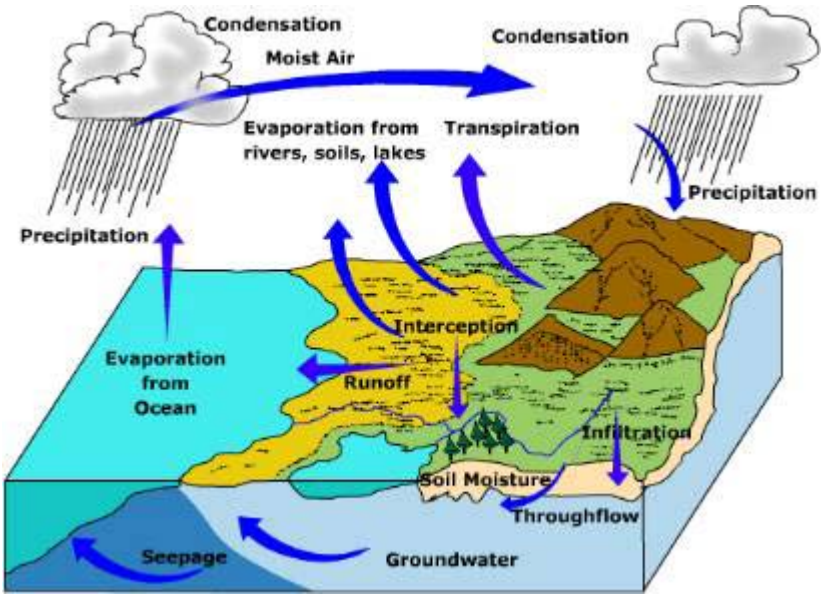
AGENDA AND AGENDA NOTES FOR THE 40th MEETING OF THE WORKING GROUP OF NIH

JUNE 4-5, 2014
AT 1100 HRS



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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 40th MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

Page#

ITEM NO. 40.1 Opening remarks by the Chairman

ITEM NO. 40.2 Confirmation of the minutes of 39th meeting of the Working Group.

ITEM NO. 40.3 Action taken on the decisions/ recommendations of the previous Working Group meeting.

ITEM NO. 40.4 Presentation and discussion on the status and progress of the work programme for the year 2013-2014.

ITEM NO. 40.5 Presentation and finalization of the work programme for the year 2014-2015.

ITEM NO. 40.6 Any other item with permission of the Chair.

ITEM NO. 40.1 Opening Remarks by the Chairman

ITEM NO. 40.2 Confirmation of the minutes of 39th meeting of the Working Group

The 39th meeting of the Working Group was held during October 21-22, 2013. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/39th WG/NIH/13 dated Dec. 26, 2013**. No comments were received on the circulated minutes. A copy of the minutes of the 39th Working Group is given in **Annexure A.**

The Working Group may please confirm the minutes.

ITEM NO.40.3 Action taken on the decisions/recommendations of the previous Working Group meeting

During the 39th Working Group meeting, recommendations/ suggestions were made by the Working Group members and the actions taken shall be informed by the respective Divisions during the meeting.

ITEM NO.40.4 Presentation and discussion on the status and progress of the work programme for the year 2013-2014.

The approved Work Programme of the six Divisions of the Institute for the year 2013-14 has been given in the **Annexure B** in the following order**:**

Page#

1. Environmental Hydrology Division
2. Ground Water Hydrology Division
3. Hydrological Investigation Division
4. Surface Water Hydrology Division
5. Water Resources System Division
6. Research Management & Outreach Division (RMOD)

The numbers of studies/projects being handled by each division under different categories are given below:

Division	Studies		Total
	Internally funded	Sponsored (including HP-II)	
Environmental Hydrology	06		**06**
Ground Water Hydrology	02	04	**06**
Hydrologic Investigation	06	08	**14**
Surface Water Hydrology	10		**10**
Water Resources System	10	02	**12**
RMOD	03	01	**04**
Total			**52**

During the present meeting, Division-wise progress and status of the work programme for the year 2013-14 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2013-2014.

ITEM NO. 40.5: Presentation and finalization of the work programme for the year 2014-2015.

The proposed Work Programme of the six divisions of the Institute for the year 2014-15 has been given in the Annexure – B in the following order:

Page#

1. Environmental Hydrology Division
2. Ground Water Hydrology Division
3. Hydrological Investigation Division
4. Surface Water Hydrology Division
5. Water Resources System Division
6. Research Management & Outreach Division (RMOD)

The work programme has been categorized into three groups: (a) Internally funded studies, (b) Sponsored projects and (c) Consultancy Projects. During the present meeting, Division-wise proposed work programme for the year 2014-15 shall be presented.

	No. of Studies/Projects During the Year 2014-2015					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	1	1	5	1	**8**	
Ground Water Hydrology			1	3	**4**	
Hydrologic Investigation	2	-	4	5	**11**	**3**
Surface Water Hydrology	5	1	7	-	**13**	
Water Resources System	3	-	8	3	**14**	
Research Management & Outreach	1	1	1	1	**4**	
Total					**54**	

ITEM NO. 40.6: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 39TH MEETING OF WORKING GROUP

MINUTES OF THE
39TH MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING OCTOBER 21-22, 2013

The 39th meeting of the Working Group of NIH was held at NIH, Roorkee, during October 21-22, 2013 under the Chairmanship of Director, NIH. The list of the participants of the meeting is given in Annexure-I.

ITEM NO. 39.1: OPENING REMARKS BY THE CHAIRMAN

Er. R D Singh, Director, NIH & Chairman, WG welcomed the Working Group members and the Scientists of the Institute. The Chairman mentioned the monthly monitoring of milestones/deliverables by the Ministry of Water Resources, and suggested that the scientists should prepare the internally-funded studies in the same format as of the sponsored projects (including the provision of budget under defined heads).

The Chairman then asked the Member-Secretary to take up the agenda of the meeting.

ITEM No. 39.2: CONFIRMATION OF THE MINUTES OF 38TH MEETING OF THE WORKING GROUP

The 38th meeting of the Working group was held during April 3-4, 2013. The minutes of the meeting were circulated to all the members and invitees vide letter No. RMOD/38th WG/NIH/13 dated July 1, 2013. As no comments were received on the circulated minutes, the minutes were confirmed.

ITEM No. 39.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING

Dr. V. C. Goyal, Scientist F & Member Secretary, gave a brief account of the actions taken on the recommendations/decisions of the 38th working group meeting.

ITEM No. 39.4: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR THE YEAR 2013-14.

The Member-Secretary requested the respective Divisional Heads to present their progress of studies and work programme of the year 2013-14 in the meeting. Accordingly, the progress of various studies and sponsored projects was presented by all scientific Divisions on their turn during two day deliberations of the Working Group. The Division wise minutes of each study/project presented during the meeting are given below:

ENVIRONMENTAL HYDROLOGY DIVISION

S.No.	Title of the Study, Study Group, Date of Start and Completion	Recommendation/Suggestion
1.	Assessment of Water Quality in Hindon River Basin Study Group: M. K. Sharma (PI), Omkar Singh, Rakesh Goel, Dayanand DOS: 11/11, DOC: 10/14	Dr. S. N. Rai suggested to include metal concentrations for calculating water quality index for ground water. Dr. N. B. Narasimha Prasad advised to take a new study in future to study the extent of river pollution on ground water quality considering ground water flow direction.
2.	Development of Low Cost Media for Fluoride Removal from Drinking Water of Fluoride Affected Areas Study Group: Rajesh Singh (PI), Dayanand DOS: 04/2011, DOC: 09/2013 Extended for 6 months up to March 2014	Dr. V. C. Goyal suggested to include some photograph of column study. Dr. S. N. Rai suggested patenting the developed adsorbant, which was further supported by Dr. V. C. Goyal to do patenting through RMOD.
3.	Applications of Nanotechnology in Water Sector Study Group: C. K. Jain (PI), Dinesh Mohan (JNU), Babita Sharma DOS: 04/13, DOC: 03/14	No comments.
4.	Ground Water Quality Mapping and Surveillance for Safe Water Supply in District Hardwar and Dehradun, Uttarakhand Study Group: C. K. Jain (PI), Rama Mehta, S. K. Sharma, Yatveer Singh, Babita Sharma DOS: 04/2013, DOC: 03/2014	No comments.
5.	Water Quality Modelling using Soft Computing Techniques Study Group: Rama Mehta (PI), C. K. Jain DOS: 04/2013, DOC: 03/2014	Dr. S. N. Rai suggested to prepare a User Manual for using the developed software.
6.	Environmental Flows Assessment of Hemavathi River in Karnataka	No comments.

	Study Group: D. G. Durbude (PI), C. K. Jain DOS: 04/2013, DOC: 03/2015	
7.	Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier Study Group: M. K. Sharma (PI), C. K. Jain, Renoj Thayyan, Manohar Arora, Naresh Saini, Jatin Malhotra, Rakesh Goyal DOS: 10/2013, DOC: 09/2016	No comments.

GROUND WATER HYDROLOGY DIVISION

Dr. N.C. Ghosh, Scientist-F and Head of the division presented an overview of studies and activities carried out by the Division during the period April – September, 2013. While presenting the technical activities carried out and progress made on different studies during last six months, he gave an account of scientific personnel available at the division and the consultancy projects being pursued by the division. He informed that out of 6 R&D studies approved for the year 2013-14, two are in house studies and 4 are sponsored continued studies of the year 2012-13.

The division has proposed two activities to be organized during 2013-14, one braining storming session and one training course training course. Initiative has already been taken up to get those activities sponsored from external sources. Besides those activities, Dr. Anupma Sharma, Scientist-D organized one half day joint interactive workshop on 'DSS(P) Applications for Mahi Basin, Gujarat' at State Water Data Centre, Gandhinagar on Aug. 29, 2013. As professional scientific activities, scientists of the Division have submitted/published a number of research papers in various journals/conferences/symposia, delivered lectures in various training courses and guided ME/M.Tech and summer trainees during the period.

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

Project Ref. Code: NIH/GWD/NIH/13-14: **Estimation of specific yield and storage coefficient of aquifers**

Dr. Surjeet Singh (PI) presented the progress of the study and various methods for the estimation of specific yield and storage coefficient. Dr. N.C. Ghosh explained the importance of precise estimation of specific yield and storage coefficient in estimation of groundwater resources. The PI also presented merits and demerits of various methods and techniques, their data requirements and a qualitative assessment on suitability of methods. Dr. Singh reported that the quantitative assessment on suitability of various methods for varying field conditions

is to be carried out. Dr. S.N. Rai suggested reviewing few more recent research papers on the estimation of specific yield.

Project Ref. Code: NIH/GWD/NIH/13-14: **State-of-the-Art Report on Modeling of Coastal Aquifers Vulnerable to Sea Water Ingress.**

The preparation of the state-of-the-art report emerged as an action suggested by the Ministry of Water Resources under its National Water Mission on Climate Change has been reported.

Project Ref. Code: NIH/GWD/HP-II/10-12: **Coastal Groundwater Dynamics and Management in the Saurashtra Region, Gujarat.**

Dr. Anupma Sharma (PI) presented the progress of the study and groundwater salinity issues in the coastal Saurashtra region and the various measures taken by the State Deptt. to prevent ingress of saline water through creeks and freshwater reservoir schemes. The details of data collection program undertaken for the Minsar Basin, topography and geology of Minsar Basin, observation well network, rainfall pattern in the area etc. were also presented. Impact of low rainfall in the previous year and normal rainfall in the current year with resulting variations in water table and groundwater salinity along the coast during different months were also explained. Variation in profile salinity during different months and locations was illustrated. Results obtained from chemical analysis of water samples were shown using various plots of different water quality parameters. Possible cation exchange reactions in the region were discussed. Dr Deshpande suggested studying the time lag in the phenomena of advance and retreat of the salinity and related ion exchange in the groundwater system. Dr Jacob enquired about the depth of wells in the study area. The variation in the well depths near and away from the coast was explained using a scatter plot. The importance of runoff from the hilly region in terms of its utilization in the downstream areas was discussed and simulations from hydrologic modeling were shown.

Dr. Sharma reported that extensive field investigations had been carried out under this PDS of HP-II to gather representative data from the field. She informed, the study would be completed within the stipulated time.

Members of the Working Group appreciated such detailed investigations and systematic data collection efforts. Dr. S. N. Rai suggested that NIH can think bringing out 'Professional Paper' on studies, which involved detailed field investigations and innovative approach in field data collection.

Project Ref. Code: EU-sponsored Project no. 282911 : Saph Pani - Enhancement of natural water systems and treatment methods for safe and sustainable water supply in India"

Dr. N. C. Ghosh presented the progress made during the last six months period in the EU sponsored collaborative R & D project, 'Saph Pani'.

Dr. Ghosh informed that water sampling campaign in Haridwar RBF site from 29 locations to determine the concentrations of 20 water quality constituents (16 physico-chemicals, 2 bacteriological and 2 heavy metals) and isotopic composition carried out

bimonthly during monsoon months. Other auxiliary data, such as river stages and groundwater levels had also collected for modelling the well fields of the RBF wells. . Dr. Ghosh informed, the analyzed results are being shared with task leaders from time to time for carrying out other tasks of this work package. The transient simulation of the steady-state model developed for the case study site is in progress at the HTWD, Germany. Dr. Ghosh informed that semi-analytical models involving a new approach for analyzing "River, Canal, Aquifer and Well field interaction" have been developed for estimation of increase in canal recharge and river depletion consequent to pumping in the vicinity of the river and canal network. The models have been applied to simulate the wells field of the Haridwar site.

Dr. Ghosh informed that during July, 2013 a second round of visit to different potential RBF sites of Bihar, Jharkhand, Andhra Pradesh, and Jammu had been carried out by respective Regional Centre of NIH along with HTWD, Germany and collected data from various places as part of the activities of baseline data generation to prepare master plan.

The other technical activities carried out under the Work Package-7 : Training and Dissemination, had also been reported. It was also informed that the 4th biannual review meeting together with the third and the last training course of its series on "Application of wetlands and other natural systems in India" is being organized by IIT Bombay and NIH at Mumbai during 20-26 November, 2013.

Project Ref. Code: NIH/GWD/NIH/11-14 : Managed Aquifer Recharge (MAR) and Aquifer Storage Recovery (ASR)

Mr. Sumant Kumar (PI) presented the progress and achievements made during last 6 months and the future plan of the study. PI informed that bathymetric survey of the Telebanda lake has been conducted and geometry and capacity of the lake has been determined. The status of some water quality constituents has also been analyzed to know the pollution level of the lake. The weekly water level of the lake is being monitored from June, 2013. The future plan of the study has been envisaged as to estimate the groundwater recharge using water balance approach.

Project Ref. Code: EU-sponsored Project no. 282911 : **Flow and Contaminant Transport Modeling of Riverbank Filtration.**

As the PI of the study Ms. Shashi Poonam Indwar, Sc.-B is on long leave on health ground; the progress of this study has not been reported. The work programme of the division for the year 2013-14 is given at annexure-I.

Annexure-I

WORK PROGRAMME OF THE GROUND WATER HYDROLOGY DIVISION FOR THE YEAR 2013-14

S. No. & Reference Code	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/NIH/13-14	Estimation of specific yield and storage coefficient of aquifers	Surjeet Singh (PI) N.C. Ghosh (Co-PI) Sumant Kumar	1 year (04/13 – 03/14) **Status**: Continuing	NIH
2.	* State-of-the-Art	Anupma Sharma	1 year	NIH

NIH/GWD/NIH/13-14	Report on Modeling of Coastal Aquifers Vulnerable to Sea Water Ingress	(PI) C.P. Kumar (Co-PI) Rajan Vatsa	(04/13 – 03/14) **Status**: Continuing	(Reffered by MoWR)
Sponsored & HP-II Projects				
3. NIH/GWD/HP-II/10-12	Coastal Groundwater Dynamics and Management in the Saurashtra Region, Gujarat.	N. C. Ghosh (Coordinator) Anupma Sharma (PI) C P Kumar SE(GWRDC, Gujarat) C.K. Jain Sudhir Kumar D.S. Rathore M.S. Rao Surjeet Singh Rajan Vatsa	3 years (10/09 – 12/13) **Status:** Continuing	PDS (HP-II)
4. EU-sponsored Project no. 282911	Saph Pani - Enhancement of natural water systems and treatment methods for safe and sustainable water supply in India"	Project Coordinator & P.I. : N. C. Ghosh Other Team Members V. C. Goyal C. K. Jain Sudhir Kumar B. Chakravorty A. K. Lohani Anupma Sharma Surjeet Singh Sumant Kumar Shashi Poonam Indwar	36 months (Oct., 2011-Sept.,2014) Status: Continuing	European Union under 7th - Framework Programme
5. NIH/GWD/NIH/11-14	Management of Aquifer Recharge (MAR) and Aquifer Storage Recovery (ASR)	Sumant Kumar (PI) Rajan Vatsa N.C. Ghosh C.P. Kumar Surjeet Singh Sanjay Mittal	3 years (04/11 – 03/14) **Status:** Continuing	Saph Pani Project
6. EU-sponsored Project no. 282911	Flow and Contaminant Transport Modeling of Riverbank Filtration	Shashi Poonam Indwar (PI) N.C. Ghosh Anupma Sharma Rajan Vatsa Sanjay Mittal **Support:** Uttarakhand Jal Sansthan (UJS	2 ½ years (04/12 – 09/14) **Status:** Continuing	Saph Pani Project
Consultancy Projects				
7.	Study of hydrological and hydro-geological aspects of the Jhabua Power Project in Madhya Pradesh to assess water source	N.C. Ghosh (PI) M.K. Goel A.K. Lohani T.R. Nayak S.P. Rai Surjeet Singh T. Thomas	03 months **Status:** In progress	JPL, APIL, Gurgaon

	sustainability	Sanjay Mittal		
8.	Study of hydrological and hydro-geological aspects of the Korba Power Project in Chhattisgarh to assess water source sustainability	N.C. Ghosh (PI) A.K. Lohani S.P. Rai Ravi Galkate Surjeet Singh R.K. Jaiswal Sanjay Mittal	03 months **Status:** In progress	KWPCL, APIL, Gurgaon

HYDROLOGICAL INVESTIGATIONS DIVISION

S. No.	Title of Study/Project, Study Team, Date of Start (DOS) and Date of Completion (DOC)	Status and Recommendations/Suggestions
	INTERNAL STUDIES	
1.	Assessment of Sensitivity of Open Water Evaporation to Increase in Temperature for Different Climatic Regions of India S. D. Khobragade (PI), C. P. Kumar, Manohar Arora, A. R. Senthil Kumar **DOS: 04/2012, DOC: 03/2014**	Status: On-going Study There were no specific suggestions.
2.	Water Quality, Hydrogeology and Isotopic Investigations in SW Punjab M. S. Rao (PI), C. P. Kumar, Gopal Krishan **DOS: 07/2012, DOC: 06/2014**	Status: On-going Study There were no specific suggestions.
3.	Water Availability Studies for Sukhna Lake, Chandigarh S. D. Khobragade (PI), C. P. Kumar, Sudhir Kumar, A. R. Senthil Kumar, P. K. Garg, V. K. Agarwal **DOS: 04/2013, DOC: 03/2015**	Status: On-going Study There were no specific suggestions.
4.	Isotope Studies for the Identification of Different Aquifer Groups and their Dynamics in Upper Yamuna River Plains Sudhir Kumar (PI), C. K. Jain, S. P. Rai, S. D. Khobragade, P. K. Garg, Two Officers from CGWB **DOS: 07/2013, DOC: 06/2015**	Status: New Study The wells for collection of sampling have been identified. Forty samples have been collected from U.P. side of the study area. Preliminary isotopic analysis of the samples indicates that deeper aquifers are not directly recharged by the shallow aquifers. There were no specific suggestions.

S. No.	Title of Study/Project, Study Team, Date of Start (DOS) and Date of Completion (DOC)	Status and Recommendations/Suggestions
5.	Identifying Wind Patterns and Cloud Condensation in Parts of Himalayas using Isotopes M. S. Rao (PI), C. P. Kumar, Gopal Krishan DOS: 10/2013, DOC: 09/2015	Status: New Study Dr. N. K. Sharma suggested to interact with SASE and install few additional stations including one at Ladakh/Leh. Dr. N.C. Ghosh suggested to include this as part of IWIN Phase-II.
6.	Estimation of Radon Concentration in Waters and Identification of Paleo-groundwater in Parts of Satluj River Basin Using Isotopes S. K. Verma (PI), S. P. Rai (Co-PI), M. S. Rao, C. P. Kumar, Mohar Singh DOS: 10/2013, DOC: 09/2015	Status: New Study There were no specific suggestions.
SPONSORED PROJECTS		
7.	National Program on Isotope Fingerprinting of Waters of India (IWIN) M. S. Rao (PI), Sudhir Kumar, S. P. Rai, S. K. Verma, P. K. Garg, Gopal Krishan DOS: 07/2007, DOC: 12/2013	Status: On-going Study Dr. S. N. Rai suggested to update the graphs with 2013 data in the final report. Dr. S. K. Bartariya expressed his willingness to participate in IWIN Phase –II.
8.	Groundwater Dynamics of Bist-Doab Area, Punjab using Isotopes M. S. Rao (PI), Sudhir Kumar, S. K. Verma, P. K. Garg, Gopal Krishan, CGWB Officials DOS: 10/2008, DOC: 12/2013	Status: On-going Study There were no specific suggestions.
9.	Groundwater Management in Over-Exploited Blocks of Chitradurga and Tumkur Districts of Karnataka Sudhir Kumar (PI), J. V. Tyagi, S. P. Rai, Anupma Sharma, B. K. Purandara, C. Rangaraj DOS: 10/2008, DOC: 03/2014	Status: On-going Study There were no specific suggestions.

S. No.	Title of Study/Project, Study Team, Date of Start (DOS) and Date of Completion (DOC)	Status and Recommendations/Suggestions
10.	The Use of Environmental Isotopes to Assess Sustainability of Intensively Exploited Aquifer Systems in North Eastern Parts of Punjab, India M. S. Rao (PI), C. P. Kumar, S. P. Rai DOS: 09/2012, DOC: 08/2015	Status: On-going Study There were no specific suggestions.
11.	The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates S. P. Rai (PI), M. S. Rao, Surjeet Singh, S. K. Verma, C. P. Kumar, Sudhir Kumar, V. K. Agarwal, Rajeev Gupta, S. L. Srivastava, Vishal Gupta, Mohar Singh DOS: 06/2012, DOC: 05/2015	Status: On-going Study Dr. S. N. Rai suggested to prepare subsurface geology map for demarcation of confined and unconfined aquifer conditions. Dr. Noble Jacob suggested plotting of $\delta^{18}O$ data of groundwater with depth and also emphasized on seasonal analysis of rainfall isotopic data instead of annual analysis.
12.	Review of Groundwater Resources in the Indo-Gangetic Basin: A Case Study on Resilience of Groundwater in the Punjab to Withdrawal and Environmental Change M. S. Rao (PI), C. P. Kumar, Gopal Krishan DOS: 02/2013, DOC: 05/2014	Status: On-going Study Dr. N. B. N. Prasad suggested to update the irrigation data of Ganga basin and refer the report of Dr. Sunita Narayan of CSE, New Delhi. Dr. V. C. Goyal and Dr. N. C. Ghosh suggested to keep the review report mainly confined to groundwater component, as stated in the project title. Dr. S. Bartariya suggested to refer the report of Highnoon project.
13.	Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques S. P. Rai (PI), R. V. Kale, M. S. Rao, C. P. Kumar, Sudhir Kumar, V. K. Agarwal, Vishal Gupta, Mohar Singh DOS: 10/2012, DOC: 09/2015	Status: On-going Study There were no specific suggestions.

