, September 24-26, 2017 Raipur, School of studies in Geography, Pt. Ravishankar Shukla University, Raipur Chhattisgarh
60.	Singh, D., S. P. Rai, S. Kumar, M. Arora, Pant Neeraj, S.K. Swain, R.S. Ahluwalia and H.N. Nainwal "Inferences derived from isotopic characterization of river water (Bhagirathi River) sampled near snout of Gangotri Glacier in Western Himalaya". International conference on "Water Resources: Innovations in Quality and Quantity, Sustainable Development and Challenges " (ICWR- 2018) 15th -17th March 2018, University of Kerala
61.	Singh, Surjeet, Ghosh, N.C., Kumar, Sumant and Krishan, Gopal, 'Development of index for wastewater quality assessment,' International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
62.	Singh, Rajesh, Jeffery Westroop, Chris Elofsan, Arindam Malakar, Dan Snow, T. Christopherson, Bo Bonn, KA Weber, 'Source Identification for Arsenic in Groundwater of Southwestern Nebraska. pp – 165', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
63.	Singh, R., Kanbienaa, D., Pandey, A. (2018), Water Quality Status of Upper Ganga Canal. In: Proceedings of International Conference on Sustainable Technologies for Intelligent Water Management organized by IIT Roorkee and Indian Water Resources Society during Feb 16-19, 2018, Roorkee, pp. 295.
64.	Singh, R. Westroop, J., Elofsan, C., Malakar, A., Snow, D., Christopherson, T., Bonn, B., and Weber, K. A. (2017), Source identification for Arsenic in groundwater of southwestern Nebraska. In: Proceedings of International Ground Water Conference (IGWC-2017) organized by NIH and CGWB during 11-13 Dec. 2017 at New Delhi, pp. 165.
65.	Tarafdar, Soukhin, Sudhir Kumar. 2017. Stable water isotope variation in smaller water resource from headwater catchment in Lesser Himalaya dominated by rain. 7th International Groundwater Conference (IGWC-2017) "Groundwater Vision 2030: Water Security, Challenges & Climate Change Adaptation", December 11-13, 2017, New Delhi, India
66.	Sumant Kumar, NC Ghosh, AA Kazmi, 'Optimal Coagulant & Polymer Dose for High Rate Clarifier for Urban Runoff Treatment', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
67.	Sujitha, Vidya, B. K. Purandara and A. V. Shivapur. 2017. Assessment of Aquifer Vulnerability using GALDIT model – a Case Study. Presented in International Conference on Ideation and Innovations in Sustainable Sciences and Technologies. Univ. of Malaysia, 30th June-2nd July, 2017.
68.	Tyagi, J.V. and Rao, Y.R.S. (2018). Evaluation of SWAT for modelling the water balance and water yield of Yerrakalva river basin, A.P., Proc. SWAT-2018, Int. conference on Soil and Water Assessment Tool, 10-12 Jan., 2018, IITM, Chennai.
69.	Venkat Raman, R., , Y R Sataji Rao, V S Jeyakanthan, 'Forecasting short term water table fluctuation in different geological formations using wavelet coupled ANN', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi
70.	Venkatesh.B., Nayak, P.C. and Thomas, T., 2018 Assessing the impact of Calibration data length on performance of SWAT model, Presented in International Conference on SWAT from 8-12 Jan 2018

	organised by IIT Chennai at Chennai.
71.	Venkatesh.B., Vijay Vastrad, Nayak,P.C., and Thomas, T., 2017Impact of Climate Change on groundwater recharge in a semi-arid catchmet in Karnataka, India, Proceedings of International Groundwater Conference, December 11-13, 2017, organsied by NIH at New Delhi
72.	Vijay Vastrad, Ujval Utag, Purandara, B.K., and Venkatesh B., 2017 Soil and water salinisation studies in Doni River Catchment, Proceedings of International Groundwater Conference, December 11-13, 2017, organsied by NIH at New Delhi
73.	Vijayakumar, S.V., E. Amminedu; V. Venkateswara Rao, 'Quantification of artificial recharge intervention during different stages of urban development', International Groundwater Conference (IGWC-2017) Groundwater Vision 2030 – Water Security, Challenges and Climate Change Adaptation, during 11-13 December, 2017 at NASC, ICAR, New Delhi