S. No.	Title of Study/Project, Study Team, Date of Start (DOS) and Date of Completion (DOC)	Status and Recommendations/Suggestions
14.	Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains Sudhir Kumar (PI), S. P. Rai, C. K. Jain, P. K. Garg DOS: 05/2013, DOC: 04/2015	Status: New Study The wells for collection of sampling have been identified. Forty samples have been collected from U.P. side of the study area. Preliminary isotopic analysis of the samples indicates that deeper aquifers are not directly recharged by the shallow aquifers. There were no specific suggestions.
CONSULTANCY PROJECTS		
15.	Integrated Hydrological Investigations of Sukhna Lake, Chandigarh for its Conservation and Management S. D. Khobragade (PI), C. P. Kumar, R. D. Singh, S. P. Rai, C. K. Jain, V. K. Agarwal DOS: 07/2011, DOC: 06/2013	Status: Project completed
16.	Pre-dredging and Post-dredging Bathymetric Survey of Ramgarh Tal Lake, Gorakhpur, UP S. D. Khobragade (PI), C. P. Kumar, R. D. Singh, V. K. Agarwal DOS: 11/2012, DOC: 04/2013 (Pre-dredging)	Status: On-going Project
17.	Assessment of Impact of Coal Mining from Mahan Coal Block on Groundwater Recharge and Sedimentation in Rihand Reservoir and to Suggest Appropriate Measures to Mitigate the Identified Impacts Sudhir Kumar (PI), Sanjay Kumar Jain, J. V. Tyagi, Surjeet Singh, S. D. Khobragade, R. K. Jaiswal, P. K. Garg DOS: 04/2013, DOC: 09/2013	Status: Project completed

S. No.	Title of Study/Project, Study Team, Date of Start (DOS) and Date of Completion (DOC)	Status and Recommendations/Suggestions
18.	Hydrogeological Study for Dewatering of Jhamarkotra Mines, Distt. Udaipur Sudhir Kumar (PI) DOS: 05/2013, DOC: 04/2016	New Project
19.	Impact Assessment of Ash Pond on the Groundwater Quality in the Surrounding Villages of NTPC Simhadri through Stable Isotopic Studies Sudhir Kumar (PI) DOS: 07/2013, DOC: 06/2014	New Project
20.	Identification of Source and Locations of Leakage/Seepage from Kaushalya Dam, Haryana S. P. Rai (PI) DOS: 08/2013, DOC: 01/2014	New Project

SURFACE WATER HYDROLOGY DIVISION

1. CLIMATIC VARIABILITY ANALYSIS AND ITS IMPACT ON HIMALAYAN WATERSHED IN UTTARAKHAND

Dr. Avinash Agarwal, Scientist F presented the study and the results in the light of suggestions from previous meeting. Presented study area and methodology and results so obtained in details along with the climatic variability and the impacts on stream and spring flows. The study is concluded and the draft of the report was presented for its finalization.

2. MONITORING AND MODELLING OF STREAMFLOW FOR THE GANGOTRI GLACIER

Mr Jatin Malhotra presented the progress of the study. He informed that the field investigations for the summer season (May to October) 2013 have been completed. He informed that Bhagirathi River experienced a major landslide event comprising of big boulders, cobbles, sand and silt from 16th to 18th June 2013. The total rainfall during this 5-day storm was 178 mm. Sudden increase of discharge in the river resulted in flooding of the downstream area. Mr Malhotra explained the house besides many difficulties due to unusual flood event the NIH team

successfully completed the data collection for the summer season and analysis of the data is in progress. During the presentation Director, NIH suggested that necessary action should be taken to upgrade the observatory and discharge site before the start of the next summer season.

3. HYDROLOGICAL STUDIES FOR UPPER NARMADA BASIN

Mr. Jagadish Prasad Patra, PI of the study presented the progress during past six months. Objectives of the study with brief methodology and work progress with results achieved were presented. The Mike-flood model setup and initial runs with PMF were discussed in details during the presentation. There were no specific comments from the members.

4. STUDY OF HYDRO-METEOROLOGICAL DROUGHTS FOR CHITRAKOOT DISTRICT OF BUNDELKHAND REGION IN INDIA

Dr R.P. Pandey, PI of the project presented details of activities carried out in respect of ongoing study during past six months. Dr Pandey reported that the Bundelkhand region of the country had faces acute drinking water shortages during summer months and this problem was very severe during drought years in the recent past i.e. 2004-2008. The major objective of the study is to quantify water scarcity during droughts and to identify possible options for augmenting water supply and minimizing crop loss due to droughts**.** The PI further reported that the necessary data processing, preparation of base maps and analysis of rainfall data have been completed. He further informed that the long-term monthly rainfall data for 1901-2010 and daily rainfall and other meteorological records for 1969-2011 were collected and analyzed for rainfall departure, probability distribution of annual and seasonal rainfall, dryspell analysis and estimation of supplemental water requirement for dry-spell periods for kharif season crops have been completed and same was presented in the meeting. It was informed that a new methodology has been devised for regular drought monitoring using rainfall data. The method has been compared with Standardized Precipitation Index (SPI) and Effective Drought Index (EDI). The method provides comparable assessment of onset of drought and its progression. Further, it was informed that the same methodology has been incorporated in the DSS(P) for identification of onset of drought events and quantification of their severity. The results of the method applications were demonstrated in the meeting. The PI informed that the flow measurement records for Paisuni river are not available. Therefore, MIKE Basin NAM Model has been used to estimate flow series using Tons flow data for its calibration. The River Tons is flowing adjoining to the Pasuni river and have nearly identical topographic features. It was informed that the interim Report on progress of this study was submitted in June 2013.

5. SEDIMENTATION STUDIES FOR PONG RESERVOIR, HIMACHAL PRADESH

Dr. A. R. Senthil kumar, PI of the project, presented the objectives, methodology and progress of the study for the period from October 2012 to March 2013 and from April 2013 to September 2013 in brief. He presented the development of sediment yield model for pong dam using ANN and the simulation of sediment yield for future 25, 50, 75 and 100 years using the generated series of rainfall and flow volume. He also presented the uncertainty analysis of the rainfall and flow volume for future 25, 50, 75 and 100 years. Dr. S. N. Rai

(SNR) inquired about the division of data for the calibration and validation of the model. The PI replied that the data of 1987 to 2007 and 2008 to 2009 have been used for the calibration and validation of the model respectively. SNR suggested to update the data and carry out the analysis. The PI replied that the base year of the modelling would be changed then. SNR requested to model the effect of sediment consolidation in the recharge from the dam. Dr. N. C. Ghosh replied that the selection of the dam site is made in such a way that the recharge from the reservoir is almost zero.

6. DEVELOPMENT OF REAL TIME FLOOD FORECASTING FOR DOWNSTREAM OF HIRAKUD DAM

Dr. A K Lohani presented the background and objectives of the study. Dr Lohani mentioned that the floods are regular phenomenon in the downstream portion of the Mahanadi river. Flood forecasting is used to provide warning to people residing in flood plains and can alleviate a lot of distress and damage. Dr Lohani presented the data collection, processing and flood forecasting model development tasks carried out during the period from April 2013 to September 2013. He presented the soft computing based models developed for the forecasting of the floods. He further mentioned that the work is in progress and likely to be completed by March 2014. Mr R.K. Khanna appreciated the study and suggested that these models will be useful for the Central Water Commission. Further, Dr V.C. Goyal, Sc F suggested that the technology transfer workshop may be organised to disseminate the knowledge and technology to the field engineers.

7. APPLICATION OF DSS (P) FOR INTEGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT

Dr. A K Lohani presented the background and objectives of the study. Dr Lohani mentioned that the DSS(P) software has been developed under HP-II and the same model will be applied in a selected basin to demonstrate the capabilities of the DSS(P) model. Dr Lohani mentioned that the data has been collected from Chhattisgarh for the application of DSS(P) software in a sub basin of Seonath basin. Dr Lohani mentioned that the collected data has been computerized and a model has been setup in Mike basin and Mike -11 RR. Some trial runs of NAM model have been taken for the selected site. Members of the working group appreciated the proposed study.

8. STATUS REPORT ON SOIL EROSION AND SEDIMENT TRANSPORT MODELLING

Dr. J. V. Tyagi, PI of the study informed the house that the National Water Mission document of National Action Plan on Climate Change (NAPCC) has recommended for building a Universal Soil Loss model depicting erosion and sediment transport etc. Before taking up the model development, the action plan of the activity envisages preparation of a state-of-the-art report on soil erosion and sediment transport modeling and the work is entrusted to NIH. Accordingly, preparation of state-of-the-art report has been taken up. Dr. Tyagi further informed that the literature on soil erosion and sediment transport modeling has been collected from various sources. Collection of some more literature is in progress. A thorough review of the collected literature on various methodologies available for soil erosion and sediment transport modelling is being carried out for preparation of the state-of-the-art report. The report will be submitted as per schedule. There were no comments on the study.

9. QUANTITATIVE ASSESSMENT OF UNCERTAINTIES IN RIVER DISCHARGE ESTIMATION

Dr. Sanjay Kumar presented the study on "Quantitative assessment of uncertainties in river discharge estimation". He explained the background and objectives of the study and mentioned that study is a part of the systemic review of uncertainty clause of the ISO 9123 document. He explained the methodology based on ISO documents GUM (Guide to the expression of uncertainty in measurement), HUG (Hydrometric uncertainty guidance) and presented the progress made in the study. He mentioned that a NWIP (New Work Implementation Plan) has been submitted along with a working draft of the uncertainly clause of the above ISO document. He also mentioned that NWIP and the submitted document are currently under review of ISO committee on Water Resources (WR).

10. SUSPENDED SEDIMENT FLUX MODELLING IN THE LARGEST SUB-BASIN OF BRAHMAPUTRA

Mrs Archana Sarkar, PI of the study presented the background, objectives, methodology, progress of last six months and expected deliverables of the new study. Mrs Sarkar informed that the study area is the Subansiri River basin, the biggest northern tributary of Brahmaputra River within India which originates in Tibet, contains snow-fed tributaries and glaciers and has a huge hydropower potential for the country. She informed the house that Hydrological modeling studies in Brahmaputra basin" is one of the thrust areas of "12th Five Year Plan" of the institute. She further informed Subansiri River promises stupendous hydropower potential (22 projects having potential of 15,191 MW already proposed/in progress) for the country, therefore, accurate assessment of sediment flux is of prime importance. Mrs Sarkar presented the identified ANN models to be developed for the study and also presented the data processing and data preparation for the models already done in the last six months. Mrs Sarkar informed that this study would conclude by providing discussion about how the different type of input data, length of input data, lagging of input data and scale of input data effect the accuracy of sediment flux estimation in a large Himalayan River basin and also guidance on the types of tasks for which different types of input data may be preferable. Dr Bartaria enquired about the input variables for various ANN models if lineament etc. are directly considered. Mrs Sarkar informed that for the present study, hydro-meteorological data along with snow cover area data have been considered which in turn also account indirectly for other basin characteristics. Working group members noted the progress of the study.

11. EVALUATION AND MODELING OF HYDROLOGICAL SUPPORT SYSTEM FOR WATERSHEDS OF GARHWAL, UTTARAKHAND HILLS

Dr. Agarwal presented a new study and informed that this study has been submitted to DST for possible funding. Some prelim works on spring recession envelop and delineation of spring shed were presented for further suggestions. Dr. Rai suggested that study of lineament and flow in aquifer is important for proposed work. Dr SK Bartarya suggested the confirmation of spring recharge zones using stable isotopes is essential as identified in the study by assuming similarity with surface flow similarity under lineaments control. Dr NC Ghosh suggested that for the cases when flow in aquifer bypass the lineament the conservation of mass is not preserved and delineating the spring shed may not be correct. After discussion it was agreed that the springs of the area do not bypass the lineaments and the work

will be suitable for the springs in which the aquifer flow is controlled by the lineaments. Working group accepted the study as internal study subjected to financial approvals from Director NIH.

WORK PROGRAMME OF SURFACE WATER HYDROLOGY DIVISION FOR THE YEAR 2013-14

S. No. & Ref. Code	Title	Study Team	Duration
Internal Studies			
1. NIH/SWD/NIH/ 10-13	Climatic variability analysis and its impact on Himalayan watershed in Uttarakhand	A. Agarwal, Manohar Arora R K Nema	3 years (Nov. 10 – Oct. 13)
2. NIH/SWD/NIH/ 08-	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora Rakesh Kumar	March 08 -To be continued
3. NIH/SWD/NIH/ 11-14	Hydrological Studies for Upper Narmada Basin.	Jagdish P. Patra Rakesh Kumar Pankaj Mani T R Sapra	3 years (April 11 – March 14)
4. NIH/SWD/NIH/ 12-15	Study of Hydro-Meteorological Droughts for Bundelkhand Region in India	R.P. Pandey	3 years (April 12- March 15)
5. NIH/SWD/NIH/ 12-15	Sedimentation Studies for Pong Reservoir, Himachal Pradesh	A. R. S. Kumar, Manohar Arora Suhas D Khobragade, A. Agarwal, Sanjay K. Jain	3 years (April 12 – March 15)
6. NIH/SWD/NIH/ 13-14	Development of Real Time Flood Forecasting for downstream of Hirakud dam	A.K. Lohani	1 year (April 13- March 14)
7. NIH/SWD/NIH/ 13-15	Application of DSS(P) for Integrated Water Resources Development and Management	A.K. Lohani Surjeet Singh Rahul Jaiswal,	2 year (April 13- March 15)
8. NIH/SWD/NIH/ 13-14	Status Report on Soil Erosion and Sediment Transport Modelling	J.V. Tyagi	1 year (April 13- March 14)
9. NIH/SWD/NIH/ 13-16	Quantitative assessment of uncertainties in river discharge estimation	Sanjay Kumar Sharad Jain	3 year (April 13- March 16)
10. NIH/SWD/NIH/ 13-16	Suspended Sediment Flux Modelling in the largest sub-basin of Brahmaputra	Archana Sarkar Rakesh Kumar	1 year (April 13- March 14)
11. NIH/SWD/NIH/ 13-16	Evaluation and modelling of hydrological support system for watersheds of Garhwal, Uttarakhand hills	Avinash Agarwal Manohar Arora R K Nema	3 years (Nov 13- Oct 16)

WATER RESOURCES SYSTEM DIVISION

Dr. Sanjay K. Jain presented about the scientific strength of the Division and the activities carried out by the Division during last six months. He has given brief overview of all the ongoing as well as of the new studies. He also informed about the sponsored and consultancy projects undertaken by the Division. After that PI of the study presented progress of the study carried out in detail. Following are the comments received from different working group members on the different studies.

Ongoing studies

Study title: *NIH_Basin* – A WINDOWS based model for water resources assessment in a river basin

Dr. M. K. Goel (MKG) presented the progress of the study. He informed that as per the objectives of study, a WINDOWS interface has been planned and model modifications have been initiated. MKG presented the layout plan of the software which consists of four main modules: Database preparation, GIS analysis, Model execution, and Analysis of results. The basic functionality of these modules was explained. He also presented one sample form for entry of attribute data. In the process of model modification, MKG presented the equations to be adopted for representation of elevation-area and elevation-capacity curves for various reservoirs in a river basin.

In response to a query from Dr. N. C. Ghosh (NCG), MKG informed that the present model provides more detailed hydrological analysis at the basin scale in comparison to the hydrological tools (NAM/Mike BASIN) used in the recent DSS development. In response to various queries from Dr. Kishore Kumar (KK), MKG informed that the present development is being made on the Java platform and it is not a web-based tool. Rather, it is planned to be made available on NIH web-site for downloading and further use. In response to a query from Sh. R. P. Singh (RPS), MKG informed that irrigation return flow is accounted for in the model. Dr. R. K. Khanna (RKK) and Dr. S. K. Mittal (SKM) suggested discussing the model development with CWC and CGWB. MKG informed that recently, the detailed model report has been sent to the Director, CWC (NTBO), Gujarat. Further, after developing the interface (so that it can be easy to adapt and understood), the model will be demonstrated to different concerned departments. It is also planned to organize a few courses for its dissemination and widespread use. Dr. S. N. Rai (SNR) suggested some modifications related to the use of terminology in the presentation which was accepted for correction in subsequent stages.

Study title: Web GIS based snow cover information system for Indus basin

The progress of the study was presented by Mr D.S. Rathore. It was informed that MODIS snow cover maps (Terra and Aqua 8-day composite) and MODIS reflectance (band 1-7) for Terra 8- day composite were downloaded for 2007. Reflectance data were processed using bands 2, 4 and 6 for snow delineation (snowmap algorithm excluding snow in vegetation covered area and Temperature threshold). Two snow maps were overlaid. MODIS snowmap algorithm is cloud conservative (maximize cloud) and snow covered are also likely to be identified as cloud. Using NDSI and NIR criteria alone leads to reduction on cloud area compared to NSIDC snow cover

product (those having cloud cover). Various classes namely snow using MOD10A2, MOD09A1, combined MOD10A2 and MOD09A1, over bare land and in vegetation covered land, additional snow from MOD09A1 and cloud (MOD10A2) classes were presented graphically. Shri Kishor Kumar inquired regarding year of the data. It was informed that data for year 2007 were being processed. Dr Rai had given suggestion on improving presentations.

Study title: Assessment of Water Footprint of the National Capital Territory (NCT) of India

Mrs. Deepa presented the study. She informed that the water footprint of an area is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of that area. Looking at the increasing skewed supply and demand of the water resources in NCT region of India, this study has been undertaken to make an assessment of the Water Footprint of the NCT region, which may help the decision makers and government bodies in making timely intervention. She added that NCT is an urban area and domestic water use has an important contribution. As a first step, water footprint assessment is purely done for the domestic water use. In this regards a simple use-friendly calculator has been developed for the NCT region to give the residents an estimate of the water they use on a daily basis. A demonstration of the web-based software developed for this purpose was done.

Director, CWRDM enquired whether such study has been done earlier. He suggested that such type of studies can be done for a small area. Mrs. Deepa replied that as lot of data is required for such type of studies, data availability is a problem. As data availability of NCT is better so this area has been selected for the study. Dr S N Rai enquired about the use of this study. Dr V C Goyal informed that it can be used for increasing the water use efficiency. Mrs Deepa informed that the calculator will be installed on the institute's website.

Working group noted the progress of the study.

Study title: Impact of Climate and Landuse Change on Floods of Various Return Periods

Dr. P K Bhunya presented the status of the completed study under HP2 and in brief covered the on-going study starting with the objectives, then methodology and results achieved so far. He further appraised the house regarding duration of this study. Also informed the house about the major objectives that has been stressed during the period since the last working group. They are briefly the processed hydrological stream flow data, imagery and geomorphology characters from toposheets taken from the HP2 report. Dr. Bhunya presented briefly the expected outcome, results in regards to the objectives and the works to be distributed to individual study group members. He also presented the uncertainty band in return period flood and the land use in Mahanadi basin as reported by WALMI in Orissa. The technical publications that are allied in this project area were also discussed. There were no questions from the members.

Study titles:

1. **Glaciological studies of Phuche Glacier, Ladakh Range (Ongoing)**
2. **Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, Ladakh Range (Ongoing)**

Dr. Renoj J Thayyen, Scientist “D” presented the above two studies. There were no specific suggestions/ comments from any Working Group Member.

Study Title: Trend and variability analysis of Rainfall and Temperature in Himalayan region

The study was presented by Sh. L. N. Thakural. The objective of the study is to create the database (Rainfall, Temperature) for the Himalayan region and carry out statistical analysis to detect trend and variability in these variables in the Himalayan region, India. The parametric and non-parametric approaches are being used to determine the trends in the time series data of these meteorological variables. During the presentation, analysis for the hydro meteorological data in the eastern Himalayas for temporal and spatial characteristics was explained. The climate change variability and trend of temperature and rainfall carried out for the observational sites in the eastern Himalayan region was also presented.
Dr. S. N Rai, NGRI, Hyderabad suggested that it is very important to make field visits to some of the stations lying in the study area. There were no specific comments.

Study title: Assessing Climate Change Impact across KBK (Kalahandi-Bolangir-Koraput) region of Odisha
The status of the study was presented by Shri P.K. Mishra on behalf of his team. His presentation was centred around the approved work plan in the 38th Working Group meeting and the progress made in the last six months (April-September 2013). During the last six months Shri Mishra informed on the progress made in the data requirement vis-à-vis its collection from different sources/ agencies. He further informed on the digitization work ongoing on the SOI toposheet (21 nos.) and Soil map (04 nos.). He presented the results and inferences drawn from the trend analysis of the rainfall data (1901-2010) for the KBK region. Dr. N.B.N Prasad & Shri R D Singh suggested finding the linear trend as shown after removing the outliers. Dr. S N Rai enquired on the temperature trend as well as suggested to explore soft computing techniques (ANN) for the downscaling as per the 2nd objective of the study. The presenter noted the suggestions. Shri Mishra ended the presentation informing the next course of actions (finalization of data collection yet to be collected; finalization of digitization works for different themes; conducting a field visit; analyzing trend for other variables) during the next six months.

<u>New study</u>

Study title: Glacier change and glacier runoff variation in the upper Satluj river basin
The study was presented by Dr. Sanjay K Jain, Scientist “F”. There were no specific suggestions/ comments from any Working Group Members.

Study title: Variability of the Hydro-climatic variables in Punjab Plains of lower Satluj
During the presentation of this new study by Shri Manish Nema, Scientist “B” there was no specific comment except about the timeframe of the project. One of the members of working group (Dr. SN Rai) suggested that the time frame of the study

should be more elaborated in terms of quarterly progressive divisions instead of yearly segments. Suggestion has been noted.

Study title: Present status of water storage and diversions in major rivers in India

Shri P. K. Agarwal, Scientist "B" presented the proposed new study. Dr. Niladri Naha informed that the work may have been done by ISRO & CWC. He suggested that before taking up the work, the status may be examined.

The approved work program of the division for 2013-14 is given below in Table 1.

Table 1: Approved work program for the year 2013-14

S. N.	Title	Study Team	Duration	Funding
Ongoing Internal Studies				
1.	NIH_Basin A WINDOWS based model for water resources assessment in a river basin	Dr. M.K. Goel Dr. S.K. Jain Smt. D. Chalisgaonkar Shri P.K. Mishra	2 years (4/13-3/15) **Continuing study**	NIH
2.	Web GIS based snow cover information system for the Indus basin	Shri D.S. Rathore Smt. D. Chalisgaonkar Shri L.N. Thakural Shri Tanvear Ahmed	2 years (4/13-3/15) **Continuing study**	NIH
3.	Assessment of Water Footprint of the National Capital Territory (NCT) of India	Smt. D. Chalisgaonkar Dr. Sharad K. Jain Shri P.K. Mishra	2 years (4/13-3/15) **Continuing study**	NIH
4.	Impact of climate and landuse change on floods of various return periods	Dr. P.K. Bhunya Dr. Sanjay Kumar Shri D.S. Rathore	2 years (4/13-3/15) **Continuing study**	NIH
5.	Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, Ladakh Range	Dr. Renoj J Theyyan Dr. S P Rai Dr. M.K. Goel	4&1/2 years (9/09-3/14) **Continuing study**	NIH
6.	Trend and variability analysis of rainfall and temperature in Himalayan region	Shri L.N.Thakural Dr. Sanjay Kumar Dr. Sanjay K. Jain Dr. Sharad K. Jain Shri Tanvear Ahmed	3 years (10/11-09/14) **Continuing study**	NIH
7.	Assessing climate change impact across KBK region of Odisha	Shri P.K. Mishra Dr. Sharad K. Jain Dr. Sanjay K. Jain Dr. P K Bhunya Smt. A Choudhury	2 years (4/13-3/15) **Continuing study**	NIH
Sponsored Studies				

1.	Glaciological studies of Phuche Glacier, Ladakh Range.	Dr. Renoj J Theyyan Dr. S P Rai Dr. M.K. Goel	5 years (1/10-12/14) **Continuing study**	DST
2.	Preparation of Ganga River Basin Environment Management Plan (GRBEMP)	Dr. Sharad K Jain, Dr. N.C. Ghosh, Dr. Sanjay K Jain, Dr. M.K. Goel	**Continuing study**	
New Internal Studies				
1.	Variability of the Hydro-climatic variables in Punjab Plains of lower Satluj	Shri Manish K. Nema Dr. Sharad K. Jain	**New study**	NIH
2.	Glacier change and glacier runoff variation in the upper Satluj river basin	Dr. Sanjay K. Jain Dr. Sharad K. Jain Dr. Renoj J. Theyyan	**New study**	NIH
3.	Present status of water storage and diversions in major rivers in India	Shri P K Agarwal Shri Tanvear Ahmed Dr. Sharad K. Jain Dr. Sanjay K. Jain Dr. M.K. Goel	**New study**	NIH

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)
2013-14

S.N.	Title of Project/Study, Study Team, Start/Completion Dates	Status and Recommendations/Suggestions
1.	Recession Flow Analysis for Evaluation of Spring Flow in Indian Catchments **Team:** Ravindra V. Kale (PI), V. C. Goyal DOS: Apr 2011; DOC: Mar 2014 (with extension)	**Status:** Ongoing study No specific comments. The study was granted the requested extension.
2.	Pilot Basin Studies (PBS) at six identified sites, jointly with the RCs and CFMSs (**Joint Study)** **NIH HQs:** V C Goyal (Leader) Omkar Singh Ravindra V. Kale **NIH RCs/CFMSs:** RC-Belgaum, RC-Jammu, RC-Kakinada, RC-Sagar, CFMS-Guwahati, CFMS-Patna DOS: Apr 2012; DOC: Mar 2015	**Status:** Ongoing study No specific comments.
3.	Action Research for Water Conservation and Management in Selected Village (s) in Hardwar District (Uttarakhand)	**Status:** Ongoing study Dr. Prasad appreciated the study and informed that some studies of ponds have also been carried out by

	Team: Omkar Singh, V.C. Goyal and C.K. Jain DOS: Apr 2013; DOC: March 2015	CWRDM. Dr. S.N. Rai was keen to know about next steps in this study, and Dr. Goyal responded to his query. Er. R.K. Khanna, informed about RRR program of MOWR is relevant to this study for possible funding. Dr. Arya opined that photographs of the village ponds may be useful for developing histroy of the water conservation efforts in the village.
4.	Integrating hydrology, climate change and IWRM with livelihood issues: Development of methodology and a DSS for water-scarce Bundelkhand region in India (Sponsored by TIFAC, GOI under INDIA-IIASA Programme of TIFAC) **Team (NIH):** Dr. V. C. Goyal (PI) Dr T Thomas (Co-PI) Dr. R. V. Kale (Co-PI) **Nodal Coordinator :** Dr (Mrs.) K Vijaya Lakshmi, DA, New Delhi Dr Sandeep Goyal, MAPCOST, Govt. of MP (India) **International Collaborators:** IIASA, Austria DOS: Aug 2013; DOC: Jan 2016	**Status:** New Study No specific comments.

The Working Group noted the progress of the studies undertaken by all divisions. Dr. N.C. Ghosh, Scientist F & Head, GWH Division presided over the proceeding of the working group on 2nd day and thanked the members for their valuable contributions during deliberations in the Working Group meeting.

The meeting ended with vote of thanks to the Chair.

ANNEXURE-I

List of Working Group Members attended the 39th WG meeting

1.	Er. R.D. Singh, Director, NIH	Chairman
2.	Dr. R P Singh, Regional Director, CGWB, Dehradun	Member
3.	Sh. Sanjiv K. Sharma, Dy. Director General, GSI, Faridabad	Member
4.	Dr. R.D. Deshpande, PRL, Ahmedabad	Member
5.	Dr. Kishore Kumar, NIC, New Delhi	Member
6.	Dr. S.N. Rai, CSIR-NGRI, Hyderabad	Member
7.	Dr. N.B. Narasimha Prasad, CWDRM, Kozhikode	Member
8.	Dr. S.K. Bartarya, WIHG, Dehradun	Member
9.	Dr. S C R Vishvakarma, GBPIHED, Almora	Member
10.	Dr. Nobel Jacob, BARC, Mumbai	Member
11.	Sh. Niladri Naha, State Water Invest. Dir., Kolkata	Member
12.	Dr. B M M Krishna Rao, Director, GW Deptt., Hyderabad	Member
13.	Er. R K Khanna, Chief Engineer (Retd.), CWC, New Delhi	Member
14.	Dr. Ritesh Arya, Arya Drillers, Haryana	Member
15.	Sh. A Tharanirajan, Dy. Director (NWP), CWC, New Delhi	Member
16.	Dr. G P Juyal, CSWCRT, Dehradun	Member
17.	Dr. S K Mittal, CSIO, Chandigarh	Member
18.	Dr. N.C. Ghosh, Sc. F & Head GWH Division, NIH	Member
19.	Dr Rakesh Kumar, Sc. F & Head SWH Division, NIH	Member
20.	Sh. C.P. Kumar, Sc. F & Head HI Division, NIH	Member
21.	Dr. V.C. Goyal, Sc. F & Head RMO Division, NIH	Member-Secretary

Scientists from National Institute of Hydrology, Roorkee

1. Dr. S. K. Singh, Sc. F
2. Dr. Sanjay Jain, Sc.F
3. Dr. Avinash Agarwal, Sc.F
4. Dr. J.V. Tyagi, Sc.F
5. Dr. Sudhir Kumar, Sc.F
6. Dr. M.K. Goel, Sc.F
7. Smt. D.Chalosgaonkar, Sc.F
8. Dr. D.S. Rathore, Sc.F
9. Dr. A.K. Lohani, Sc.F
10. Dr. R.P. Pandey, Sc.F
11. Er. Omkar Singh, Sc.E
12. Dr. P.K. Bhunya, Sc.D
13. Dr. S.P. Rai, Sc.D
14. Dr.A R Senthil Kumar, Sc.D
15. Dr. Anupama Sharma, Sc.D
16. Dr. M S Rao, Sc.D
17. Dr. Sanjay Kumar, Sc.D
18. Dr. Surjeet Singh, Sc.D
19. Dr. Renoj J. Thayyen, Sc.D
20. Sh. S K Verma, Sc.D
21. Dr. D G Durbude, Sc.D
22. Smt. Archana Sarkar, Sc.C
23. Dr. M K Sharma, Sc.C
24. Sh. P.K. Garg, Sc.B
25. Dr. Ravindra Vitthal Kale, Sc.B
26. Sh. J.P. Patra, Sc.B
27. Sh. Sumant Kumar, Sc.B
28. Dr. Rajesh Singh, Sc.B
29. Sh. L.N. Thakural, Sc.B
30. Sh. P.K. Mishra, Sc.B
31. Sh. Manish Nema, Sc.B
32. Sh. Tanveer Ahmad, Sc.B
33. Sh. P K Agrawal, Sc.B

ANNEXURE – B

Division-wise Work Programme

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. C K Jain	Scientist G & Head
2	Dr. (Mrs.) Rama Mehta	Scientist D
3	Dr D G Durbude	Scientist D
4	Dr. M K Sharma	Scientist D
5	Dr. Rajesh Singh	Scientist B
6	Smt. Babita Sharma	RA
7	Smt. Bina Prasad	RA

Progress of Work Programme for the Year 2013-14
&
Proposed Work Programme for the Year 2014-15

S.No.	Study	Study Team	Duration
Internal Studies			
1.	Assessment of Water Quality in Hindon River Basin	M. K. Sharma (PI) Omkar Singh Rakesh Goel Dayanand	3 Years (11/11-10/14) Status:**Completed**
2.	Development of Low Cost Media for Fluoride Removal from Drinking Water of Fluoride Affected Areas	Rajesh Singh (PI) Dayanand	2 Years (04/11-03/13) Extended for 6+6 months upto Mar. 2014 Status: **Completed**
3.	Applications of Nanotechnology in Water Sector	C. K. Jain (PI) Dinesh Mohan (JNU) Babita Sharma	1 Year (04/13-03/14) Status:Under writing stage
4.	Ground Water Quality Mapping and Surveillance for Safe Water Supply in District Hardwar and Dehradun, Uttarakhand	C. K. Jain (PI) Rama Mehta S. K. Sharma Yatveer Singh Babita Sharma	1 Year (04/13-03/14) Status:Completed for Bahadrabad Block
5.	Water Quality Modelling using Soft Computing Techniques	Rama Mehta (PI) C. K. Jain	1 Year (04/13-03/14) Status:Completed for two blocks in Delhi
6.	*State-of-the-art Report on Water Quality Modelling for Each Major River and Aquifer	N. C. Ghosh (PI) M. K. Sharma	6 Months (04/13-09/13) Status: **Completed**
7.	Environmental Flow Assessment of Hemavathi River in Karnataka	D. G. Durbude (PI) C. K. Jain	2 years (04/13-03/15) Status: Part 1 Completed
8.	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	3 Years (10/13-09/16) Activities of the study will be continued under DST sponsored project.
New Proposed Studies			
9.	Himalayan River Water Quality Assessment in a Stretch from	Rajesh Singh (PI) C. K. Jain	3 Years (06/14-03/17)

	Gangotri to Haridwar	D. G. Durbude M. K. Sharma S. P. Rai Renoj J. Thayyan J. P. Patra	
Sponsored Projects			
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	3 Years (01/14-03/17) Sponsored by DST, New Delhi
2.	Low Cost Technology for Purification of Arsenic and Microbes Contaminated Water using Nanotechnology	Vijaya Aggarwala, IITR (PI) Rama Mehta, NIH (Co-PI)	2 Years (04/14-03/16) Sponsored by DST, New Delhi
Consultancy Project			
1.	Pilot Study on Ground Water Pollution in Hindon - Kali - Krishini River Catchment in Western Uttar Pradesh	C. K. Jain (PI) M. K. Sharma Rajesh Singh Babita Sharma Rakesh Goyal Daya Nand	6 Months 12/12-05/13 Status: **Completed**

*The study was proposed as per the action plan suggested by MoWR under its National Water Mission on Climate Change.

Mass Awareness Programmes Organized

S.No.	Activity	Venue	Date
1.	Mass Awareness Programme on 'Water Conservation and Water Quality'	Village Sultanpur (Haridwar)	8th Feb. 2013
2.	Mass Awareness Programme on 'Water Conservation and Water Quality'	Village Ibrahimpur (Haridwar)	9th Feb. 2013
3.	Mass Awareness Programme on 'Water Conservation and Water Quality'	Village Kasampur (Haridwar)	2nd Mar. 2013
4.	Mass Awareness Programme on 'Water Conservation and Water Quality'	Village Matlabpur (Haridwar)	4th May 2013
5.	Mass Awareness Programme on 'Water Conservation and Water Quality'	Village Banjarwala (Haridwar)	25th May 2013
6.	Mass Awareness Programme on 'Water Conservation and Water Quality'	Village Gumaniwala (Dehradun)	28th July 2013
7.	Mass awareness programme on 'Water Conservation and Water Quality'	Village Pitthuwala (Dehradun)	31st Aug. 2013
8.	Mass Awareness Programme on 'Water Conservation and Water Quality' for Panchayati Raj Institutions	NIH, Roorkee	5th Oct. 2013
9.	Mass Awareness Programme on 'Water Conservation and Water Quality' for	NIH, Roorkee	4th Jan. 2014

	Aanganwadi Workers		
10.	Mass Awareness Programme on Water Conservation and Water Quality	Rishikesh	5th Jan. 2014

Competitions Organized During Water Conservation Year - 2013

S.No.	Event/Competition	Venue	Date
1.	Debate Competition on the theme Water Conservation for School Children of Class IX-XII	NIH, Roorkee	19th Sep. 2013
2.	Essay Competition on Water Conservation and Water Quality for School Children of Class VI-VII	NIH, Roorkee	20th Sep. 2013
3.	Drawing Competition on Water Conservation for School Children of Class III-V	NIH, Roorkee	23rd Sep. 2013
4.	Quiz Competition on Water Conservation and Water Quality for Women Participants of Degree Colleges	NIH, Roorkee	24th Sep. 2013

Study – 1

1. Title of the Study: Assessment of Water Quality in Hindon River Basin

2. Study Group:

Project Investigator Dr. M. K. Sharma, Sc. 'D'
Co-Investigator Sri. Omkar Singh, Sc. 'E'
Scientific/Technical Staff Sri. Rakesh Goyal, Tech. Gr. I Sri. Dayanand, Tech. Gr. II

3. Type of Study : Internal
4. Nature of Study **:** Water Quality and Human Health
5. Date of Start **:** Nov. 2011
6. Scheduled Date of Completion **:** Oct. 2014
7. Duration of the Study **:** 3 years
8. Study Objectives:

i) Monitoring and assessment of water quality of Hindon River
ii) Examining the suitability of ground water in the vicinity of River Hindon for various designated uses
iii) Characterizing different point source contributing River Hindon
iv) To estimate rate of re-aeration and de-oxygenation coefficients in different reaches of Hindon River
v) To estimate downstream DO deficit in different stretches of river using Streeter-Phelps oxygen sag equation
vi) Explore possible remedial measures for improvement of river water quality

9. Statement of the Problem:

The River Hindon is subjected to varying degree of pollution caused by numerous untreated and/or partially treated waste inputs of municipal and industrial effluents. The main sources of pollution in River Hindon include municipal and industrial (sugar, pulp and paper, distilleries etc.) wastes from Saharanpur, Muzaffarnagar and Ghaziabad urban areas. The water quality of the River Hindon gets further deteriorated due to confluence of River Kali and River Krishni. The river is highly influenced due to heavy metals, pesticides, which enter the river system, by direct discharges of municipal and industrial effluents and surface runoff. These toxic pollutants will ultimately reach the ground water and will enter in the food chain posing a threat to human health because of their carcinogenic nature. The amount of dissolved oxygen (DO) in water is one of the most commonly used indicators of a river's health. As DO drops below 4 mg/L, the forms of life that can survive, begin to reduce and it is essential to estimate DO in different reaches of the river.

In view of these facts, assessment of the present status of surface water quality by estimating DO deficit in different stretches of the river Hindon and ground water quality in the Hindon River Basin will be carried out.

10. Approved Action Plan / Methodology:

i) Sampling of River Hindon and point sources contributing to river and ground water sources in the vicinity of the river in summer, monsoon and winter seasons.

ii) Analysis of the samples for Physico-chemical parameters, Bacteriological parameters, Toxic (Heavy) Metals and Pesticides.

iii) Processing of data for different seasons as per BIS and WHO standards to examine the suitability of surface water and ground water for drinking purpose and irrigation purpose on the basis of total soluble salts, SAR, RSC.

iv) Classification of water using Piper trilinear diagram, Durov plots, Chadha's diagram, U S Salinity Laboratory Classification and Gupta Classification.

v) Identification of degraded water quality locations using spatial distribution map.

vi) Identification of degraded water quality stretches of the River Hindon using Water Quality Index.

vii) Rate of re-aeration in different stretches of the Hindon River would be determined using equation given by O' Connor and Dobbins (1958), $k_r = (3.9u^{1/2})/(H^{3/2})$, where, u is average stream velocity (m/s) and H is average stream depth (m).

viii) The de-oxygenation rate constant (k_d) is often assumed to be same as the (temperature adjusted) BOD rate constant (k) obtained in standard laboratory BOD test (typical values for the BOD rate constant k at 20 ^oC in accordance with Davis and Cornwell (1985) is $k = k_{20}\theta^{(T-20)}$.

ix) Finally, the estimation of downstream DO deficit in different stretches will be carried out using Streeter-Phelps oxygen sag equation,
$D = (k_dL_0/k_r-k_d)(e^{-kd.t}-e^{-kr.t})+D_0\, e^{-kr.t}$ (Streeter and Phelps, 1925)
Where D = Dissolved oxygen deficit (DO_s-DO), DO_s=Saturated value of dissolved oxgen, DO=Actual dissolved oxygen at a given location in the river, k_d=de-oxygenation rate constant (day^{-1}), L_0=initial BOD of the mixture of stream water and wastewater (mg/L), K_r=re-aeration constant ($time^{-1}$), t=elapsed time between discharge point and distance x downstream (x/u), u=stream speed.

11. Timeline:

S. No.	Major Activities	2011-12		2012-13				2013-14				2014-15	
		3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.
1.	Literature survey												
2.	Reconnaissance Survey of the Study Area												
3.	Field visit, sampling and analysis												
4.	Analysis and processing of data												
5.	Report preparation												

12. Objectives and achievement during last six months:

Objectives	Achievements
Analysis and processing of the data	i) Water quality index for groudwater was recalculated including metal concentrations. ii) The DO Sag analysis (using Streeter & Phelps, 1925 and differential equations of DO Sag) used to predict the DO level at different location of the river.

13. Recommendation / Suggestion: None

Recommendation / Suggestion	Action Taken
Dr. S. N. Rai suggested to include metal concentrations for calculating water quality index for groudwater.	Water quality index for groudwater was recalculated including metal concentrations.

14. Analysis & Results:

i) Water quality indices for different ground water sources in Hindon river basin were recalculated for pre- and post-monsoon season including metal concentrations and type of water was classified and most of the ground waters fall between good to excellent type. In post-monsoon season, the quality of ground water was observed to be improved.

ii) DO level for different stretches of the river was estimated using Streeter-Phelps equation and DO Sag differential equation using Microsoft Excel spread sheet and the results were found in agreement.

iii) Possible remedial measures for improvement of river water quality and recommendations for supply of safe drinking water have been given.

iv) Final report has been submitted in March, 2014.

15. End Users / Beneficiaries of the Study: Policy makers and planners of State Government and common people of the affected areas.

16. Deliverables: Technical report and research papers

17. Major items of equipment procured: None

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

19. Data procured or generated during the study: Surface and ground water quality data and discharge data of the river Hindon basin.

20. Study Benefits / Impacts:

i) Ground water quality and surface water quality data

ii) Identification and characterization of point sources

iii) Rate of re-aeration, de-oxygenation coefficients and DO deficit in different stretches of the Hindon River

21. Involvement of end users/beneficiaries: Local people

22. Specific linkage with Institution and /or end users / beneficiaries: None

23. Shortcoming/Difficulties: No

24. Future Plan: None.

Study – 2

1. Title of the Study: Development of Low Cost Media for Fluoride Removal from Drinking Water of Fluoride Affected Areas.

2. Study Group:

Project Investigator Dr. Rajesh Singh, Sc. 'B'
Scientific/Technical Staff Sri. Dayanand, Tech. Gr. II

3. Type of Study : Internal
4. Nature of Study **:** Technology Development
5. Date of Start **:** April 2011
6. Scheduled date of Completion **:** March 2014
7. Duration of the Study **:** 3 Years
8. Study Objectives:

i) Development of low cost media for removal of fluoride from drinking water.
ii) Establishing the mechanism involved in removal of fluoride.
iii) Establishing the capacity of media for fluoride removal.

9. Statement of the Problem:

Fluoride is an essential element for human being as it helps in normal mineralization of bones and formation of dental enamel. At the same time, it adversely affects the health of human being when their concentration exceeds the limit of 1.5 mg/L. About 96% of the fluoride in the body is found in bone and teeth. Fluoride is double-edged sword. Ingestion of large amount of fluoride is as harmful as ingestion of its inadequate amount.

In India, more than 76% of the population lives in rural areas. The problem of endemic fluorosis occurs with varying intensity in different parts of the country. Out of the 29 countries known to have excess fluoride in drinking water, the number of people suffering from fluorosis in India is highest in the world, and, with time, the number is increasing rapidly. Excess fluoride ingestion is a major health problem, 20 of the 30 states and union territories in India being endemic for fluorosis.

Therefore, there is a need for development of low cost treatment and remediation technology for fluoride removal.

10. Approved Action Plan / Methodology:

i) Synthesis of media from bagasse fly ash.
ii) Characterization of media using SEM, TEM, XRD and wet analysis.
iii) Sorption studies.
iv) Column study for application at field scale.
v) Testing of developed media in actual field condition.

11. Timeline:

S.No.	Major Activities	2011-12				2012-13			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1	Literature Survey								
2	Development of media								
3	Characterization								
4	Adsorption studies / model evaluation								
5	Kinetic & thermodynamic studies								
6	Field trials								
7	Report preparation								

12. Objectives and achievement during last six months:

Objectives	Achievements
Development of media and characterization	• Media synthesized from bagasse fly ash. • Characterization completed.
Adsorption studies	• Adsorption studies completed.
Kinetic & thermodynamic studies	• Kinetic and thermodynamic studies completed
Column Study	• Column studies completed
Field Trials	• Column trials on field sample completed
Report Preparation	• Final report prepared and submitted

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
1. Dr. S. N. Rai suggested to include the photograph of column study in the presentation. 2. Dr. V. C. Goyal suggested to apply for the patent and RMOD will help in filing the patent.	Will be included. Technical write up for filing patent has been completed.

14. Analysis & Results:

- Fluoride specific zeolite based media synthesized from bagasse fly ash.
- Characterization of the synthesized media completed.
- Adsorption studies completed.
- Column studies on synthetic as well as field samples completed.

15. End Users / Beneficiaries of the study: Common people of the affected areas

16. Deliverables: Technical report, research papers and patent

17. Major items of equipment procured: None

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

19. Data procured or generated during the study: None

20. **Study Benefits / Impacts:**

Measurable indicators	Achievements
Development of new product	Completed
Solution of identified problem	Completed

21. Involvement of end users/beneficiaries: Local people of the affected regions.

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

23. **Shortcoming/Difficulties:** No

24. Future Plan: NA

Study – 3

1. **Title of the Study:** Applications of Nanotechnology in Water Sector
2. **Study Group:**

Project Investigator(s)
Dr. C. K. Jain, Sc. 'F' Dr. Dinesh Mohan (JNU)
Co-Investigator(s)
Smt. Babita Sharma, RA

3. **Type of Study:** Internal
4. **Nature of Study:** Technology Overview Document
5. **Date of Start:** April 2013
6. **Scheduled Date of Completion:** March 2014
7. **Duration of the Study:** One Year
8. **Study Objectives:**

   i) To develop a white paper examining potential environmental applications and implications of nanotechnology in water sector
   ii) To examine possible impacts of nanomaterials and nanoproducts on human health and the environment.
   iii) To promote the use of this new, exciting technology in a manner that protects human health and the environment.

9. **Statement of the Problem:**

The availability and access to safe drinking water, especially amongst the poor is an issue that is accelerating with time. Many water sources are contaminated with both biological and chemical pollutants such as arsenic, fluoride, etc. New problems like organic contamination (pesticides, insecticides, etc.) and increasing salinity are affecting water sources extensively. Bacterial contamination in surface water and at points of use is a major cause of concern.

Great strides have been made in applying nanotechnology in varying degrees of complexity in several fields – from space travel to cosmetics. Nanotechnology for safe water is an area that is being looked at globally and is also a priority concern in India. While there are several types of nanotechnology that are relevant to addressing safe water, there are some that may be more appropriate, affordable and sustainable for use among the poor. Nanotechnologies can provide solutions to alleviate water problems, both in terms of detection and removal of contaminants. Also since small amounts of nonmaterial are used for purification, costs and waste generation are low, providing an effective and affordable water treatment solution to the poor.

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

   i) Literature survey through international publications (research papers / reports)
   ii) Compilation / evaluation of case studies
   iii) Evaluation of benefits / drawbacks of nanotechnology and its application in water sector

iv) Report preparation

11. Timeline:

S.No.	Major Activities	2013-14			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1.	Literature survey (research papers / reports)				
2.	Compilation / evaluation of case studies in water sector				
3.	Evaluation of the benefits / drawbacks of nanotechnology				
4.	Report preparation (Draft)				
5.	Brain Storming Session / Final Report				

12. Objectives and achievement during last six months:

Objectives	Achievements
Literature survey (research papers / reports)	Completed
Compilation / evaluation of case studies in water sector	Completed
Report writing	In progress

13. Recommendation / Suggestion: Nil

Recommendation / Suggestion	Action Taken

14. Analysis & Results: Based on the literature survey, the following scheme of chapterization has been finalized and the report is under writing stage under the following heads.