National Conference

1.	Kumar, Sudhir, 2017, Application of isotopes in water resources management, 1st Mass spectrometry Indian Users Conference (MS-INDUSCON-2017): November 6-10, 2017 Goa
2.	Purandara, B.K., A. V. Shivapur and B. Venkatesh, 2018. Simulation of Soil Moisture Movement and Solute Transport Characteristics in parts of Malaprabha Command. Presented and published in Proceedings of National Seminar on Water Quality Issues and Water Resources Management organized by institution of Engineers and Karnataka Pollution Control Board, 2018.
3.	Rawat, S S, S P Rai, P G Jose, S Gurjar, R V Kale (2017) Inventorization and Adaptive strategies for revival of springs of Ravi River catchment of Himachal Pradesh for improved water security, "2nd Himachal Pradesh Science Congress" organized by Himachal Pradesh Council of Science, Technology & Environment (HIMCOSTE), Govt. of Himachal Pradesh at Hotel Peterhoff, Shimla during November 20-21, 2017.
4.	Saini, R. K., S. Mishra, R. S. Rana, G. J. Chakrapani, B. N. Bhosle, Pant Neeraj, "Distribution of REE in suspended and bed sediments of Alaknanda and Bhagirathi Rivers, Garhwal Himalayas and its implications on chemical weathering rates" Presented in National conference on "Climate and Natural Resources; impact and Sustainable Development in India Perspective" 20-21 Feb 2018
5.	Vijaya Kumar, S V, 'Seasonal groundwater balance for paleo channel aquifer underlain along Ambajipeta channel in central Godavari delta system, 'Two day BhuJal Manthan session on 16-17 Feb 2018 with focus on 'Participatory groundwater management' and 'low cost artificial recharge measures for groundwater augmentation' organized by CGWB, MoWR RD & GR at Nagpur.
6.	Zameerullah, Mohammed, B. K. Purandara and A V Shivapur, 2018. Distribution and Characteristics of Micro-organisms in Ground Water of Belagavi City, Karnataka, India. Presented and published in Proceedings of National Seminar on Water Quality Issues and Water Resources Management organized by institution of Engineers and Karnataka Pollution Control Board, 2018.

International Book Chapter:

1.	Sediment Runoff Modelling using ANNs in an Eastern Himalayan Basin, India, Archana Sarkar, Nayan Sharma, R.D. Singh, Book chapter in "River System Analysis and Management" eds Nayan Sharma, Springer, Singapore, 2017, pp 73-82.
2.	Study of Climate Change in Uttarakhand 2 Himalayas: Changing Patterns 3 of Historical Rainfall, Archana Sarkar and Vaibhav Garg, Book chapter in "Climate Change Impacts, Water Science and Technology Library 82" V.P. Singh et al. (eds.), DOI 10.1007/978-981-10-5714-4_14.
3.	Hydrologic regimes under climate change in Indo-Gangetic basin and their impact on fruit production (2017), G Krishan, AK Lohani, Horticultural Sciences-perspectives and applications, Publisher: Brillion Publishing, New Delhi, Editors: K.V. Peter, pp.257-273.
4.	Statistical Downscaling of Minimum Temperature of Raipur (C.G.) India (2018), R. K. Jaiswa, H. L. Tiwari, A. K. Lohani, R. N. Yadava, In: Singh V., Yadav S., Yadava R. (eds) Climate Change Impacts. Water Science and Technology Library, vol 82. Springer, Singapore, pp 35-45.
5.	Fuzzy Logic in Multi-Objective Decision Making and Hydrological Modelling (2017) A. K. Lohani, Chandra S. P. Ojha, and Sanjay Kumar Jain, in: Sustainable Water Resources Management Edited by: Chandra S. P. Ojha, Rao Y. Surampalli, AndrásBárdossy, Tian C. Zhang, Chih-Ming Kao, ISBN (print): 9780784414767ISBN (PDF): 9780784480908, © 2017 American Society of Civil

	Engineers, pp 119-159.
6.	Surface Water Data Collection and Processing (2017) Chandra S. P. Ojha, A. K. Lohani, Adebayo J. Adeloye, Sanjay Kumar Jain, RabeeRustum, in: Sustainable Water Resources Management Edited by: Chandra S. P. Ojha, Rao Y. Surampalli, AndrásBárdossy, Tian C. Zhang, Chih-Ming Kao, ISBN (print): 9780784414767ISBN (PDF): 9780784480908, © 2017 American Society of Civil Engineers, pp 15-49.
7.	Development of a Fuzzy Flood Forecasting Model for Downstream of Hirakud Reservoir of Mahanadi Basin, India. (2017) Kar A.K., Lohani A.K., Goel N.K., Roy G.P. In: Sharma N. (eds) River System Analysis and Management. Springer, Singapore, 211-218.