1.0 INTRODUCTION
2.0 USES OF NANOTECHNOLOGY
- 2.1 Nano Films
- 2.2 Nano Tubes
- 2.3 Drug Delivery Techniques
- 2.4 Nanoscale Transistors
- 2.5 Water Filtration Techniques

3.0 NANOTECHNOLOGY IN WATER SECTOR
- 3.1 Nanofiltration and Desalination
- 3.2 Nanocatalysts and Magnetic Nanoparticles
- 3.3 Nanosensors

4.0 RECENT CASE STUDIES
5.0 RISKS OF NANOTECHNOLOGY
- 5.1 Environmental Risks
- 5.2 Health Risks

6.0 OPPORTUNITIES AND CHALLENGES

7.0 CONCLUSIONS AND RECOMMENDATIONS
8.0 REFERENCES

15. **End Users / Beneficiaries of the Study:** Academic and research institutions engaged in R&D in nanotechnology

16. **Deliverables:** Technical Report / Research Papers

17. **Major items of equipment procured:** NA

18. **Lab facilities used during the study:** NA

19. **Data procured or generated during the study: NA**

20. **Study Benefits / Impacts:**

Measurable Indicators	**Achievements**

21. **Involvement of end users/beneficiaries:** Academic and research institutions engaged in R&D in nanotechnology

22. **Specific linkage with Institution and / or end users / beneficiaries:** No

23. **Shortcoming/Difficulties:** No

24. **Future Plan:** Nanotechnology will be used for removal of pollutants from water and wastewater.

Study – 4

1. Title of the Study: Ground Water Quality Mapping and Surveillance for Safe Water Supply in District Hardwar and Dehradun, Uttarakhand

2. Study Group:

Project Investigator Dr. C. K. Jain, Sc. 'F'
Co-Investigators Dr. Rama Mehta, Sc. 'D' Dr. S. K. Sharma, Sc. 'B' Sri. Yatveer Singh, PRA Smt. Babita Sharma, RA

3. Type of Study: Internal
4. Nature of Study: Applied Research
5. Date of Start: April 2013
6. Scheduled Date of Completion: March 2014
7. Duration of the Study: One Year
8. Study Objectives:

i) To examine the quality of ground water for drinking and irrigation purpose
ii) To identify degraded water quality zones for quality improvement
iii) To characterize ground water quality using different classification schemes
iv) To suggest water safety plan for District Hardwar and Dehradun
v) To organize mass awareness programmes on water related issues

9. Statement of the Problem:

Nearly 80% of the sewage generated in India flows untreated into its rivers, lakes and ponds, turning the water sources too polluted to use. The end result: ground water in almost the entire country has nitrate levels higher than the prescribed levels – a result of sewage leaching into ground water aquifers. Indian cities produce nearly 40,000 millions litres of sewage per day, enough to irrigate 9 million hectares and barely 20% of this is treated. In most cities, the sewage simply mixes into open drains, polluting water sources. Untreated sewage is seeping into water resources leading to pollution of water resources. Almost half of the urban population still depends upon ground water sources for drinking, cooking and bathing which puts them at direct risk from polluted water (Source: The Times of India, 6th March 2013).

The major issues in the Rural Water Supply sector are lack of sustainability of drinking water sources and systems. As a consequence, availability of drinking water both in terms of adequacy and quality on a sustainable basis has become a major challenge. Water quality has become a major issue as ground water table goes down further. The levels of natural contaminants such as fluoride and arsenic and man-made chemical pollutants such as metals, pesticides and insecticides are high and still rising. The biological contamination of large number of drinking water sources is a serious problem primarily due to prevalent open defecation and insanitary conditions around the drinking water sources in rural India. After introduction of rural drinking water supply and basic sanitation programme in the villages,

the prevalence of water borne diseases such as diarrohea, cholera, etc. has decreased, but the incidence is still relatively high in some parts of the country. However, it is seen that at the implementation / field level, rural water supply programme is not integrated with sanitation, nor is it integrated or coordinated with primary health care and other related programmes. The new guidelines seek to remove this handicap by formulating a coordinating mechanism through convergence of related programmes at the field level e.g. National Rural Health Mission (NRHM), National Rural Employment Guarantee Scheme (NREGS) etc. The outcome of the study will be forwarded to MoWR for proper implementation through NHRM and NREGS.

10. Approved Action Plan / Methodology:

i) Sampling of ground water in pre- and post-monsoon seasons based on habitations
ii) Analysis of 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, B etc.)
iii) Analysis of bacteriological parameters: Total & Faecal Coliform
iv) Analysis of metals ions: Fe, Mn, Cu, Ni, Cr, Pb, Cd, Zn, As, Hg.
v) Data processing: Data will be processed as per BIS and WHO standards, ionic relationships will be developed and water types will be identified. Spatial distribution maps will be prepared using GIS to identify degraded water quality zones for quality improvement. Suitability of ground water for irrigation purpose will be studied on the basis of total soluble salts, SAR, RSC and B content. Classification of water will be made using Piper trilinear diagram, Chadha's diagram and U.S. Salinity Laboratory classification.

11. Timeline:

S.No.	Major Activities	2013-14			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1.	Collection of information (Water supply)				
2.	Field monitoring survey / Sample collection	**Pre**		**Post**	
3.	Laboratory investigations				
4.	Data processing / analysis				
5.	Report preparation				
6.	Mass Awareness Programmes*				

* As per the directions of MoWR

12. Objectives and achievement during last six months:

Objectives	Achievements
Sampling of ground water during pre-monsoon season	Completed for Bahadrabad Block as per the approval
Analysis of physico-chemical and bacteriological parameters	Completed for Bahadrabad Block
Analysis of metals ions on ICP-MS	Completed for Bahadrabad Block

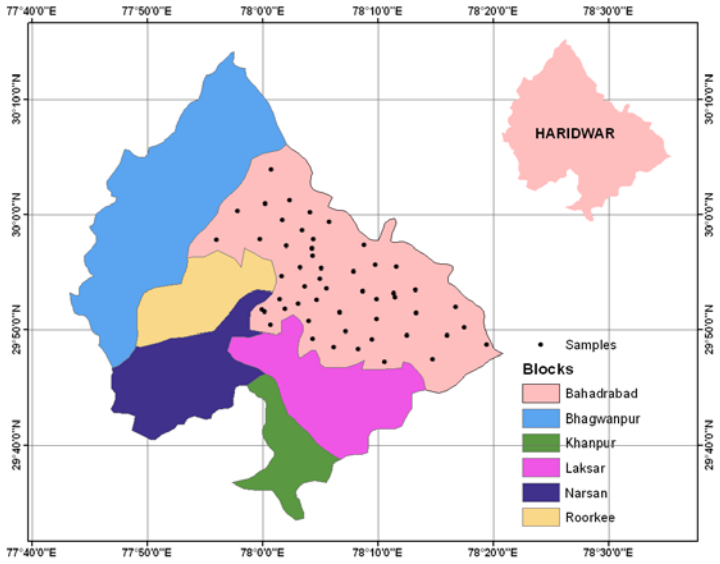
Data processing	Completed
Report writing	Completed

13. Recommendation / Suggestion: Nil

Recommendation / Suggestion	Action Taken

14. Analysis & Results:

The ground water quality of Bahadrabad Block in District Hardwar has been assessed to see the suitability of ground water for domestic and irrigation applications. Fifty two ground water samples from various abstraction sources were collected and analysed for various water quality constituents. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards, ionic relationships were studied, hydrochemical facies were determined and water types identified.



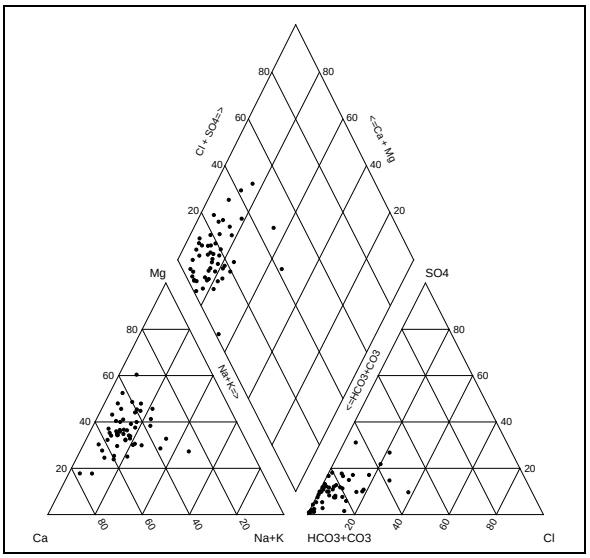
Sampling Locations

The concentration of total dissolved solids exceeds the acceptable limit of 500 mg/L in 42.3% of the samples analyzed but the values are well within the permissible limit of 2000 mg/L. The alkalinity values exceed the acceptable limit of 200 mg/L in 76.9% of the samples but these are also within the permissible limit of 600 mg/L. From the hardness point of view, more than 80% of the samples exceed the acceptable limit of 200 mg/L but these are also within permissible limits. Two samples of the study area exceed the acceptable limit of 45 mg/L for nitrate. Higher concentration of nitrate at these locations may be attributed due to improper sanitation and unhygienic conditions around the structures. Other constituents like chloride, sulphate and fluoride are within the acceptable limits.

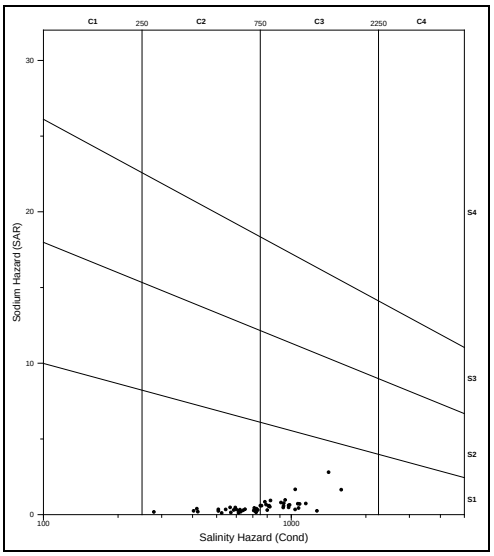
The bacteriological analysis of the ground water samples indicates bacterial contamination at few locations. Inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination in ground water of the region and is a cause of concern. It is recommended

that the water drawn from such sources should be properly disinfected before being used for drinking and other domestic purposes.

The presence of heavy metals in ground water has been recorded at many locations. The water quality standards have been violated for iron, manganese and nickel at many locations. The concentration of iron varies from 3002 to 19771 µg/L as against the acceptable limit of 300 µg/L. The concentration of manganese varies from 5.5 to 2712 µg/L as against the permissible limit of 300 µg/L and concentration of nickel varies from 63 to 527 µg/L as against the permissible limit of 20 µg/L. The concentration of copper, chromium, lead, cadmium and zinc were found well within the permissible limits at most of the locations.



Piper Trilinear Diagram



USSL Classification

An attempt has also been made to classify the ground water on the basis of different classification schemes, viz., Piper trilinear, Chadha's diagram and U.S. Salinity Laboratory classifications. The grouping of samples according to their hydrochemical facies indicates that all the samples of the study area fall under Ca-Mg-HCO_3 hydrochemical facies. The suitability of ground water for irrigation purpose has been evaluated based on salinity, Sodium Adsorption Ration (SAR), Residual Sodium Carbonate (RSC) and boron content. In general the ground water of Bahadrabad Block is safe for irrigation purpose. According to U.S. Salinity Laboratory classification of irrigation water, about 50% of the samples fall under water type C2-S1 and about 50% under water type C3-S1 type.

15. End Users/Beneficiaries of the Study: Common people of the affected areas.

16. Deliverables: Technical Report / Research Papers

17. Major item of equipment procured: NA

18. Lab facilities used during the study: WQL of NIH & IIC of IITR

19. Data procured or generated during the study: Ground Water Quality Data of Bahadrabad Block in District Hardwar

20. Study Benefits / Impacts:

Measurable Indicators	Achievements

21. Involvement of end users/beneficiaries: Local people

22. Specific linkage with Institution and/or end users / beneficiaries: No

23. Shortcoming/Difficulties: Required approvals for field visits could not be granted due to which field/laboratory work could not be completed as contemplated and the study had to be limited to Bahadrabad Block in District Hardwar only as per the approval for field work.

24. Future Plan:

The study will be carried out for other blocks in District Hardwar.

Study – 5

1. Title of the Study: Water Quality Modeling using Soft Computing Techniques

2. Study Group:

Project Investigator Dr. Rama Mehta, Sc. 'D'
Co-Investigator Dr. C. K. Jain, Sc. 'G'
Scientific/Technical Staff Ms. Anju Chowdhary, SRA

3. Type of Study: Internal
4. Nature of Study: Applied Research
5. Date of start: April 2013
6. Scheduled date of completion: March 2014
7. Duration of the Study: One year
8. Study Objectives: To develop a model for assessment of water quality using soft computing techniques.
9. Statement of problem:

The quality of ground water within National Capital Region (NCR) Delhi varies from place to place along with the depth of water table. The kind and concentration of dissolved salts depend on their source and nature of sub surface environment.

Various methods are discussed in literature on drinking water quality criteria and decision-making. But most of the reports on the water quality revealed that deterministic approach in decision making by comparing values of parameters of water quality with prescribed limits provided by different regulatory bodies is used without considering uncertainties involved at various steps throughout the entire procedure. To overcome the difficulties of complex ground water quality there has been a need to develop techniques that can help to find meaningful solutions. Soft computing techniques are relatively new emerging techniques used in hydrologic and water resources systems. Fuzzy logic technique used in uncertainties in water resources system arises not only due to randomness of hydrological variable but also due to imprecision, subjectivity, vagueness associated with decision making and lack of adequate data. Such uncertainties are best addressed through fuzzy logic technique. Therefore, new emerging techniques as Neuro-Fuzzy techniques and ANN are frequently used to develop the models. Fuzzy_Mamdani Inference technique has been used during the study.

10. Approved Action Plan / Methodology:

Water quality indices (WQI) giving a single value to the water quality of a source, which translates the list of constitutes and their concentrations present in a sample in a single value. One can compare different samples for quality on the basis of the index value of each sample. The use of WQI has been strongly advocated by agencies responsible for water supply and control of water pollution.

Following methods have been employed to calculate the water quality index:

- Empirical Method
- Soft Computing Techniques (SCT)-Mamdani_ Fuzzy Inference System (M_FIS)
- Canadian Water Quality Guidelines

11. Timeline:

S.No.	Major Activities	2013-14			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1.	Literature review and data analysis				
2.	Model development with application of soft computing methods				
3.	Testing, evaluation and comparison with conventional methods				
4.	Analysis of results and report writing				

12. Objectives and achievement during last six months:

Objectives	Achievements
Model Development with application of soft computing methods	Six models (Two models with Empirical method, two models with CCME_ WQIG and two models with Fuzzy Inference Technique) have been developed for two blocks viz. Alipur and Khanjhawala.
Testing, Evaluation and comparison with conventional method.	Results via Fuzzy model have been compared with conventional method and Canadian formula (CCME) For Khanjhawala block. Comparative results have shown through graphs and performance indices.
Result Analysis	Results are analyzed and comparative analysis has been shown by graphical representation.
Report Preparation	Final report prepared and submitted

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
A manual could be prepare with .exe files of developed models for other users.	In progress, will be submitted in June 2014.

14. Analysis & Results:

- The ground water quality of the Alipur Block has been assessed with all three methods as Empirical method, CCME Water Quality Index guidelines (CCME_WQI) and Fuzzy Inference method.
- The ground water quality of the Kanjhawala Block has been assessed with all three methods as Empirical method, the CCMEWQG Water Quality Index (CWQI) and Fuzzy WQI.

- Comparative graphs with all results have been drawn for both blocks.

15. End Users / Beneficiaries of the study: Common people of NCR region

16. Deliverables: Technical report, research papers and manual

17. Major items of equipment procured: None

18. Lab facilities used during the study: None

19. Data procured or generated during the study: None

20. Study Benefits / Impacts:

Measurable indicators	Achievements
Model development with new techniques	Completed
Solution of identified problem	Completed

21. Involvement of end users/beneficiaries: Local people of the NCR region.

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

23. Shortcoming/Difficulties : No

24. Future Plan: Models will be developed for other four administrative blocks of NCR.

Study – 6

1. **Title of the Study:** State-of-the-art Report on Water Quality Modelling for River and Aquifer

2. **Study Group:**

Project Investigator Dr. N. C. Ghosh, Sc. 'F'
Co-Investigator Dr. M. K. Sharma, Sc. 'C'

3. Type of Study: Referred by MoWR

4. Nature of Study: Thrust Area- Water Quality Modelling

5. Date of Start: April 2013

6. Scheduled Date of Completion: Sep. 2013

7. Duration of the Study: 6 months

8. Study Objectives: To prepare a state of art report on Water Quality Modelling

9. Statement of the Problem:

Water quality modelling is an attempt to simulate the behaviour of natural surface and ground water and hydrologic system by defining the essential feature of the system in some physical manner. It provides the idea of status of pollution at downstream sites using the water quality and hydrological data of upstream site and can be used for prediction purposes in space and time in case of surface water. Groundwater quality modelling can be used to simulate the behaviour of complex aquifers including the effects of irregular boundaries, heterogeneity and different processes such as groundwater flow, solute transport and heat transport. Because of the complexity of hydro geological setup of aquifers and dynamic nature of pollutants and groundwater, groundwater quality modelling is becoming indispensible tool to understand the fate and transport of pollutants in groundwater and to address various groundwater quality problems in space and time. In India, few attempts have been made covering the aspects of surface as well as ground water quality modelling. There is urgent need to carry out these studies in different basins. In view of the above, a state of the art report will be prepared within a period of six months.

10. Methodology:

The report will be prepared covering the following heads by carrying out extensive literature survey:

i) Introduction
ii) Surface water quality modeling – Global and Indian Scenario
iii) Ground water quality modeling – Global and Indian Scenario
iv) Gaps needs to be filled up

v) Concluding Remarks

11. Timeline: 6 months

12. Objectives and achievement during last six months:

Objectives	**Achievements**
To prepare a state of art report on Water Quality Modelling	Draft of river water quality modelling part completed and submitted to Dr. N. C. Ghosh.

13. Recommendation / Suggestion: None

14. Analysis & Results: Extensive literature survey has been carried out to update the information.

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

16. Deliverables: Technical report

17. Major items of equipment procured: None

18. Lab facilities used during the study: None

19. Data procured or generated during the study: None

20. Study Benefits / Impacts: Status of surface and ground water modelling

21. Involvement of end users/beneficiaries: None

22. Specific linkage with Institution and /or end users / beneficiaries: None

23. Shortcoming/Difficulties: No

24. Future Plan: None.

Study – 7

1. Title of the Study: Environmental Flow Assessment of Hemavathi River in Karnataka

2. Study Group:

Project Investigator Dr. Dilip G. Durbude, Sc. 'D'
Co-Investigator Dr. C. K. Jain, Sc. 'G'

3. Type of Study: Internal

4. Nature of Study: Applied

5. Date of Start: April 2013

6. Scheduled Date of Completion: March 2015

7. Duration of the Study: 2 years

8. Study Objectives:

i) To study the flow characteristics and bio-diversity of the river
ii) To assess the environmental flow requirement for the river

9. Statement of Problem:

It is prime importance to assess the ecological status of rivers before making any decisions to develop water resources. Making changes to the flow in rivers for water resource development may leads to changes in the diversity of aquatic communities. Species adapted to natural flow regimes will disappear due to change in flow regime. Reducing river flows due to water resources project means less aquatic (fish) and terrestrial life (wildlife) and lowering quality of water. Ignoring the need for environmental flows to keep river ecosystems healthy may do serious and even irreversible damage.

Karnataka state was comfortable position in the power sector till 1972. But, 1973 onwards, there was acute shortage of power. This affects not only industrial development but also the other sectors of economy including agriculture. Hydropower contributes about 63.4% of the Karnataka power system. Due to increasing demand, a large deficit in peak power demand and energy availability, which generate a scope for development of Hydropower. Harnessing the hydropower potential to mitigate the power demand, there is need to develop the number of river flow diversion type hydropower projects. These activities will have adverse impact on the fluvial ecosystem due to changed environmental flow regime on the river bed and river bank ecology. To maintain the health, function and integrity of the river ecosystem through the protection of aquatic organism dwelling in these fluvial ecosystems, an appropriate environmental flow is required. Therefore, the study is proposed to assess the environmental flow requirement of one of important tributary of Cauvery river in Karnataka State.

10. Approved Action Plan/Methodology

The following steps will be involved to carry out the study:

i) Data collection/procurement from Water Resource Development Organization (WRDO), Bangalore/Centre Water Commission (CWC), New Delhi
ii) Field survey to study bio-diversity existed in the river ecosystem
iii) Statistical analysis of water quality and flow data
iv) Computation of environmental flow using various methodologies/approaches
v) Recommendation for environmental flow requirement at various stretches of the river

11. Timeline:

S. No.	Major Activities	1st Year 2013-14				2nd Year 2014-15			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1	Literature Survey								
2	Secondary data collection								
3	Field survey								
4	Procurement of flow data								
5	Preparation of Interim report								
6	Field monitoring programme								
7	Data interpretation using GIS								
8	Computation of EFR								
9	Preparation of Final report								

12. Objectives and achievement during last six months:

Objectives	Achievements
Flow characteristics and bio-diversity of the river	i) Collected the daily stream flow data monitored by WRDO, Bangalore at three gauging stations of Hemavathi river ii) Collected secondary data such as toposheet, Hemavathi river drainage network and bio-diversity of basin periphery from different sources iii) Analysed statistically the stream flow data for its characteristics
Assessment of the environmental flow requirement	i) The various hydrological and desktop approaches were used for computing E-flows ii) The report (part I) prepared and submitted

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken

14. Analysis & Results:

In the present study, the literature survey has been carried out to know the present status of the environmental flow assessment methodologies and work done so far. The daily stream flow data monitored by WRDO, Bangalore at three locations namely, Belur, Hadige and Akkihebal were collected and statistically analyzed for its characteristics. The variation of daily stream flow has been prepared for the available data series of various gauging station under study as shown in following Fig. 1.

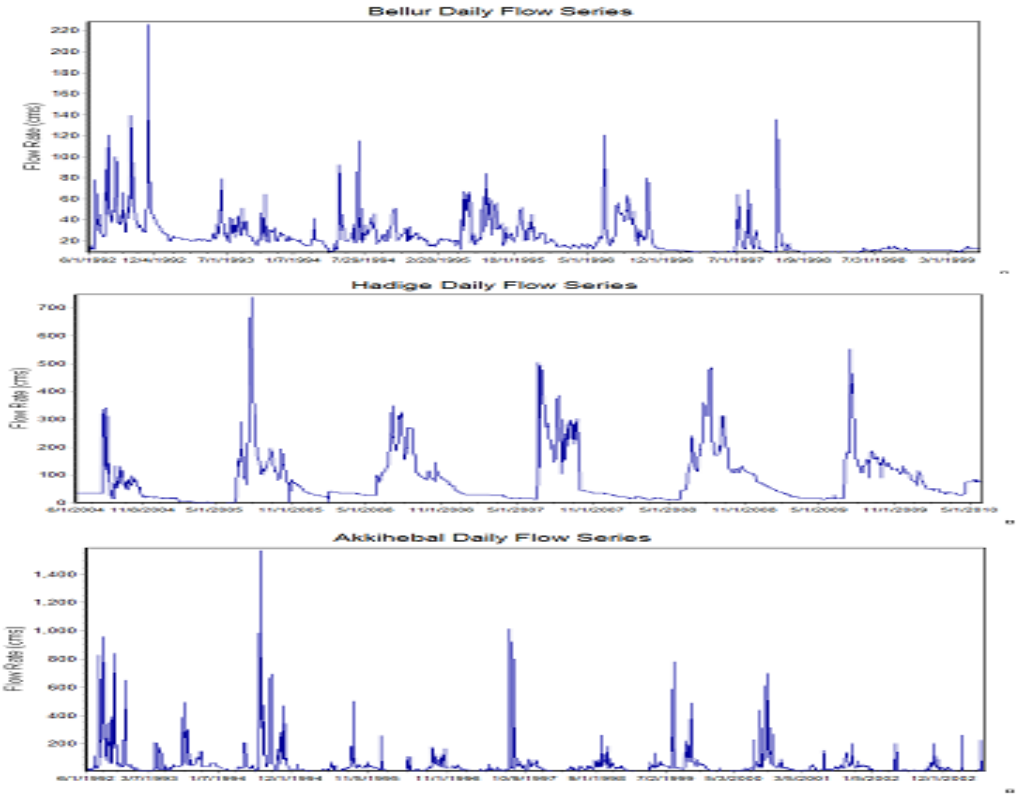


Fig. 1. Variation of observed daily stream flow at selected gauging sites

The ten daily and monthly flow series were generated for computing the environmental flows. The various E-flows methodologies such as Look-up tables, Tennant and modified Tennant method, EMC-FDC, desktop approach, IHA analysis, etc., were applied on daily and monthly flow series observed at various gauging stations. The results of computed E-flows using hydrological index method is presented in Table 1 and graphically presented in Fig. 2.

Table 1. Environmental Flow Assessment using Various Hydrological Index Methods

Name of EFA method	EFR at Various Gauging Sites (Cumec-day)					
	Bellur		Hadige		Akkihebal	
	Cumec day	% MAF	Cumec day	% MAF	Cumec day	% MAF
i) Look-Up Tables						
WCD (2000)	2.26	10	8.35	10	4.90	10
FRANCE	0.57	2.5	2.09	2.5	1.22	2.5
CWC (2007)	0.45	2	1.67	2	1.18	2
ii) **Low Flow Indices**						

Q99	0.02	0.1	0.43	1	1.18	2
UK (Q95)	0.07	0.3	4.08	5	8.90	18
Q90	0.11	0.5	14.78	18	9.22	19
Q75	4.42	1.0	24.89	30	13.13	27

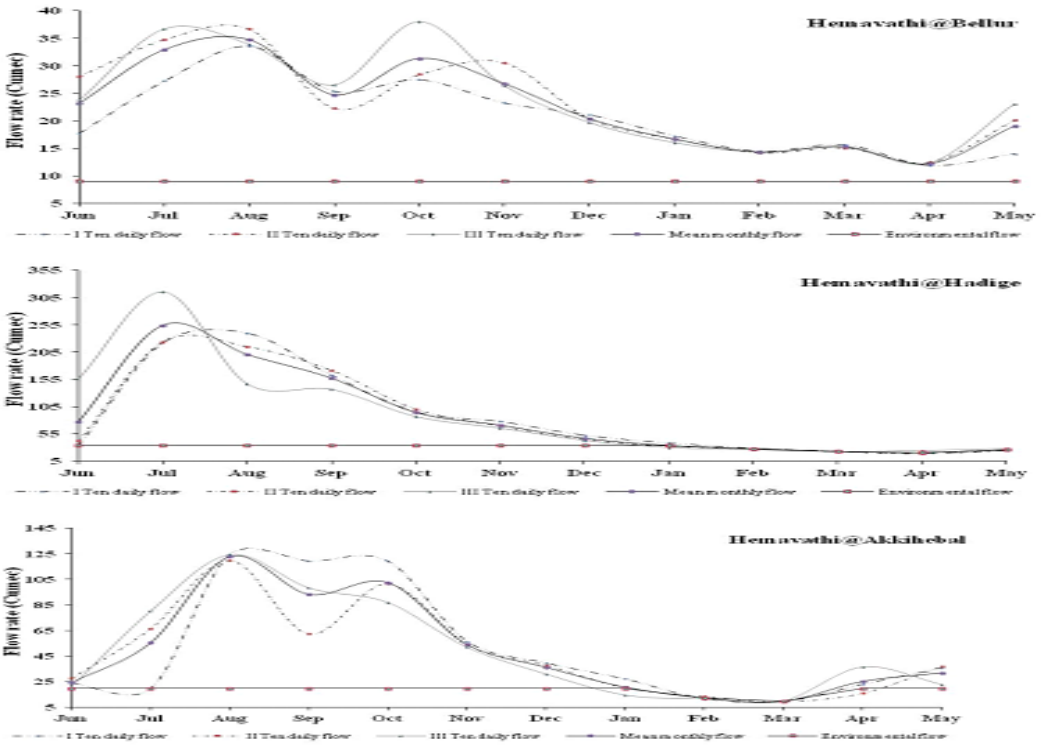


Fig. 2. The E-flow Assessment using Modified Tennant Method

The look up table used in the various countries such as France, USA and UK are area specific and the same may not suitable for Indian condition. Hence, the maximum values computed using these methods/approaches are recommended as E-flows with the remarks that the minimum value should be ensured at any circumstances, which can be an initial estimates of E-flows. Further, the desktop approach was used for computing E-flows. Flow Duration Curve (FDC) was generated for various EMCs at all gauging stations to use in IWMI EMC-FDC approach as presented in Table 2. The expert judgment was made for deciding EMC of river. Another method based on indicators hydrological alteration (IHA) was also used for computing E-flows. The IHA suggested spatio-temporal variation of quantity, duration and timing of historical flow condition, which may useful for deciding effectively the E-flows requirement at selected stretches of river under study and further planning of water resources projects in that stretch of the river. The parameters of Environmental Flow Components (EFCs) using IHA approach are graphically shown in Fig. 3.

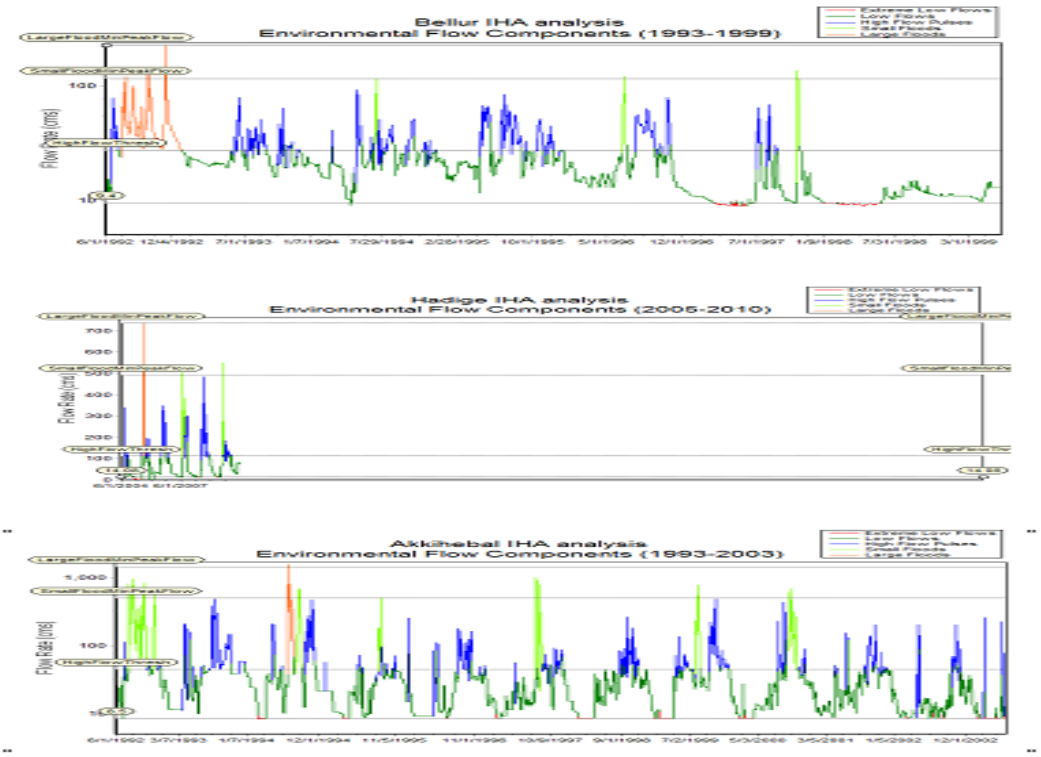


Fig. 3. Environmental Flow Components using IHA method at various gauging sites

Part I of the report completed and submitted.

16. **End Users/Beneficiaries of the Study:** Karnataka Power Corporation Limited, Karnataka State Irrigation Department, etc.

17. **Deliverables:** Technical report and research papers
18. **Major items of equipment procured:** None
18. **Lab facilities used during the study:** None
19. **Data procured or generated during the study:** None
20. **Study Benefits/Impacts:**

Measurable Indicators	Achievements
Quantification of E-flows	E-flows estimated using various methods/approaches

21. **Involvement of end users/beneficiaries:** Local community in the basin catchment
22. **Specific linkage with Institution and /or end users / beneficiaries**: Nil
23. **Shortcoming/Difficulties:** No
24. **Future Plan:** Following study components will be performed

- Field visit
- Secondary data collection
- River water sampling

Study – 8

1. Title of the Study: Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier

2. Study Group:

Project Investigator Dr. M. K. Sharma, Sc. 'D'
Co-Investigator Dr. C. K. Jain, Sc. 'G' Dr. Renoj Thayyan, Sc. 'D' Dr. Manohar Arora, Sc. 'D'
Scientific/Technical Staff Sri. Naresh Saini, PRA Sri. Jatin Malhotra, SRA Sri. Rakesh Goyal, Tech. Gr. I Sri. Dayanand, Tech. Gr. II

3. Type of Study: Sponsored project by DST, New Delhi, **Budget: Rs 30.60 lacs**

4. Nature of Study: Applied Research

5. Date of start: Jan. 2014

6. Scheduled date of completion: March 2017

7. Duration of the Study: 3 Years

8. Study Objectives:

i) To characterize the seasonal variability of the major-ion chemistry of glacial meltwater.
ii) Chemical characterization of the suspended sediment of Gangotri glacial system
iii) To study Ionic enrichment dynamics of meltwater-glacial sediment interaction
iv) To investigate open and closed system low temperature ionic enrichment process

9. Statement of the Problem:

Higher level of pollutant load in the lower reaches of River Ganges is as an unresolved problem for the past many decades. There were number of projects launched by the Government of India to address this issue, but failed to achieve the desired result during the past two decades. Contribution of Himalaya rivers originating from snow and glacier fields of higher Himalaya spread across India, Nepal and Tibet, play an important role in controlling the solutes levels in the River Ganges. As these mountain waters with significant amount of snow, glacier meltwaters and rainfall is characterised by low ionic concentrations and play a major role in diluting the high solute load emanating from Ganga plain catchments. Hence any change in the quality and quantity of the Himalayan tributaries of River Ganga under the climate change regime will impact the quality parameters of River Ganga. Understanding of low temperature solute acquisition processes is therefore very important for assessing the solute acquisition and pollutant loading further downstream. Higher sediment load in the glacier fed streams play a significant role in solute acquisition by its interaction with dilute glacial and snow melt waters. Further downstream, higher sediment

load due to anthropogenic activities added another dimension to the problem. As Gangotri glacier is the biggest glacier in the region as well as the source of River Ganga, it is imperative to study the dynamics of solute acquisition by dilute glacier waters in interaction with freshly grinded glacier sediments. Hence this study is conceptualised to build the existing knowledge gap on solute acquisition of glacier melt waters during its transit with high sediment load under prevailing low temperature conditions close to the glacier.

10. Approved Action Plan/Methodology:

i) Literature survey through international publications (research papers/ reports)
ii) Reconnaissance survey of Gangotri glacier catchment for site selection.
iii) Collection Suspended sediment samples and meltwater samples from selected sites seasonally.
iv) Chemical analysis for major cations, anions and trace metals in the collected suspended sediment and meltwater.
v) Geochemical analysis of suspended sediments
vi) Study of closed system characteristics and open system dynamics
vii) Dissolution experiments of glacial meltwater-suspended sediment interaction

11. Timeline:

Activity	2014-15				2015-16				2016-17			
	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.
Literature survey												
Reconnaissance Survey												
Collection of SS and meltwater samples												
Chemical analysis of SS and meltwater samples												
Geochemical analysis of SS												
Open and close system study												
Dissolution experiments of glacial meltwater -SS interaction												
Interim Report Writing												
Final Report Writing												

12. Objectives and achievement during last six months:

Objectives	Achievements
Literature Survey	Extensive literature survey carried out and a status report has been prepared.

13. Recommendation / Suggestion: None

Recommendation / Suggestion	Action Taken
None	None

14. Analysis & Results: Extensive literature survey carried out and a status report has been prepared covering the studies carried out on hydrological and hydrochemical aspects of Gangotri Glacier by different workers.

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

16. Deliverables: Technical report and research papers

17. Major items of equipment procured: i) Low Temperature pH Meter ii) Low Temperature EC Meter iii) Temperature probe with data logging iv) Deep Freezer

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

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

20. Study Benefits / Impacts:

- Study of low temperature ionic enrichment during interaction between glacial sediment and melt water especially for glaciers with huge supraglacial debris cover.
- Ionic enrichment dynamics of meltwater-glacial sediment interaction under open and close system.
- Provide a strong basis extending studies of solute variability and sediment and pollutant loading further downstream.

21. Involvement of end users/beneficiaries: Local people

22. Specific linkage with Institution and /or end users / beneficiaries: None

23. Shortcoming/Difficulties: No

24. Future Plan:

- Recruitment of JRF and procurement of Equipments/labwares
- Reconnaissance Survey of the study area and selection of the site for sample collection Collection of meltwater and suspended sediments (SS)
- Chemical analysis of SS and meltwater sample

Study – 9 (New Study)

1. **Thrust Area under XII Five Year Plan:** Surface, ground and wastewater quality monitoring and modelling
2. **Project Team:**
   - **a. Project Investigator:** Dr. Rajesh Singh, Sc. 'B', EHD
   - **b. Project Co-investigator:** Dr. C. K. Jain, Sc. 'G', EHD
     Dr. D. G. Durbude, Sc. 'D', EHD
     Dr. M. K. Sharma, Sc. 'D', EHD
     Dr. S. P. Rai, Sc. 'E', HID
     Dr. Renoj J. Thayyan, Sc. 'D', WRSD
     Dr. J. P. Patra, Sc. 'B', SWHD
3. **Title of the Project:** Himalayan River Water Quality Assessment in a Stretch from Gangotri to Haridwar
4. **Objectives:**

   i) Catchment characterization affecting river water quality
   ii) River water quality assessment for different designated uses
   iii) Decipher the different sources of solutes controlling the river water quality
   iv) Nutrient loading due to anthropogenic activity
   v) CO_2 consumption during chemical weathering

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

Water of sound quality is the key for vital socio-economic functions on Earth. Most users of water depend on adequate levels of water quality. When these levels are not met, these water users must either pay an additional cost for water treatment or incur at least increased risks of damage or loss. As populations and economies grow, more pollutants are generated and degradation of water resources has become one of the most pressing global concerns currently facing mankind. Increasingly, the major efforts and costs involved in water management are devoted to water quality protection and management. Conflicts among various users of water are increasingly over issues involving water quality as well as water quantity. Evidently, there is a need for effective management efforts, where one possible action is to focus on minimizing pollutant load from pollutant-producing areas to water resource areas. In September 2000, the European Union (EU) passed a new water framework directive (WFD) with the goal of increasing and establishing a good ecological status on a long-term basis. Groundwater, surface waters and coastal waters are affected by this regulation making extensive management of rivers and their catchment areas indispensable. River basin management consists of coordinating all activities which can affect the water resources with the goal of maintaining good quality of water. The management decisions for improving the health of the water bodies can be possible with the help of modeling techniques.

Generally, water quality is the process to determine the chemical, physical and biological characteristics of water bodies and identifying the source of any possible pollution or contamination which might cause degradation of the water quality. Chemical weathering of the rocks leads to introduction of dissolved solids in the river water and conversely stream chemistry provides information on chemical erosion processes (Chetelat et al., 2008). Chemical weathering is a chemical reaction; therefore it requires a "substrate" and "reacting

agents" for it to occur. The substrates on the earth surface are the minerals in rocks and the reacting agents are acids, such as, carbonic acid (HCO^-_3 derived from dissolution of CO_2); sulfuric acid (H_2SO_4 derived from pyrite oxidative weathering and a number of organic acids (oxalic, acetic and humic), which liberate protons to weather the minerals. In addition to these acids, H_2O also acts an agent in dissolving evaporite minerals. Among the various acids, H_2CO_3 is the dominant source of protons for chemical weathering reactions and a regulator of atmospheric CO_2. In addition to H_2CO_3, weathering through organic acids and H_2SO_4 may also be important on local and regional scales (Galy and France- Lanord, 2001). Globally, rivers carry about 2130 x 10^6 tons/yr dissolved material from weathering of rocks (Gaillardet et al., 1999) and transport it to sea. In India, the stream erosion study in Himalayan region dates back to 1970 (Raymahasay, 1970) followed by geochemical characterization of River Ganga water (Handa, 1972). Afterwards, Abbas and Subramanian (1984) described the erosion and sediment transport pattern in the Ganga basin. In a pioneering study, Sarin and Krishnaswami (1984) reported major ion chemistry of Ganga River, which was followed by a number of studies related to geochemistry of Himalayan Rivers in India and abroad (Harris, 1995; Jain et al., 1998; Pierson-Wickmann et al., 1998; France-Lanord and Galy, 1999; Jain, 2002; Semwal and Akolkar, 2006; Singh and Singh, 2007; Trivedi et al., 2010; Singh et al., 2012; Tyagi et al., 2013).

Our main interest is to analyze the river water sample for physico-chemical and bacteriological parameters to understand the different sources of solutes controlling the river water quality. We will also model the pollutant load reaching the river and its behavior in a river stretch.

6. Methodology:

i) Collection of river water, suspended sediments and bed sediment samples from Gangotri to Haridwar on monthly basis.
ii) Analysis of river water samples for physico-chemical, isotopic and bacteriological composition.
iii) Analysis of river bed sediments for elemental and mineral composition.
iv) Processing of data to understand the contamination of water and consumption of CO_2 during the weathering process.

7. Research Outcome from the Project:

i) Geo-spatial data base of river water quality
ii) Annual dissolved and suspended solid flux in the river
iii) CO_2 consumption due to chemical weathering
iv) Technical report and papers

8. Cost Estimate:

a. **Total cost of the project:** Rs. 23,49, 200=00
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.)	2 37 600	2 37 600	2 64 000	**7 39 200**
2	Travelling expenditure	1 00 000	1 00 000	1 00 000	**3 00 000**

3	Infrastructure / Equipment / Consumable	7 00 000	2 00 000	2 00 000	**11 00 000**
4	Experimental charges	20 000	20 000	20 000	**60 000**
5	Misc. Expenditure	50 000	50 000	50 000	**1 50 000**
	Grand Total	11 07 600	6 07 600	6 34 000	**23 49 200**

a. 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: June 2014
b. Duration of the project: 3 Years
c. Stages of work & milestone

S. No.	Major Activities	2014-15			2015-16				2016-17				17-18
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.
1	Literature Survey												
2	Field Investigation												
3	Sample Collection and Analysis												
4	Data Collection and Interpretation												
5	Status Report												
6	Interim Report												
7	Final Report												

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. N C Ghosh	Scientist G & Head
2	Dr. Anupma Sharma	Scientist D
3	Dr. Surjeet Singh	Scientist D
4	Sri Rajan Vatsa	Scientist B
5	Sri Sumant Kumar	Scientist B
6	Ms. Shashi Poonam Indwar	Scientist B
7	Sri Sanjay Mittal	SRA
8	Sri Ram Chandra	RA

APPROVED WORK PROGRAMME OF THE DIVISION FOR THE YEAR 2013-14

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/NIH/13-14	Estimation of specific yield and storage coefficient of aquifers	Surjeet Singh (PI) N.C. Ghosh (Co-PI) Sumant Kumar	1 year (04/13 – 03/14) **Status** : In progress and an interim report prepared	NIH
2. NIH/GWD/NIH/13-14	State-of-the-Art Report on Modeling of Coastal Aquifers Vulnerable to Sea Water Ingress	Anupma Sharma (PI) C.P. Kumar (Co-PI) Rajan Vatsa	1 year (04/13 – 03/14) **Status :** Completed and report submitted to MoWR in September. 2013.	NIH (Reffered by MoWR)
Sponsored & HP-II Projects				
3. NIH/GWD/HP-II/10-12	Coastal Groundwater Dynamics and Management in the Saurashtra Region, Gujarat.	N. C. Ghosh, Anupma Sharma (PI) C P Kumar (Co-PI) SE (GWRDC, Gujarat), C.K. Jain, Sudhir Kumar D.S. Rathore, M.S. Rao Surjeet Singh, Rajan Vatsa	4 years (10/09 – 12/13) **Status:** Completed and the draft final report submitted to	PDS (HP-II)
4. EU-sponsored Project no. 282911	Saph Pani - Enhancement of natural water systems and treatment methods for safe and sustainable water supply in India"	N. C. Ghosh (PI), V. C. Goyal, C. K. Jain, Sudhir Kumar, B. Chakravorty A. K. Lohani, Anupma Sharma, Surjeet Singh Sumant Kumar, and Shashi Poonam Indwar	36 months (10/ 11-9/14) **Status:** Progressing satisfactorily as per time schedule.	EU sponsored collaborative R & D Project.
5. NIH/GWD/NIH/11-14	Management of Aquifer Recharge (MAR) and Aquifer Storage Recovery (ASR)	Sumant Kumar (PI) Rajan Vatsa, N.C. Ghosh C.P. Kumar, Surjeet Singh, Sanjay Mittal	3 years (04/11 – 03/14) **Status:**Raipur case study completed as per 'Saph Pani' requirements. One year extension is sought for under - taking second phase.	Saph Pani Project/
6.	Flow and Contaminant Transport Modeling of Riverbank Filtration	Shashi Poonam Indwar (PI), N.C. Ghosh Anupma Sharma, Rajan Vatsa	2 ½ years (04/12 – 09/14) **Status:** PI is on long leave since June, 2013, Analysis part of Haridwar case site completed and draft final report is in final stage.	Saph Pani Project
Consultancy Projects				
7.	Study of hydrological and hydro-geological aspects of the Jhabua Power Project in Madhya Pradesh to assess water source sustainability	N.C. Ghosh (PI) M.K. Goel, A.K. Lohani, T.R. Nayak S.P. Rai, Surjeet Singh, T. Thomas, Sanjay Mittal	03 months **Status:** Completed and final report submitted on 1st week of Jan., 2014	JPL, APIL, Gurgaon
8.	Study of hydrological and hydro-geological aspects of the Korba Power Project in Chhattisgarh to assess water source sustainability	N.C. Ghosh (PI), A.K. Lohani, S.P. Rai Ravi Galkate, Surjeet Singh, R.K. Jaiswal Sanjay Mittal	03 months **Status:** Completed and final report submitted on 1st week of Jan., 2014	KWPCL, APIL, Gurgaon

In addition to the above studies, Dr. N. C. Ghosh has prepared one Base paper o*n* "**Assessment and strategies for development potential of deeper aquifers"** referred by the Ministry of Water Resources, GoI and submitted it to the Ministry in the month of September, 2013.

The detailed status of the studies are given in Annexure-I.

Status of outreach activities carried out during the year 2013-2014

1. Organized a two-day training course and practitioners' group meeting jointly with IIT Bombay on "Significance of constructed wetland technology for treatment & reuse of sewages & Industrial wastewaters", during 20-22 November, 2013 at Mumbai under the "Saph Pani" project.
2. Organized a two-week training course on "Application of GIS to Groundwater Modelling and Management", during 10-21 February, 2014. The course was sponsored by the Ground Water Department, Govt. of Rajasthan for 15 of its officials

3. Organized an one week training course on "Coastal Groundwater Development, Modeling and Management", under HP-II(PDS) during 3-7 March, 2014 at Ahmedabad.

4. Scientists guided 7 Summer interns students of Kurukshetra University (3 students), Dr. P. D. K. V, Akola , Maharashtra (2 students), and CAE-Baptala, Hyderabad (2 students).

5. Dr.Sujeet Singh guided 3 M.E. & M. Tech dissertations and Dr. R. P. Singh (Resource Person) guided 5 M. Tech dissertations during the year.

6. Scientists (Dr. Anupma Sharma, Sc-D (3), Dr. Surjeet Singh, Sc-D(5) , Mr. Rajan Vatsa, Sc.-B(1) and Mr. Sumant Kumar, Sc.-B (2)) attended 11 training programmes.