APPENDIX 71.4.3

LIST OF WORKSHOPS/ TRAINING COURSES/ SYMPOSIA ORGANISED DURING AUGUST, 2017 – MARCH, 2018

Organisation of Workshop/ Training Courses/ Seminars/ Symposia

S.No.	Name of Course	Period	Venue
1.	3rd World's Large River Conference on the "Status and Future of the World's Large Rivers"	18-21 April, 2017	New Delhi
2.	Workshop was organized for all the states and Unions Territories (UTs) on Preparation of State Specific Action Plan (SSAP) for Water Sector	5 June, 2017	CWC, New Delhi
3.	Workshop on Noting and Drafting in Hindi	June 28, 2017	Roorkee
4.	Training course on 'Basics of Hydrology' under NHP	June 27 – July 1, 2017	Roorkee
5.	Training Course on "Water Conservation Practices through Adaptation of appropriate Management and Technological Interventions: A Practitioners Approach	July 3-7, 2017	Roorkee
6.	Network Design and Instrumentation	17-21 July, 2017	CWPRS under NHP in ass. With NIH, Rke
7.	Bank filtration for sustainable drinking water supply jointly organized by NIH, Roorkee; HTWD, Germany; UJS, Dehradun; UCOST, Dehradun; DST, New Delhi	September 18-22, 2017	PHED, Shillong
8.	Stakeholder consultation workshop on 'DSS-H modules and database protocol'	6-7 Sept.2017	Phulbani, Odisha
9.	Application of CROPWAT Software" for Irrigation in-Service Engineers.	9-12 October 2017	HIRMI, Kurukshetra, Haryana
10.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	10-11 August, 2017	Dewas, M.P.
11.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	16-17 August, 2017	Amrawati (Nagpur), Maharasthra
12.	Workshop on "Water quality basics and measurement"	16-18 August, 2017	Belagavi
13.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	22-23 August, 2017	Nalgonda, Telangana
14.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	28-29, August, 2017	Chittor (Tirupati), Andhra Pradesh
15.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	6-7 Sept., 2017	Phulbani, Odisha
16.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	11-12, Sept, 2017	Rancji, Jharkand
17.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	14-15 Sept, 2017	Raipur (Jashpur), chattisgarh
18.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	25-26 Sept., 2017	Kutch (Bhuj), Gujarat
19.	Stake holder workshop on "DSS(H): Deliberating Modules & Database"	5-6 Oct., 2017	Jodhpur, Rajasthan
20.	Training course on "Application of CROPWAT Software" for Irrigation in-Service Engineers.	9-12 October 2017	HIRMI, Kurukshetra,

			Haryana
21.	workshop on "Basic Hydrology"	9-13 Oct., 2017	Trissur, Kerala
22.	International Groundwater Conference (IGWC-2017)	11-13 Dec., 2017	NASC, ICAR, New Delhi
23.	Training Course on "Water Conservation Practices through Adaptation of appropriate Management and Technological Interventions: A Practitioners Approach	18-22 Dec., 2017	IGFRI, Jhansi
24.	Indian Science Academies' Refresher Course on "Hydrology of Floods"	8-19 Jan., 2018	NIH, Roorkee
25.	Training Workshop on "River Basin Modelling"	15-19 Jan., 2018	WALMI, Bhopal
26.	Training Course on "Ground Water Quality Modelling" under NHP-PDS	12-16 Feb., 2018	NIH, Roorkee
27.	Training Course on "Water Quality: Concepts and Analysis" under NHP	19-23 March, 2018	NIH, Roorkee
28.	Training Course on Hydro-Meteorological Data Collection for Spring Mapping in Ravi River Catchment under NHP-PDS	23-24 March, 2018	Chamba, Himachal Pradesh

APPENDIX 71.4.4

PROGRESS OF LABORATORY WORK DURING THE PERIOD AUGUST, 2017 – MARCH, 2018

1. **Nuclear Hydrology Laboratory**
2. **Water Quality Laboratory**
3. **Soil-Water Laboratory**

Isotopic Analyses of Water Samples at Nuclear Hydrology Laboratory

Sample Analysed from August 2017 to March 2018

No.		Samples	Analysed
1	^{18}O		5,821
2	^{2}H		4,876
3	^{3}H	Measurements	260
		Enrichment	136
4	^{13}C		255
5	IC	Chemical Analysis	824
Total			14,749