7. Scientists/scientific staff delivered 32 lectures/tutorials in different training courses and Workshops.

8. Scientists published **5** papers in international Journals, **5** in national journals, and **4** papers in Conferences.

1. PROJECT REFERENCE CODE: NIH/GWD/NIH/13-14

Title of the Study: Estimation of specific yield and storage coefficient of aquifers

Date of Start: April 01, 2013
Scheduled Date of Completion: March 31, 2014
Location Map: Multi-sites data and information will be used.

Statement of the Problem:

The specific yield and the storage coefficient are the two main parameters that play vital role in assessment of groundwater resources potential and groundwater modelling. The accuracy of groundwater resource estimation primarily relies on these parameters. Numerous methods are available in literature, however, selection of suitable method and its data requirements under varying range of field conditions are a tedious job. In this context, the present study proposes to compile various methods and prepare a state-of-the-art report on the estimation of '*Specific yield*' and '*Storage coefficient*'.

Approved action plan:

- Exhaustive literature review.
- Compilation of various methods suggested by researchers; inter-comparison of methods wherever possible by a set of field data.
- Identification of merits and demerits of each method and suggesting suitable method for varying range of field conditions.
- Preparation of the report.

Timeline and justification for time over runs:

1-6 months: Literature review & data collection.
7-12 months: Inter-comparison, sensitivity analysis of various methods under varying field conditions and accordingly identify suitable methods, and report writing.
13-18 months: Difficulty in collection of data and hence six month extension is required for numerical comparison of techniques.

Objectives & Achievements:

Compilation and critical appraisal on various methods developed and widely used for estimation of specific yield and storage coefficient.	• Review of various techniques and methods has been completed. • Merits and demerits of various methods **their data requirements.** • **Qualitative assessment on the suitability of methods.** • **Data collection.** • **An interim report prepared.**
Preparation of a state-of-the-art report on estimation of specific yield and storage coefficient.	• Numerical comparison and suitability of methods under various varying field conditions is under progress.

Recommendations/suggestions in previous meetings of Working Group/TAC/GB – Dr. S.N. Rai of CSIR-NGRI had suggested to review some recent research papers on the estimation of specific yield.

Analysis and Results:

1. Comprehensive review of literature.
2. Merits and demerits of various methods.
3. Data requirements of various methods.
4. Qualitative assessment on suitability of various methods and their prioritization.
5. Preparation of thematic layers in GIS.

List of deliverables: Compilation on various methods of specific yield estimation, and identify suitable methods for varying field conditions.

Data procured and generated:

- Soil profile details and texture, groundwater levels, groundwater recharge and draft, some lithologs, etc have been collected for the Ghaggar basin.
- Some high frequency data, rainfall, geology, etc are under collection.

Future Plan:

The study would need six months extension for analysis of field data and the final report will be submitted by 30th November, 2014.

2. PROJECT REFERENCE CODE: NIH/GWD/INT/13-14

Title of the study: **State-of-the-Art Report on Modeling of Coastal Aquifers Vulnerable to Sea Water Ingress**

Study objectives:

1. To describe the general hydrogeology of coastal regions in India
2. To characterize water quality problems of coastal regions.
3. To review recent advances in hydro-chemical and solute transport investigations and modeling in areas vulnerable to seawater ingress.
4. To compile investigations and modeling studies undertaken in coastal regions of India.
5. To compile research studies on impact of climate change on water resources of coastal regions.

Specific linkages with Institutions and/or end-users/beneficiaries: The study has emerged as an action suggested by Ministry of Water Resources (MoWR) under its National Water Mission on Climate Change. The report would be utilized by National Water Mission on Climate Change.

Work Done/ Analysis:

1. Literature review under progress
2. One base paper on 'Coastal Aquifer Management Including Use of Hydraulic Barriers for Control of Seawater Ingress' prepared and submitted to MoWR.

List of deliverables : Report, Review Paper

Future Plan: A report has been submitted to Ministry of Water Resources, Govt. of India in the month of September, 2013.

PROJECT REFERENCE CODE: NIH/GWD/HP-II/10-12

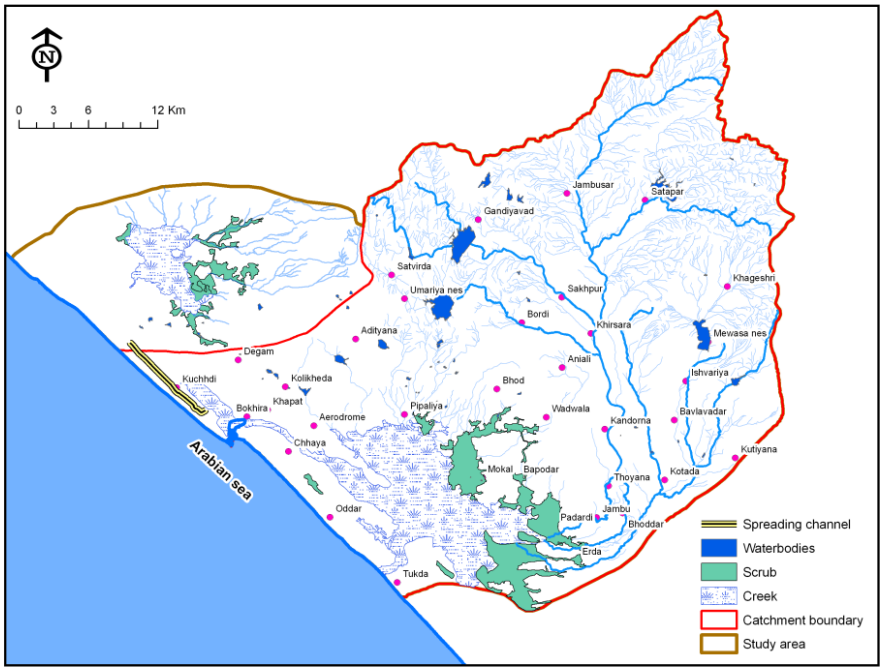
Title of the study: **Coastal Groundwater Dynamics and Management in the Saurashtra Region, Gujarat.**

Type of study (sponsored/consultancy/referred/internal): Sponsored; *Purpose Driven Study* under World Bank funded Hydrology Project Phase-II (HP-II). Study in collaboration with Gujarat Water Resources Development Corporation (GWRDC), Govt. of Gujarat, Gandhinagar

Date of start: Oct. 26, 2009

Report Submission: May 30, 2014

Location map:



Study Area: Minsar River Basin, Coastal Saurashtra, Gujarat

Study objectives:

- To characterize the various hydrologic components and establish their quantitative inter-relationships in the coastal aquifer system.
- To identify causes of increasing groundwater salinity and its far reaching consequences on the coastal aquifer system, and to establish the physico-chemical mechanism of mixing of freshwater-saltwater in the coastal aquifer system of Saurashtra region.
- To simulate the transport of saltwater in the coastal aquifer system through numerical modeling and study impact of existing aquifer management practices on the groundwater regime.
- To evaluate the impact of anticipated climate change on groundwater recharge and dynamics of coastal aquifer system and suggest suitable remedial measures.

- Analysis of effect of water quality degradation due to saltwater intrusion on the socio-economic growth.
- Rollover of project output to State Departments in Gujarat and concerned users in terms of technology transfer of technical know-how gained during the project for implementation of program for sustainable development of coastal groundwater resources.

Statement of the problem:
To investigate the coastal groundwater dynamics and saltwater intrusion phenomenon in the Porbandar District of Coastal Saurashtra.

Analysis and Results

The work in the coastal aquifer system of Minsar River Basin has been carried out under the following major components: (i) Hydrogeologic investigations (ii) Water quality and stable isotope investigations (iii) Numerical modeling of coastal aquifer system and water management aspects (iv) Impact of groundwater salinity on socioeconomics of the coastal river basin. A report containing the analysis and conclusions drawn from the study has been submitted to MoWR. Details of the work carried out under the study would be presented in the Working Group.

PROJECT REFERENCE CODE: EU-sponsored Project no. 282911

EU-sponsored Project no. 282911 entitled **"Saph Pani - Enhancement of natural water systems and treatment methods for safe and sustainable water supply in India".**

i. List of Work Packages

Work Package (WP) number	WP Title	Lead organization
WP 1	Bank Filtration in Urban areas under varying Pollutant loads and flood situation	HTWD, Germany
WP 2	Managed Aquifer Recharge and Soil Aquifer Treatment	KWB, Germany
WP 3	Constructed wetlands and other natural treatment systems for wastewater treatment and reuse..	IIT Bombay
WP 4	Post-treatment of water from natural treatment systems for different applications	IHE, Netherlands
WP 5	Modelling and system design	BRGM, France
WP 6	Integrated sustainability management	CEMDS, Austria
WP 7	Training and Dissemination	NIH
WP 8	Management	FHNW, Switzerland

ii. NIH's involvement

- In Work Packages (WPs) - WP1 , WP2 , WP 5 and WP7.
- NIH is the Lead agency in WP7.

iii. Targeted Areas for R & D works

For WP 1 : Haridwar, and Baseline data collection from existing RBF sites in India and modelling.

For WP 2 : Managed aquifer recharge and soil aquifer treatment – Urban storm water management in Raipur

.

For WP 5 : Based on the baseline data to be collected from WP1, & WP2, involvement in modelling of the respective site.

iv. Progress made (Since September, 2013 till now)

(a) Work Package 1 : Bank Filtration in Urban areas under varying Pollutant loads and flood situation.

Based on the Riverbank filtration scheme in Haridwar, a semi-analytical mathematical model to asses: i) enhancements of seepage from a canal, and ii) induced flow from a partially penetrating river in an unconfined aquifer consequent to groundwater withdrawal in a well field in the vicinity of the river and canal has been developed.

A paper based on the work of Haridwar has been submitted to 'Groundwater' journal and the paper has been tentatively accepted for publication.

Numerical model for transient flow conditions has been developed by the HTWD, Germany. The tasks assigned to NIH under this Work Package are progressing as per time line.

(b) Work Package 2 : Managed Aquifer Recharge and Soil Aquifer Treatment

NIH has been entrusted with the task of assessing feasibility of MAR-ASTR for the Talibandha Lake. The study has been completed and the draft final report has been submitted to the WP2 Leader of the 'Saph Pani' project.

(c) Work Package 5 : Modelling and System Design

In this work package, NIH has a secondary role, i.e., data being collected from WPs 1,& 2,will be used for the activities of WP5.

(d) Work Package 7 : Training & Dissemination

In this Work Package, NIH has the lead role supported by 11 other project partners.

The 5th biannual meeting of the 'Saph Pani' project to review the progress of activities was held at Orleans, France during 12 -14 May, 2014 along with a back-to back training program on "Natural Systems for Water and Wastewater Treatment and Reuse" at Delft, The Netherlands during 15-16 May, 2014.

Following three scientists from NIH attended both the review meeting at Orleans, France and the training course at Delft:

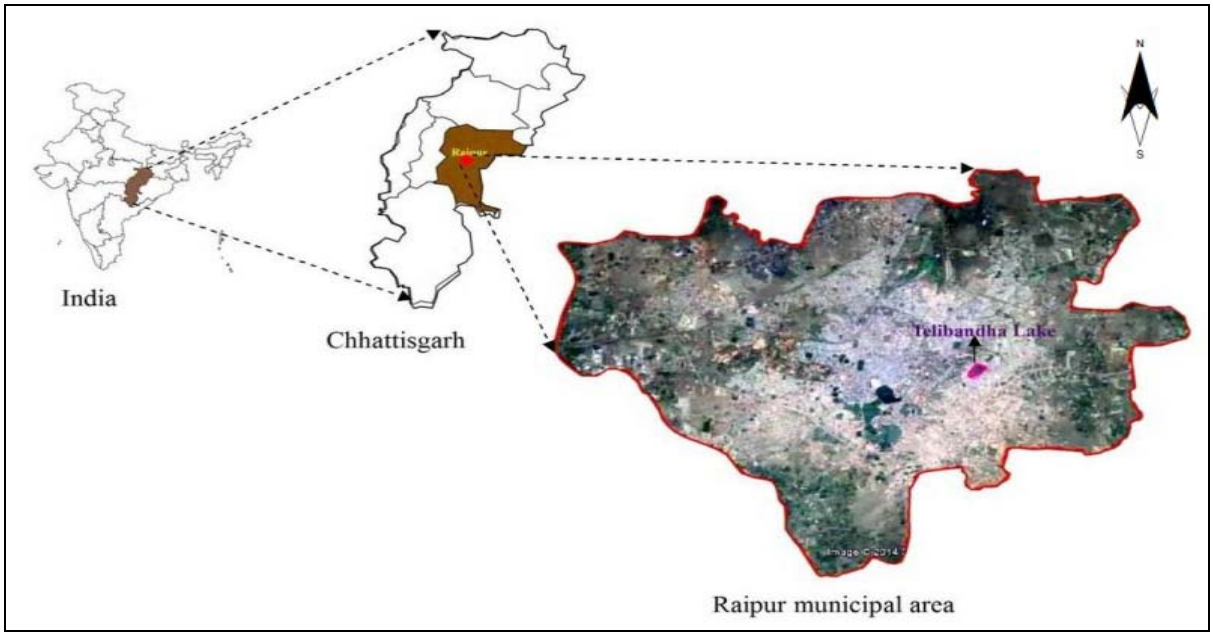
(i) Dr. N. C. Ghosh, Scientist-G & Project Coordinator
(ii) Dr. V. C. Goyal, Scientist-F & WP7 leader
(iii) Mr. Sumant Kumar, Scientist-B & Investigator

In the meeting, review of progress of each WP and shortfalls had been discussed along with finalization of work plan for the remaining period of the project. The final conference of the project has been decided to be organized jointly by NIH & FHNW, Switzerland during 18-19 September, 2014 at New Delhi.

PROJECT REFERENCE CODE: NIH/GWD/NIH/11-14

Title of the Study: **Managed Aquifer Recharge (MAR) and Aquifer Storage Recovery (ASR)**

Location Map Study area is Raipur, the capital city of Chhattisgarh lies between 21° 10'and 21° 21' N latitudes and 81° 32' to 81° 44'E longitudes.



Objectives

1) To identify the potential recharge sites for groundwater (GW) augmentation,
2) To model & analyze aquifer responses due to the recharge from the identified potential recharge sites,
3) To manage the augmented GW resources for subsequent potential uses.

Statement of the problem, End users/beneficiaries of the study:

Raipur city has 154 small and large water bodies. These water bodies are both natural and manmade, locally called "talab". These talabs are connected by storm water channels and hence have specific catchment area. Out of 154 talabs, 85 talabs are in place, remaining talabs have lost their entity because of the development activities. Most of the existing talabs face deteriorating water quality due to disposal of municipal wastes both solid and liquid.

Raipur area also faces problem of depleting groundwater levels due to its excessive withdrawal. To overcome these problem a Managed Aquifer Recharge (MAR) and Aquifer Storage Recovery (ASR) scheme has been envisaged as a pilot study with objectives to enhance groundwater recharge from talab through aquifer storage treatment and managing the augmented groundwater resources for subsequent potential uses. To examine potential of MAR in Raipur area, one of the talabs namely, Teliabanda lake is being studied in detail.

Objectives & Achievements

To identify the potential recharge site for groundwater (GW) augmentation	Recharge site (Teliabanda Lake) have been identified
To model & analyze aquifer response due to the recharge from the identified potential recharge site	Comprehensive analyses of hydrological and hydrogeological components of the lake for assessing viability of Managed Aquifer Recharge (MAR) has been carried out, and a semi-analytical model for estimation of groundwater recharge from the lake for variable flow conditions has been developed.
To manage the augmented GW resources for subsequent potential uses	The main aquifer formations below the lakebed and around possess thick limestone formation - a limiting factor for MAR-ASTR proposition, and hence no engineered hydrogeological intervention has been found viable. An one year extension is sought for working out alternate plan for management of 85 talabs' water in the Raipur city area.

Analysis and Results

A comprehensive analysis of hydrological and hydrogeological components of the lake has been carried out. The hydrological components viz. rainfall-runoff, evaporation rate, lake water quality, etc have been assessed using SCS-CN model and monitored field data. The hydrogeological components viz. aquifer characterization, parameters estimate, ambient groundwater level and quality have been analyzed using measured data. For estimating groundwater recharge rates and depths of water for variable flow rates, Hantush's (1967) analytical expression for water table rise due to recharge from a rectangular spreading basin have been integrated into the basic water balance equation of the lake. Semi-analytical models have been developed for estimating time variant variable water spread areas based depths of water and the corresponding recharge rates. The computed depths of water in the lake resulting from the interaction of water balance components have been compared with the measured data and found a satisfactory match. The estimated recharge rates have been found varying between 3.75 mm/day and 4.82 mm/day for depth of water in the lake between 2.5 m and 3.36 m. The lake water quality indicated contamination by bacteriological parameters (viz. Fecal coliform and Total coliform), turbidity and COD, exceeding the permissible limit of drinking water standards (IS-10500:2012).

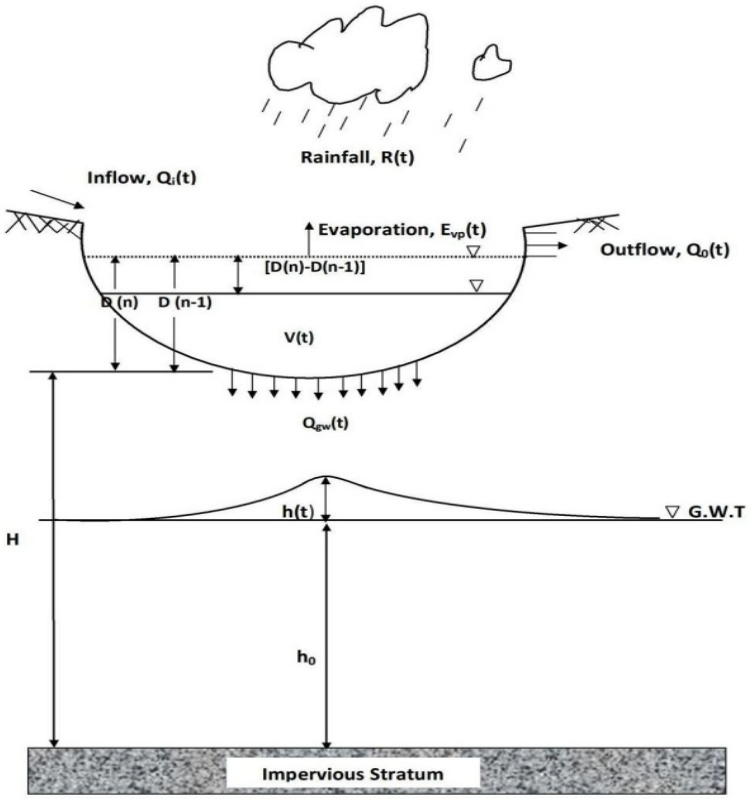


Figure : A schematic of the conceptualized Lake water balance components including description of their hydraulic parameters

6. PROJECT REFERENCE CODE: EU-sponsored Project no. 282911

Title of the study: Flow and Contaminant Transport Modeling of Riverbank Filtration.

The P.I of the study is on leave since June, 2013. Therefore, the tasks related to the ‘Saph Pani’ project have only been pursued and accordingly the report is being finalized as envisaged deliverable of the project..

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Sri C P Kumar	Scientist F & Head
2	Dr. Sudhir Kumar	Scientist G
3	Dr. S D Khobragade	Scientist E
4	Dr. S P Rai	Scientist E
5	Dr. M S Rao	Scientist D
6	Sri S K Verma	Scientist D
7	Sri P K Garg	Scientist B
8	Sri Rajeev Gupta	SRA
9	Sri U K Singh	SRA
10	Sri V K Agarwal	SRA
11	Sri Jameel Ahmed	SRA
12	Sri Vishal Gupta	RA

WORK PROGRAM OF HYDROLOGICAL INVESTIGATIONS DIVISION FOR THE YEAR 2013-2014

S. No.	Study	Team	Duration/ Status
INTERNAL STUDIES			
1	Assessment of Sensitivity of Open Water Evaporation to Increase in Temperature for Different Climatic Regions of India	S. D. Khobragade (PI) C. P. Kumar Manohar Arora A. R. Senthil Kumar	**2 years** (04/12-03/14) **Continuing Study**
2	Water Quality, Hydrogeology and Isotopic Investigations in SW Punjab	M. S. Rao (PI) C. P. Kumar Gopal Krishan	**2 years** (07/12-06/14) One year extension required **Continuing Study**
3	Water Availability Studies for Sukhna Lake, Chandigarh	S. D. Khobragade (PI) C. P. Kumar Sudhir Kumar A. R. Senthil Kumar P. K. Garg V. K. Agarwal	**2 years** (04/13-03/15) **New Study**
4	Isotope Studies for the Identification of Different Aquifer Groups and their Dynamics in Upper Yamuna River Plains	Sudhir Kumar (PI) C. K. Jain S. P. Rai S. D. Khobragade P. K. Garg B. C. Joshi (CGWB, Lucknow) Tejdeep Singh (CGWB, Chandigarh)	**2 years** (07/13-06/15) **New Study**
5	Estimation of Radon Concentration in Waters and Identification of Paleo-groundwater in Part of Punjab Located in Satluj River Basin using Isotopes	S. K. Verma (PI) S. P. Rai (Co-PI) M. S. Rao C. P. Kumar Mohar Singh	**2 years** (10/13-09/15) **New Study**
SPONSORED PROJECTS			
6	National Program on Isotope Fingerprinting of Waters of India (IWIN)	M. S. Rao (PI) Sudhir Kumar S. P. Rai S. K. Verma P. K. Garg Gopal Krishan	**6 years 6 months** (07/07–12/13) **Continuing Study**

S. No.	Study	Team	Duration/ Status
7	Groundwater Dynamics of Bist-Doab Area, Punjab using Isotopes	M. S. Rao (PI) Sudhir Kumar S. K. Verma P. K. Garg Gopal Krishan CGWB Officials	**5 years 6 months** (10/08-03/14) **Continuing Study**
8	Groundwater Management in Over-Exploited Blocks of Chitradurga and Tumkur Districts of Karnataka	Sudhir Kumar (PI) J. V. Tyagi S. P. Rai Anupma Sharma B. K. Purandara C. Rangaraj	**5 years 6 months** (10/08-03/14) **Continuing study**
9	The Use of Environmental Isotopes to Assess Sustainability of Intensively Exploited Aquifer Systems in North Eastern Parts of Punjab, India	M. S. Rao (PI) C. P. Kumar S. P. Rai	**3 years** (09/12-08/15) **Continuing Study**
10	The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates	S. P. Rai (PI) M. S. Rao Surjeet Singh S. K. Verma C. P. Kumar Sudhir Kumar V. K. Agarwal Rajeev Gupta S. L. Srivastava Vishal Gupta Mohar Singh	**3 years** (06/12-05/15) **Continuing Study**
11	Review of Groundwater Resources in the Indo-Gangetic Basin: A Case Study on Resilience of Groundwater in the Punjab to Withdrawal and Environmental Change	M. S. Rao (PI) C. P. Kumar Gopal Krishan	**One year 8 months** (02/13-09/14) **Continuing Study**
12	Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques	S. P. Rai (PI) R. V. Kale M. S. Rao C. P. Kumar Sudhir Kumar V. K. Agarwal Vishal Gupta Mohar Singh	**3 years** (10/12-09/15) **Continuing Study**
13	Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains	Sudhir Kumar (PI) S. P. Rai S. D. Khobragade C. K. Jain P. K. Garg	**2 years** (05/13-04/15) **New Study**
CONSULTANCY PROJECTS			

S. No.	Study	Team	Duration/ Status
14	Integrated Hydrological Investigations of Sukhna Lake, Chandigarh for its Conservation and Management	S. D. Khobragade (PI) C. P. Kumar R. D. Singh S. P. Rai C. K. Jain V. K. Agarwal	**2 years** (07/11-06/13) **Continuing Study**
15	Pre-dredging and Post-dredging Bathymetric Survey of Ramgarh Tal Lake, Gorakhpur, UP	S. D. Khobragade (PI) C. P. Kumar R. D. Singh V. K. Agarwal	For Pre-dredging Survey 6 months (11/12-04/13) **Continuing Study**
16	Assessment of Impact of Coal Mining from Mahan Coal Block on Groundwater Recharge and Sedimentation in Rihand Reservoir and to Suggest Appropriate Measures to Mitigate the Identified Impacts	Sudhir Kumar (PI) Sanjay Kumar Jain J. V. Tyagi Surjeet Singh S. D. Khobragade R. K. Jaiswal P. K. Garg	**6 months** (04/13-09/13) **New Study**
17	Hydrogeological Study for Dewatering of Jhamarkotra Mines, Distt. Udaipur	Sudhir Kumar (PI)	**3 years** (05/13-04/16) **New Study**
18	Impact Assessment of Ash Pond on the Groundwater Quality in the Surrounding Villages of NTPC Simhdri through Stable Isotopic Studies	Sudhir Kumar (PI)	**1 year** (07/13-06/14) **New Study**
19	Identification of Source and Locations of Leakage/Seepage from Kaushalya Dam, Haryana	S. P. Rai (PI)	**6 months** (08/13-01/14) **New Study**

PROPOSED WORK PROGRAM OF HYDROLOGICAL INVESTIGATIONS DIVISION FOR THE YEAR 2014-2015

S. No.	Study	Team	Duration/ Status
INTERNAL STUDIES			
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S. No.	Study	Team	Duration/ Status
2	Water Availability Studies for Sukhna Lake, Chandigarh	S. D. Khobragade (PI) C. P. Kumar Sudhir Kumar A. R. Senthil Kumar P. K. Garg V. K. Agarwal	**2 years** (04/13-03/15) **Continuing Study**
3	Isotope Studies for the Identification of Different Aquifer Groups and their Dynamics in Upper Yamuna River Plains	Sudhir Kumar (PI) C. K. Jain S. P. Rai S. D. Khobragade P. K. Garg B. C. Joshi (CGWB, Lucknow) Tejdeep Singh (CGWB, Chandigarh)	**2 years** (07/13-06/15) **Continuing Study**
4	Estimation of Radon Concentration in Waters and Identification of Paleo-groundwater in Part of Punjab Located in Satluj River Basin using Isotopes	S. K. Verma (PI) S. P. Rai (Co-PI) M. S. Rao C. P. Kumar Mohar Singh	**2 years** (10/13-09/15) **Continuing Study**
5	Sub-marine Groundwater Discharge and Sea-water Intrusion in Coastal Aquifers of East Coast, India	M. S. Rao (PI)	**2 years** (06/14-05/16) **New Study**
6	Monitoring Isotopes in Air Moisture in Parts of Himalayas (Himachal Pradesh & Uttarakhand) for investigating the Cloud Condensation	M. S. Rao (PI) C. P. Kumar Gopal Krishan	**2 years** (06/14-05/16) **New Study**
SPONSORED PROJECTS			
7	The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates	S. P. Rai (PI) M. S. Rao Surjeet Singh S. K. Verma C. P. Kumar Sudhir Kumar V. K. Agarwal Rajeev Gupta S. L. Srivastava Vishal Gupta Mohar Singh	**3 years** (06/12-05/15) **Continuing Study**
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CONSULTANCY PROJECTS			
12	Hydrogeological Study for Dewatering of Jhamarkotra Mines, Distt. Udaipur	Sudhir Kumar (PI)	**3 years** (05/13-04/16) **Continuing Study**
13	Impact Assessment of Ash Pond on the Groundwater Quality in the Surrounding Villages of NTPC Simhdri through Stable Isotopic Studies	Sudhir Kumar (PI)	**1 year** (07/13-06/14) **Continuing Study**
14	Isotopic Characterization of Groundwater of District Raigarh, Chhattisgarh	S. P. Rai (PI)	**6 months** (04/14-09/14) **New Study**

1. PROJECT REFERENCE CODE: NIH/HID/INT/2012-14/1

Title of the Study	:	**Assessment of Sensitivity of Open Water Evaporation to Increase in Temperature for Different Climatic Regions of India**
Study Team	:	S. D. Khobragade (PI) C. P. Kumar Manohar Arora A. R. Senthil Kumar
Type of Study	:	Internal
Date of Start	:	April 2012
Date of Completion	:	March 2014

Location Map

Udaipur

Chandigarh

Mumbai

Study Objectives

(a) To assess the impact of rising temperature on some temperature dependent factors affecting open water evaporation

(b) To assess the impact of rising temperature on open water evaporation in different climatic regions of India using routinely observed data

(c) To compare the variation in impact on open water evaporation under different climatic settings for different scenarios of temperature rise

Statement of the Problem

A number of studies have been reported in different parts of the world on the assessment of possible impacts of global temperature rise on water resources and hydrologic cycle. However, only a few studies have emphasized the impact primarily on evaporation. Trend analysis of evaporation data shows different trends in different regions, the world over. Although studies using the GCMs are considered as more realistic for global scales, not all the variables required for calculation of more complex evaporation formulae are available from all climate models. Hydrological models are, hence, claimed to be more useful and suitable for regional and local scales, as they have the ability to incorporate projected variations in climatic variables as well as other hydrological parameters. However, hydrologic models that use simpler form of evaporation and evapotranspiration formulae, generally do not have scope for assessing the impact of temperature on various atmospheric variables which affect evaporation. As far as evaporation is concerned, changes in atmosphere variables caused by temperature changes could have an important effect on overall changes in evaporation. Thus, for the purpose of studying impact of global warming on a more specific component like evaporation, specific evaporation model such as Penman model which uses as many input parameters as the factors affecting the process, could be preferable because, as pointed out by IPCC (2001), '*equations that do not consider explicitly all meteorological controls may give very misleading estimates of change*'. Moreover, use of GCMs and RCMs, as well as other sophisticated hydrological models, requires technical expertise that may not always be available locally. For such situations, there is a need for development of a simple methodology to assess the sensitivity of local evaporation to rising temperature using routinely observed meteorological data.

Action Plan

Activity Schedule (Quarterwise: April 2012 to March 2014)

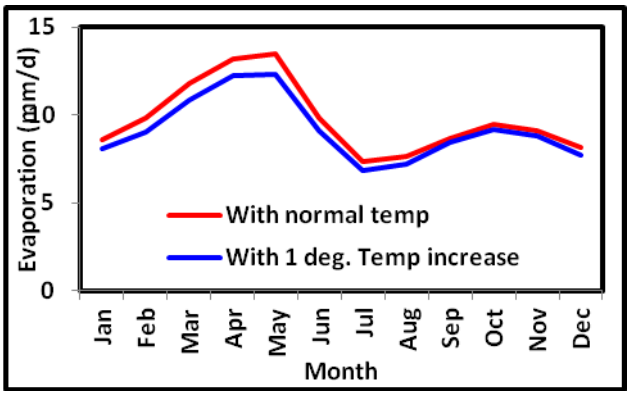
S. No.	Activities	Quarters							
		1	2	3	4	5	6	7	8
1.0	**PREPARATORY WORK**								
1.1	Selection of study area	√							
1.2	Review of literature	√	√	√	√				
1.3	Identification of data requirement	√							
1.4	Collection and compilation of data	√	√						
2.0	**DATA INTERPRETATION AND ANALYSIS**								
2.1	Impact of temperature rise on various meteorological parameters in different climatic settings			√	√				
2.2	Impact of temperature rise on evaporation in different climatic settings					√	√		
2.3	Comparison of variation in impact of temperature rise on evaporation of different climatic regions						√	√	
3.0	**PROJECT REPORT**								√

Objectives vis-à-vis Achievements

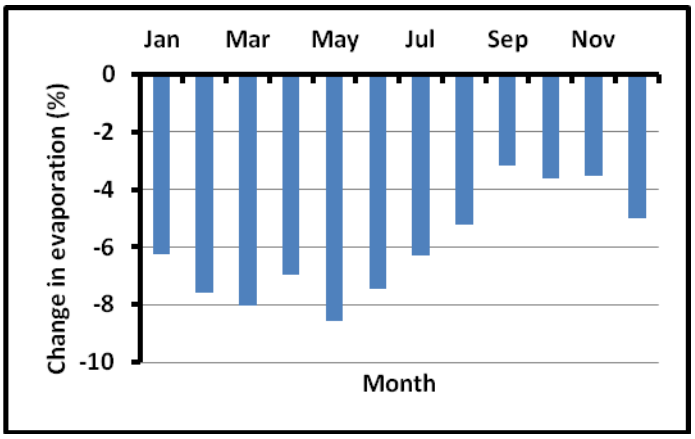
Objectives	Achievements
To assess the impact of rising temperature on temperature dependent factors	Analysis completed for Udaipur , Chandigarh and Mumbai
To assess the impact of rising temperature on open water evaporation in different climatic regions of India	Analysis completed for Udaipur, Chandigarh and Mumbai
To compare the variation in impact on open water evaporation under different climatic settings	Comparison of results carried out for Udaipur, Chandigarh and Mumbai

Analysis and Results

Based on the expected change in various temperature dependent parameters, impact on evaporation rates has been reported for Udaipur and Chandigarh during the last working group meetings. Results for Mumbai indicate that 1 degree increase in temperature is expected to decrease the evaporation rate for the region from the present range of 7.33-13.51 mm to 6.87-12.35 mm. The decrease is expected for all months of the year. However, the decrease is expected to be less than 10% for all the months. More decrease is expected for warmer months compared to the colder months. The range of decrease is expected to be 3.18% for October to 8.56% for May.



Possible impact of temperature rise on evaporation for Mumbai region



Expected change in evaporation in different months for Mumbai region

The study concludes that impact of one degree temperature rise on evaporation in different climatic settings would be different. For Udaipur region, daily evaporation rates are expected to rise significantly (upto 30%) during the monsoon and to some extent (upto 8%) during the winter. However, they are expected to fall by about 5% during the summer. As far as Chandigarh region is concerned, evaporation is expected to actually decrease during summer months. For Mumbai region, evaporation is expected to decrease in all the months, however, the decrease would not be as significant as in Udaipur region.

Detailed analysis of inter-relationships between the projected changes in various temperature dependent parameters and evaporation indicate that the changes in evaporation regime would be influenced most by changes in the regime of vapour pressure deficit (VPD). The results of the study are observed to be consistent with the trend analysis reported for pan evaporation data.

Future Plan

- Analysis to be completed for Tehri Garhwal representing a higher altitude region.
- Report writing
- Research papers

2. PROJECT REFERENCE CODE: NIH/HID/INT/2012-14/2

Title of the Study : **Water Quality, Hydrogeology and Isotopic Investigations in SW Punjab**

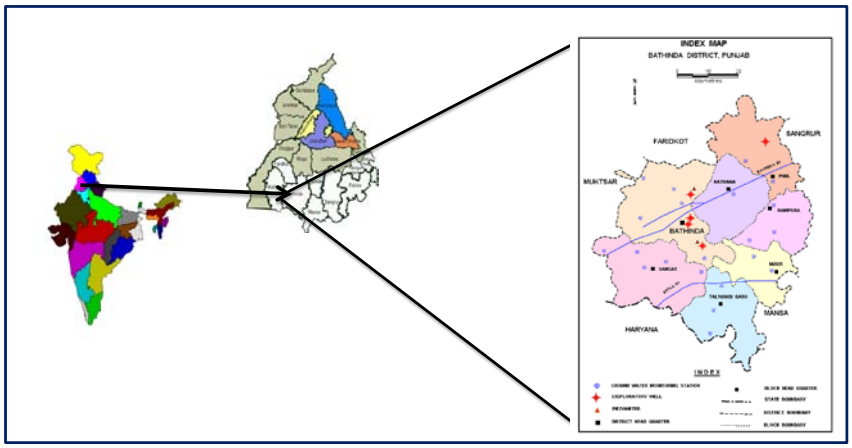
Study Team : M. S. Rao (PI)
C. P. Kumar
Gopal Krishan

Type of Study : Internal

Date of Start : July 2012

Date of Completion : June 2014 (extension of one year is requested)

Location Map



Study Objectives

i) To investigate the water quality in multi-aquifer system of Bhatinda and neighbouring area
ii) To map the groundwater age distribution and recharge zones
iii) Evaluation of groundwater quality in accordance with its source of origin and age
iv) To suggest the remedial measures to improve the groundwater conditions

Statement of the Problem

Electrical conductivity (EC) of groundwater in the district ranges from 312 to 5800 µS at 25^0C. Around 60% of the district area falls with EC value exceeding 2000 µS, whereas 20% of the district area falls with EC exceeding 3000 µS at 25^oC. The fluoride (F) values in some areas exceed 6 mg/l. Origin of high salinity and high fluoride in groundwater and its distribution in space is not well understood. In the present study, these aspects are being examined in detail for better prospects of groundwater utilization and future development.

Action Plan

Year	June 2014 to December 2014	Remark
June 2014 to December 2014	Groundwater inventory Identifying the sampling sites for isotopic and water quality analysis Data collection Water sampling, analysis and data interpretation Report writing	Extension for one year (till June 2015) is requested.

Activity Schedule (Quarter-wise from June 2014 to December 2014)

Activity	1st	2nd
Sampling (groundwater, surface water, precipitation) for monsoon & post-monsoon	♦	
Collection of data	♦	
Isotopic analysis (δD and $\delta^{18}O$) of samples	♦	
Water quality analysis of surface water and groundwater samples	♦	
Interim report	♦	♦
Publications and reporting in conferences	♦	♦

Objectives vis-à-vis Achievements

Objective	Status	Work Done
To investigate the water quality in multi-aquifer system of Bhatinda and neighbouring area	Achieved	Analysis of stable isotopes and water quality of groundwater samples
Evaluation of groundwater quality in accordance with its source of origin and age	Under Progress	Maps of water quality parameters are being prepared.

Analysis and Results

The groundwater samples were collected from 22 sites during first field visit covering the entire 7 blocks of the Bhatinda district and analysed for EC, stable isotopes and major ions.

The hydrochemical analysis of the study reveals that groundwater of the study area is contaminated in terms of nitrate concentration exceeding much above the permissible limits of WHO. The major cause for nitrate pollution is mainly anthropogenic. The Na % in groundwater indicates that from 17 groundwater sampling locations, water can be used for irrigation, leaving only 5 sampling locations which are found unsuitable for irrigation. The enriched values of $\delta^{18}O$ are found in the eastern and western parts of the district, while southern and northern parts are showing highly depleted values. The enriched values found

between the canals Bhatinda branch and Kotla branch may be attributed to evaporation from shallow water table areas. The enriched $\delta^{18}O$ values of groundwater are indicator of salinization.

An increase in EC and enrichment in isotopic composition is observed due to the evaporation effect. Therefore, the integrated data of ion chemistry and isotope is useful for identifying the salinity in semi-arid region. On the basis of this study, suitable management practices can be used to overcome the deteriorating quality and improving the sustainability of the groundwater in semi-arid region of Punjab.

Water Quality Parameters in SW Punjab

Sampling Location	**Ion Concentration (ppm)**								
	Na^{++}	**K^{+}**	**Mg^{++}**	**Ca^{++}**	**F^{-}**	**Cl^{-}**	**NO_3^{-}**	**SO_4^{--}**	**Hardness**
MehmaSurja	22.80	8.80	24.40	62.50	0.00	86.00	3.10	27.10	257.0
Burjmahema	199.0	21.60	39.30	41.00	1.50	210.0	30.10	289.0	264.0
Balluana	178.0	75.80	241.0	152.0	2.60	300.0	217.0	359.0	1371.0
Phul	124.0	20.20	57.00	41.90	1.10	134.0	17.00	106.0	339.0
Mehta	168.0	30.00	218.0	229.0	4.40	337.0	69.50	529.0	1468.0
Phul-300	127.0	20.10	98.40	120.0	0.60	152.0	55.10	164.0	705.0
Bhairupa	88.50	15.90	45.20	52.0	0.90	87.50	11.20	161.0	316.0
Bhatinda	154.0	42.00	79.60	116.0	1.10	205.0	166.0	228.0	618.0
Rama	10.20	105.0	135.0	116.0	2.20	22.40	62.00	51.40	842.0
Rampura	123.0	27.50	77.20	70.90	1.80	149.0	0.00	123.0	495.0
Jhumba	142.0	16.40	21.30	25.30	3.60	37.30	16.90	153.0	151.0
Khemuana	85.30	19.40	90.40	77.40	1.80	51.00	12.00	146.0	565.0
Ablu	127.0	105.0	89.30	52.00	0.80	167.0	113.0	229.0	497.0
Bagha	129.0	34.20	97.10	107.0	0.60	176.0	32.00	321.0	665.0
Jalal	20.00	199.0	37.10	41.50	2.00	7.30	7.20	47.80	257.0
Banawala	61.00	52.40	60.80	68.00	0.80	66.40	17.40	85.70	420.0
Bhikianwalai	23.60	8.20	43.90	37.00	0.70	62.30	46.60	69.40	272.0
Burj gill	129.0	9.80	0.00	18.00	3.30	33.60	10.80	70.60	0.00
Ramgarh	509.0	61.30	62.50	58.60	2.10	502.0	79.90	784.0	403.0
Maur	146.0	17.60	0.00	33.60	3.80	29.60	21.20	124.0	0.00
Sheikhpura	74.80	23.90	77.30	101.0	1.70	59.20	2.70	119.0	571.0
Bhagibanda	4.70	9.90	33.80	87.40	0.80	22.90	5.40	45.10	358.0
Minimum	4.70	8.20	21.30	17.50	0.60	7.30	2.70	27.10	151.0
Maximum	509.0	199.0	241.0	229.0	4.40	502.0	217.0	784.0	1468.0
Mean	120.0	42.00	81.40	77.60	1.80	132.0	47.40	192.0	542.0
Range	504.4	191.1	219.6	212.0	3.80	494.3	213.8	257.0	391.0
Standard deviation	104.1	45.3	58.3	49.1	1.1	122.7	56.5	180.0	349.0

Publications

Krishan, Gopal, Rao, M. S., Kumar, C. P. and Semwal, Prabhat, G.S. 2013. *Identifying Salinization using Isotopes and Ionchemistry in Semi-Arid Region of Punjab, India*. Journal of Geology and Geosciences 2:4 http://dx.doi.org/10.4172/jgg.1000129

Krishan, Gopal, Rao, M. S., Kumar, C. P., Semwal, Prabhat, Tuli, Naresh and Gill, G. S. 2013. *Groundwater Quality and Stable Isotopic Composition in Southwest, Punjab*. In: Proceedings of International conference on "Integrated Water, Waste Water & Isotope Hydrology IC-WWISH-2013", 25-27 July 2013 at Bangalore University, Bangalore, India. III (VI): 6-10.

- An international conference on "Advances in Water Resources Development and Management" (AWRDM-2013) was organized at Panjab University, Chandigarh during October 23-27, 2013. The selected papers were published in a special issue of "International Journal of Earth Science and Engineering". The recommendations of the conference can be uploaded from the NIH website.

Future Plan

- Sampling for monsoon and post-monsoon seasons.
- Measurement of Radon concentration

3. PROJECT REFERENCE CODE: NIH/HID/INT/2013-15/1

Title of the Study : **Water Availability Studies for Sukhna Lake, Chandigarh**

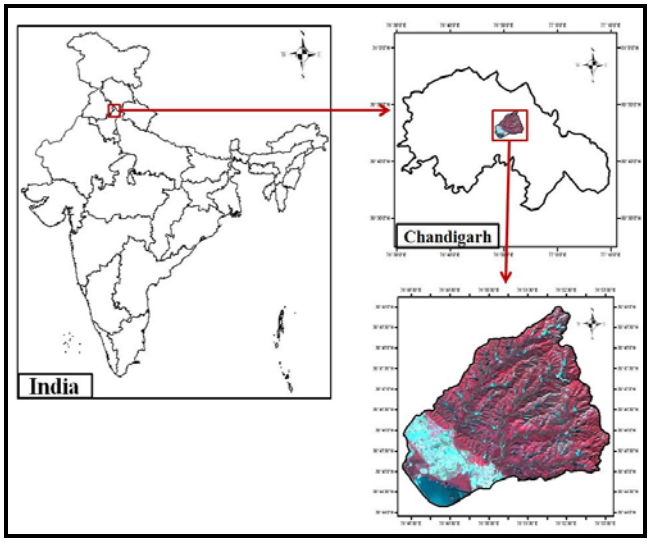
Study Team : S. D. Khobragade (PI)
C. P. Kumar
Sudhir Kumar
A. R. Senthil Kumar
P. K. Garg
V. K. Agarwal

Type of Study : Internal

Date of Start : April 2013

Date of Completion : March 2015

Location Map



Study Objectives

1. To study inflow regime of the lake
2. To study seepage losses from the lake
3. To analyze long term trends in rainfall and evaporation
4. To study the impact of aquatic weeds on lake evaporation
5. To study water availability in the lake

Statement of the Problem

Sukhna lake in Chandigarh is a popular destination for recreation and tourism. However, the lake is in limelight in recent years due to various problems being faced by it. One of the serious problems of the lake is declining water availability in recent years. Water availability analysis has already been carried out based on limited available data, under a consultancy project for the lake carried out by NIH. Further detailed investigations are required on this aspect. The present study has therefore been taken as Phase-II of the investigation being carried out on Sukhna lake by the Institute.

Action Plan

Activity Schedule (Quarterwise: April 2013 to March 2015)

Activity	Quarters							
	1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**
Collection of bathymetric map of 2012 from IPRI	*							
Setting of discharge measurement site for the lake	*							
Generation of discharge data		*	*	*	*	*	*	
Field experimental set up for evaporation losses due to aquatic weeds	*							
Collection of rainfall and other hydro-meteorological data	*	*	*	*	*	*	*	
Conducting experiment on evaporation	*	*	*	*	*	*		
Collection of water level data of lake, open wells, piezometer etc.	*	*	*	*	*	*	*	
Samples collection and analysis for stable isotopes	*	*	*	*	*	*		
Samples collection and analysis for Tritium analysis		*			*			
Compilation and processing of data	*	*	*	*	*	*	*	
Preliminary data interpretation			*	*	*			
Trend analysis for rainfall and evaporation			*					
Evaporation estimation and development of pan coefficients						*		
Seepage analysis						*		
Water balance of the lake							*	
Rainfall-runoff relationship analysis							*	
Interim Report					*			
Final Report								*

Objectives vis-à-vis Achievements

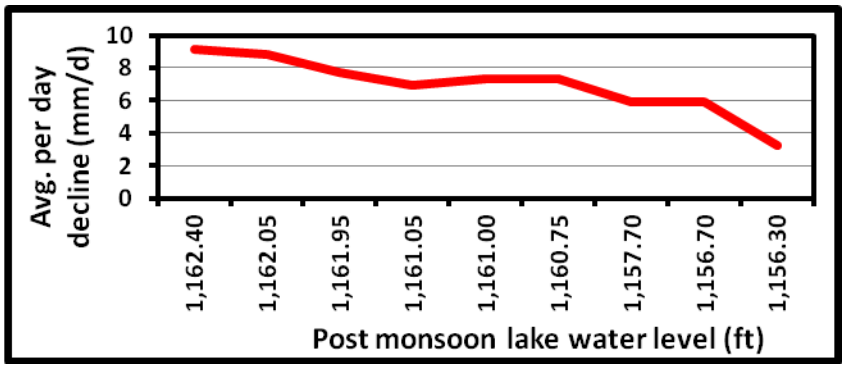
Objectives	Achievements
To study inflow regime of the lake	Inflow has been estimated using water balance approach for 2012 monsoon. Work under progress for 2013 monsoon.

	Field measurements of discharge have been planned for 2014 monsoon.
To study seepage losses from the lake	Seepage has been indirectly estimated from total losses from the lake and other losses and long term analysis of lake water levels.
To analyze long term trends in rainfall and evaporation	Analysis carried out based on trend line
To study the impact of aquatic weeds on lake evaporation	To be considered later
To study water availability in the lake	Water balance has been completed for the year 2012-13. For the monsoon season of 2013, the analysis is under progress.