Divisions/organizations whose samples have been analyzed:

- **HI Division; SWH Division; GWH Division, RC Kakinada, RC Belgaum, RC Jammu**
- **CGWB, IIT Roorkee, IIT Kharagpur; Tejpur University, Central University (Gujarat), NCESS (Trivendrum), GBPNIHED (Almora).**

Chemical and Bacteriological Analysis of Water Samples in Water Quality Laboratory for the period between August, 2017 to March, 2018

	No. of samples of Division	No. of samples of Regional Centre	No. of samples of Outside Agencies on payment basis
Physico-chemical analysis	289	32	-
Bacteriological analysis	21	-	-
Metal analysis	-	-	-
Pesticide analysis	-	-	-
Total analysis	310	32	-

Soil Water Laboratory

Laboratory Analysis carried out during the period Aug 2017 to March 2018.

Sl. No.	Name of the studies	No. of Samples	Parameters Measured
1.	Hillslope hydrological functioning along a forest degradation gradient in lesser Himalya of India	Twelve + Sixteen + FIfteen	1.Determination of soil texture using sieve shaker and laser based particle size analyser. 2. Determination of soil moisture retention characteristics by disturbed soil samples. 3. Determination of Bulk Density 4. Determination of pH and EC.
2.	Measurement and Modelling of 'ET' and other Hydrological Process in lesser Himalaya(MOES) Henval..	Three + Three	1.Determination of soil texture using sieve shaker and laser based particle size analyser. 2. Determination of Bulk Density
3.	Observation and modeling of various hydrological process in small watersheds in upper Ganga basin , Henval water-shed	Four	1.Determination of soil texture using sieve shaker and laser based particle size analyser.
4.	Observation and modeling of various hydrological process in small watersheds in upper Ganga basin , Henval water-shed	Seventeen + Fifty Six + Nineteen	1. Determination of suspended sediment concentration using filtration Unit. 2. Determination of Sediment texture using laser based particle size analyser.
5.	CEH Project (MOES)	Eighteen	1.Determination of soil texture using sieve shaker and laser based particle size analyser.
6.	Neeranchal National Watershed Project	Twelve	1.Determination of soil texture using sieve shaker and laser based particle size analyser. 2.Determination of soil moisture.
7.	Peya Jal Suraksha Project , Water Works Campous ,Agara (UP)	Twenty Three	1.Determination of soil texture using sieve shaker and laser based particle size analyser. 2. Determination of soil moisture retention characteristics by Pressure Plate Apparatus
8.	Peya Jal Suraksha Project , Mathura(UP)	Twenty	1.Determination of soil texture using sieve shaker and laser based particle size analyser. 2. Determination of PH &EC.
9.	Numerical Modelling of surface water ground water interaction Hindon River Catchment	Eight	1.Determination of soil texture using sieve shaker and laser based particle size analyser. 2. Determination of in-situ saturated hydraulic conductivity using Guelph Permeameter. 3.Determination of infiltration using Infiltrometer. 4.Determination of Permeability using ICW Lab Permeameter. 5. Determination of of Bulk Density,Soil Moisture,Saturated Density. 6. Determination of soil moisture retention characteristics by Pressure Plate Apparatus.

APPENDIX 71.4.5

LIST OF ACTIVITIES UNDER IEC SCHEME
ORGANISED DURING
AUGUST, 2017 – MARCH, 2018

Mass Awareness Programmes at Headquaters, Regional Cnetres and CFMS

The following activities have been taken under media programme by NIH, at the regional centres of NIH and its CFMS during August 2017 – March, 2018.

S.No.	Activities	Organised by & Date
1	Mass Awareness on "Earth Day 2017 : Environmental and Climate Literacy"	NIH, WALMI Campus, Patna on 22 April, 2017
	Brain Storming Session on "Ganga Information Portal"	July 26, 2017 at CFMS, Patna
2	हिंदी सप्ताह	सतम्बर 8 से १४, पश्चिम हिमालय क्षेत्रीय केंद्र-जम्मू
3	हिंदी मास	अगस्त 15 से सतम्बर 14, 2017, रा. ज. स., रुड़की
4	Vigilance Awareness Week	30th October - 4th November, 2017 at NIH, Roorkee
5	Swatchh Bharat Mission	16-31 March, 2018, NIH Roorkee