Analysis and Results

Water balance for the water year 2012-13 indicates that out of the total 705.5 Ha-m of inflow received by the lake during the water year, 197.1 Ha-m was contributed by the rain directly falling over the lake while the remaining 508.4 Ha-m was contributed by runoff from the catchment. The total volume of water lost through the lake was 446.4 Ha-m through various processes. This included 253.3 Ha-m of water lost through evaporation, 173.1 Ha-m through seepage and 20 Ha-m through pumping. As far as monsoon season of 2012 is concerned, the water balance indicates that out of the 530.29 Ha-m of total inflow received by the lake during the monsoon of 2012, 126.59 Ha-m was contributed by the rain directly falling over the lake while the remaining 403.7 Ha-m was contributed by runoff from the catchment.

Analysis of average daily decline in the lake water level during post monsoon months at different levels of post monsoon lake water levels indicate that there is a high correlation between the average daily fall in lake water level during post-monsoon months and the lake water at the end of monsoon (r =0.9). The higher is the lake water level at the end of the monsoon season, more is the change in lake water level during post monsoon months. However, after the lake water level of 1156.3 is reached, the fall reduces significantly to a very low range of about 3 mm/d which is more or less that same as evaporation rates, which indicates that there are no significant seepage losses below this level.



Average daily decline in the lake water level during post monsoon months at different levels of post monsoon lake water levels

Future Plan

- Water balance for the years 2013-14 and 2014-15 (monsoon)
- Analysis of isotope data and groundwater level data for further understanding of seepage from lake and lake-groundwater interaction

4. PROJECT REFERENCE CODE: NIH/HID/INT/2013-15/2

Title of the Study : **Isotope Studies for the Identification of Different Aquifer Groups and their Dynamics in Upper Yamuna River Plains**

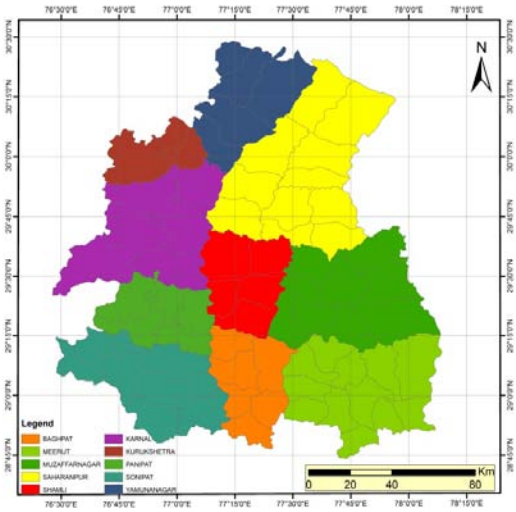
Study Team : Sudhir Kumar (PI)
C. K. Jain
S. P. Rai
S. D. Khobragade
P. K. Garg
Dr. B. C. Joshi (CGWB, Lucknow)
Mr. Tejdeep Singh (CGWB, Chandigarh)

Type of Study : Internal

Date of Start : July 2013

Date of Completion : June 2015

Location Map



Study Objectives: Objectives of the study are

i. To identify various aquifers present in alluvial tract of the Upper Yamuna Plains
ii. To identify the source of recharge of different aquifers and the interaction between various aquifers
iii. To investigate the continuity of aquifers on both sides of Yamuna river
iv. To determine the groundwater dynamics in different identified aquifers
v. To estimate the groundwater velocity and replenishment potential of the deeper aquifers

Statement of the Problem

Central Ground Water Board, Government of India has started a program for mapping the aquifers in India. This program is designed to make a significant step forward in groundwater resource management by identifying and mapping aquifers, quantifying the available groundwater resources potential and proposing plans appropriate to the scale of demand, aquifer characteristics and the institutional arrangements for management. This

work will be systematically implemented in the country, by involving organisations / institutions across India.

Alluvial aquifers are primarily composed of thick unconsolidated Quaternary deposits made up of alternating sequences of sand, silt and clay in various proportions. The major part of water demand in these areas is catered from groundwater which is by and large copiously available because of potential nature of aquifers as well as adequate recharge from rainfall. Western part of the Upper Yamuna Plains has a good irrigation canal network of Western Yamuna Canal, which originates from Hathnikund barrage in Yamunanagar district of Haryana. The unconfined aquifers in the study area are expected to be recharged by seepage from canal network and irrigation return flow apart from rainfall, which is the major source of recharge. The canal water originating at higher altitudes in the Himalayas has different isotopic composition ($\delta^{18}O$ and δD) as compared to the groundwater locally generated in the Upper Yamuna Plains.

Deeper aquifers in the area are supposed to be recharged from the Bhabhar zone, the coarse material deposited as alluvial fans on the margin of Himalayas. Groundwater velocity in the deeper aquifers is expected to be very slow, thus groundwater dating (^{14}C) should give an idea about the groundwater flow direction as well as groundwater velocity in the deeper aquifers. If there is vertical recharge through the semi-confining layers, the same should be easily detected by Tritium dating.

Thus, isotope based investigations can help understanding the surface water and groundwater interactions, aquifer-aquifer interactions, groundwater dynamics and identification of recharge sources and recharge areas of deeper aquifers for taking better management strategies**.**

Action Plan: The action plan for the next 6 months is given below.

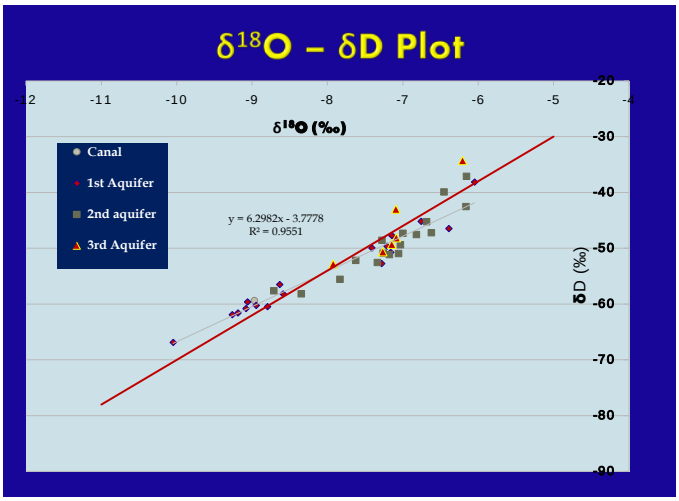
Activity	**1st Quarter**	**2nd Quarter**
Construction of aquifer geometry based on available data / information	*	
Collection of groundwater and river /canal/rainfall samples for chemical and stable isotope analysis	*	
Chemical and stable isotopic analysis of samples	*	*
Tritium samples analysis and dating	*	*
Collection of samples for ^{3}H-He dating	*	
^{3}H-He sample analysis at IAEA	*	*
Collection of samples for ^{14}C dating	*	
^{14}C samples analysis at IAEA designated laboratory	*	*
Interpretation of data	*	*

Objectives vis-à-vis Achievements

1. Most of the data available with CGWB has been collected.

2. Groundwater sampling from 21 wells ranging in depth from 100-420 m have been collected from UP side.
3. Carbon-14 and Carbon-13 analysis of 14 samples has been completed.
4. Sampling locations from Haryana side have been finalised.
5. Construction of aquifer geometry based on available data / information is under progress.
6. Analysis of groundwater and river/canal/rainfall samples for chemical and stable isotope analysis is under progress.

Analysis and Results : Results of isotopic analysis obtained so far are shown in figure below.



Future Plan

1. Collection of samples from rest of the identified locations
2. Analysis of samples for stable isotopes
3. Analysis of physico-chemical parameters
4. Dating of deeper groundwater

5. PROJECT REFERENCE CODE: NIH/HID/INT/2013-15/3

Title of the Study : **Estimation of Radon Concentration in Waters and Identification of Paleo-groundwater in Part of Punjab Located in Satluj River Basin using Isotopes**

Study Team : S. K. Verma (PI)
S. P. Rai (Co-PI)
M. S. Rao
C. P. Kumar
Mohar Singh

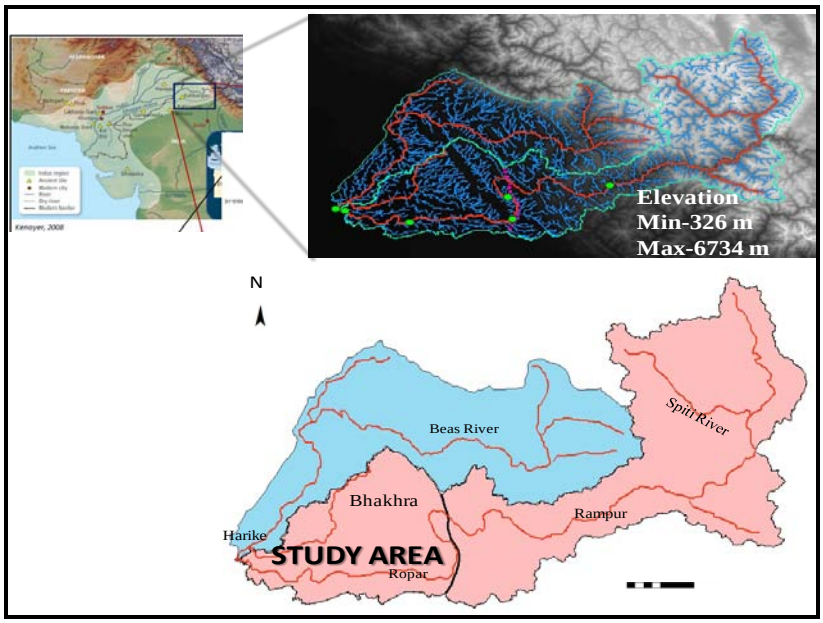
Type of Study : Internal

Date of Start : October 2013

Date of Completion : September 2015

Study Area :

A part of Punjab located in Satluj river basin has been selected for the present study. The Satluj river is the main tributary of Indus river which originates from Mansarovar lake of Higher Himalayas at an altitude of approximately 4500 m. Punjab is the northwestern state of India which is presently hotspot of groundwater depletion due to intensive irrigation. In Punjab, groundwater declining rate is highest in any other comparable-sized region on Earth (Rodell et al., 2009).



Study Objectives

- To measure radon concentration in water
- To identify the paleo-groundwater in the study area

Statement of the Problem

Radon (^{222}Rn) is a radioactive, colorless, odorless, tasteless noble gas, occurring naturally as the decay product of Uranium. It has a half-life of 3.8 days. Radon gas is considered to be a health hazard due to its radioactivity. It can cause serious diseases like lung cancer if it exceeds certain limit. It has been found that in a country like USA, more than 25,000 deaths occur every year due to high radon concentration in water as well as in air. High concentrations of radon have been observed in certain parts of India also during preliminary studies carried out by various investigators. Therefore, a National Working Group has been constituted by Government of India to study the radon concentration in different materials. NIH has been entrusted to study the radon concentration in waters. Keeping in view the facts mentioned above, this study is proposed to be carried out in parts of Satluj river basin, Punjab to meet out first objective of the study.

Paleo-groundwaters are those groundwaters which are thousands years old. People are drawing groundwater from deeper aquifers without the knowledge of their dynamics. Some of the deeper aquifers may have paleo water which may not serve the needs for water supply for longer time. However, such sources can be used to fulfill some specific needs. Therefore, there is a need to map the paleo-waters to avoid huge investments on other industrial and/or urbanizational developments in such areas. Keeping this in view, the mapping of paleo-groundwater is proposed in the study area where tapping of deeper aquifers has been started at large scale.

Brief Methodology

In order to study the radon contamination in the study area at different locations, different kinds of water samples i.e. river water, lake water, groundwater from shallow as well as deeper aquifers will be collected for in-situ radon measurement. Spatial and temporal variation of radon concentration in different kinds of waters will be studied. The groundwater samples from shallow/deeper aquifers for existing hand pumps, open wells and tube wells will also be collected for tritium and ^{14}C measurement. The hydro-geological data will also be collected for the study area in order to study the hydrogeological features to be linked with the radon concentration in waters and paleo-groundwater.

Action Plan

S. No.	Activity	Oct. 2013 to Sept. 2015							
		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 water samples for radon measurement and tritium analysis, analysis of radon concentration		♦	♦	♦	♦			
4.	Laboratory analysis of			♦	♦	♦			

	groundwater samples for tritium measurement								
5.	Collection of groundwater samples for ^{14}C measurement					♦	♦		
6.	Laboratory analysis of groundwater samples for ^{14}C measurement						♦	♦	
7.	Interpretation of isotopic data						♦	♦	
8.	Preparation of interim report				♦				
9.	Preparation of final report							♦	♦

Objectives vis-à-vis Achievements

S. No.	Objective	Achievement
1.	To measure radon concentration in water	Radon concentration has been analysed at 19 sites in three districts of Punjab located in Satluj river basin during the field visit undertaken during 4-8 Feb. 2014.
2.	To identify paleo-groundwater in the study area	A total of 19 groundwater samples from intermediate/deep aquifer using tube wells for drinking water supply have been collected for analysis for tritium dating.

Analysis and Results

- The analysis of radon concentration has been carried out for a total of 19 groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the study area.
- It is found that the radon concentration in water varies from 2 Bq/litre to 15 Bq/litre in district Jalandhar, from 3 Bq/litre to 18 Bq/litre in district Kapurthala and from 1 Bq/l to 5 Bq/l in district Ludhiana. These values fall under the safe limit recommended by the World Health Organization (WHO) for drinking water i.e. 100 Bq/litre.
- The electrical conductivity and pH of groundwater samples were also measured at 19 locations at the time of sampling.
- In addition to above, a total of 19 groundwater samples were collected from intermediate/deep aquifers using tube wells for drinking water supply each from 19 locations. These samples are being analysed for tritium dating using Tritium Enrichment unit and Quantulus available in Nuclear Hydrology laboratory.

Future Plan: As per activity chart.

6. PROJECT REFERENCE CODE: NIH/HID/INT/2014-16/1

Title of the Study : **Sub-marine Groundwater Discharge and Sea-water Intrusion in Coastal Aquifers of East Coast, India**

Study Team : M. S. Rao (PI)

(Since the study area is ~2000 km coast length in east coast of India covering West Bengal, Orissa, Andhra Pradesh and Tamil Nadu states, therefore one person representing each state from academic/state government/research institute will be included in the study and also one "Senior Resource Person" is required at Roorkee to coordinate the work)

Type of Study : Internal

Date of Start : June 2014

Date of Completion : May 2016

Location Map : To be presented during the meeting

Study Objectives

a. To identify seawater intrusion (SI) and submarine discharge zones (SGD) in east coast, India
b. Aquifer characterization in east coast, India
c. Geochemical and isotope characteristics in East Coast, India
d. Seawater Intrusion assessment using MODFLOW/SEWAT model

Statement of the Problem

In the coastal aquifer, the difference in hydrostatic pressure between groundwater and seawater results into fresh groundwater discharge into the sea as submarine groundwater discharge (SGD) or inflow of seawater into groundwater system as seawater intrusion. SGD and seawater intrusion (SI) are the pathways of interaction between groundwater and sea. Seawater intrusion and SGD are the issues of global importance. The change in sea level (due to climate change or tidal effects) and groundwater levels (due to excess withdrawal, land use change, climate change etc.) influence both SGD and SI. While SGD is the direct loss of freshwater to sea, the seawater intrusion causes groundwater salinization thereby reducing the available freshwater volume. It is also known that SGD causes loading of nutrient and release of contaminant near shore line. This rise of concentration of nutrients, nitrates, phosphates etc. above the concentration levels of the ambient seawater also results into increased biological activity at the location of SGD. Although, the SGD flow rates are very low but the total SGD flux to sea may be significant considering the areal extent of delta region and the depth over which the release of SGD occur. With the increasing population, demand of freshwater is growing accordingly, therefore mapping the zones of SGD and SI for sustainable coastal groundwater management practices is becoming increasingly important at global scale.

The east coast, India covering a total of ~2000 km shore line length includes the coastal areas of West Bengal, Orissa and Tamil Nadu. As on date, no study is available that provide SGD and SI map of the east coast, India. The present study intends to provide SGD and SI map of east coast, India using multi-techniques approach.

Methodology

In the present study, it is proposed to map the safe zones, vulnerable zones and potential risk zones for groundwater withdrawal by delineating areas of SI and SGD through a detailed coastal survey, field based data generation and modelling. SI and SGD will be assessed by analyzing groundwater for physico-chemical parameters (major ions, EC, temperature, etc.) and isotopes (stable isotopes - δD & $\delta^{18}O$ and ^{222}Rn) analysis of groundwater samples. Gradients and fluctuations in these parameters in different seasons alongwith various geologic cross-sections will be interpreted in terms of temporal and spatial fluctuations in the SI and SGD patterns. Long term data on water table, rainfall pattern, pattern of coastal algal bloom etc. will also be collected to interpret the effect of SI and SGD on the coastal environment. Based on the extensive literature survey and this study, a review report will be prepared. Sensitive parameters to fingerprint SI and SGD will be identified. The data generated will be modelled for its use to sustainable management of east coastal groundwater aquifer system.

Action Plan

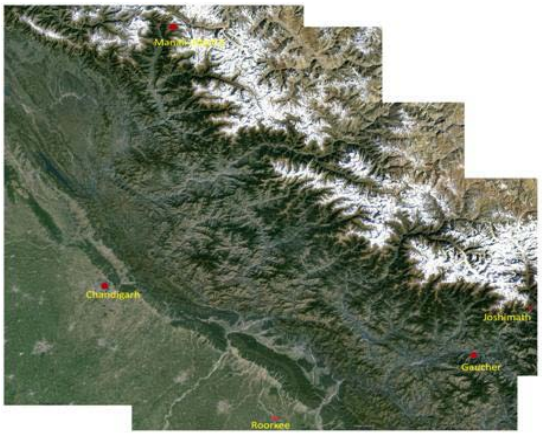
S. No.	Work Elements	Months					
		1-4	5-8	9-12	13-16	17-20	21-24
1	Literature survey and data collection	←	—	—	→		
2	Field work for sample collection		←	—	—	→	
3	Sample and data analysis			←	—	—	→
4	First year report			←	→		
5	Modelling (calibration and analysis)			←	—	→	
6	Training workshop				←	—	→
7	Publication & final project report					←	— →

7. PROJECT REFERENCE CODE: NIH/HID/INT/2014-16/2

Title of the Study : **Monitoring Isotopes in Air Moisture in Parts of Himalayas (Himachal Pradesh & Uttarakhand) for investigating the Cloud Condensation** (New Study)

Study Team : M. S. Rao (PI)
C. P. Kumar
Gopal Krishan

Type of Study : Internal
Date of Start : June 2014
Date of Completion : May 2016
Location Map



Study Objectives

1. Spatial and temporal variations in change in specific humidity across Shivalik-Himalayan region
2. Identification of sources of air moisture in different seasons
3. Monitoring the isotopes in air moisture during events of heavy rains and cloud bursts

Statement of the Problem

Atmospheric water vapours play key role in the precipitation events. The isotopic composition of local precipitation is primarily controlled by regional scale processes such as trajectories of the water vapour transport over the continents and the average rainout history of the air masses giving precipitation at a particular place. Stable isotope variation of atmospheric water vapour is controlled by the source of moisture origins, transport trajectory and moisture quantity. The wind transport trajectory is very complex within the Shiwalik-Himalayan region, as found from the results of IWIN study. The observations in IWIN study also demonstrated that increasing flux of monsoon vapour depletes the $\delta^{18}O$ of atmospheric vapour content and enrichment during the withdrawal process. The phase lags between depletion and withdrawal at four stations, two in plains and two in Himalayas, will be closely monitored to decipher the moisture circulation and the condensation process leading to mild to heavy rains in this region.

Methodology

1. Collection of ground level vapour (GLV) samples using condensation method at all the stations
2. Collection of hydro-meteorological data of all sampling stations
3. Monitoring of isotopes in air moisture - before, during and after the rain event - at Roorkee using recently installed laser based mass spectrometer to investigate the isotopic changes in vapour during moisture condensation process
4. Establishing a relation between direct vapour analysis (using laser based isotope analyser) with condensation based measurements
5. Use of results at 3 and 4 to investigate moisture condensation process in hilly regions from the condensation based sample analysis
6. Results of 2 and 5 will be integrated to attain the objectives of the study.

Action Plan

Year	June 2014 to May 2016	Remark
June 2014 to May 2016	Establishment of the sampling stations at Joshimath (Uttarakhand) and Chandigarh Daily air moisture sampling from Joshimath, Chandigarh, Roorkee, Manali Collection of Hydro-meteorological data Analysis of samples	Report preparation as per table below.

Activity Schedule (June 2014 to May 2016)

Activity	1st (Jun-Sep 2014)	2nd (Oct 2014 – Mar 2015)	3rd (Apr – Sep 2015)	4th (Oct 2015 – May 2016)
Establishing the sampling stations at Joshimath and Chandigarh	♦			
Daily sampling of air moisture and analysis	♦	♦	♦	♦
Collection of hydro-meteorological data	♦	♦	♦	♦
Annual Report/Publications		♦	♦	♦
Final Report				♦

The study proposal was submitted to Director, NIH in December, 2013 and the approval is awaited.

8. PROJECT REFERENCE CODE: NIH/HID/DST/2007-13

Title of the Study : **National Program on Isotope Fingerprinting of Waters of India (IWIN)**

Study Team : M. S. Rao (PI)
Sudhir Kumar
S. P. Rai
S. K. Verma
P. K. Garg
Gopal Krishan

Type of Study : Sponsored
Funding Agency : Funded by DST (vide IR/54/ESF/05-2004 dated July 17, 2007)
Budget : 63.34 lakhs
Date of Start : July 2007
Date of Completion : December 2013 (Completed)
Location Map

Samples were collected by NIH from 8 sites (Roorkee, Sagar, Jammu, Kakinada, Tezpur, Kanpur, Manali and Patna) and member organizations collected samples from 85 sites all over India.

NIH-IWIN SAMPLING LOCATIONS MAP

Location	Altitude (m)	Distance from Sea (km)	Starting Date
Roorkee	268	1545	Jul. 2007
Sagar	527	867	Apr. 2008
Jammu	292	1973	Apr. 2010
Kakinada	2	19	May 2010
Tezpur	48	640	May 2011
Kanpur	128	957	Jul. 2011
Manali	3000	1610	Sep.2011
Patna	53	550	Jun. 2012

Study Objectives (NIH+IWIN members)

1. Identifying regional/local water vapour components in the local atmosphere
2. Residence time and exchange estimate of vapour/water in different hydrological units
3. Identifying dominant sources of water vapour supply (Arabian sea/ Bay of Bengal/local and long distant continental sources) during different seasons
4. Isotopic database development

Statement of the Problem

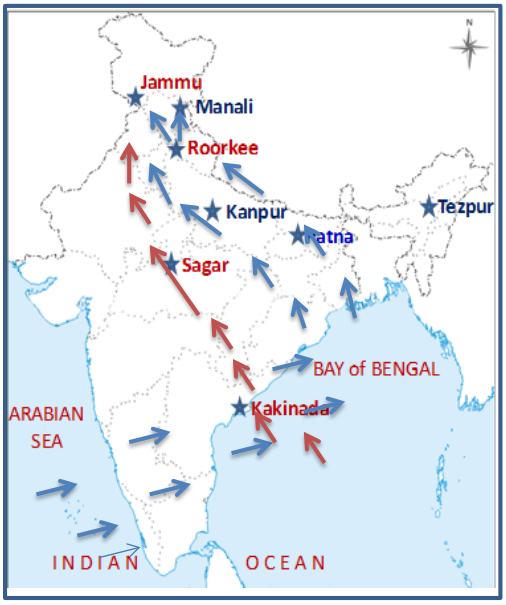
To identify the source of air moisture during different seasons, isotopic database development and support the IWIN-members in sample analysis.

Objectives vis-à-vis Achievements

Objective	Status	Work Done
Identifying regional/local water vapour components in the local atmosphere Identifying dominant sources of water vapour supply (Arabian sea/ Bay of Bengal/ local and long distant continental sources) during different seasons	Achieved	Characterized the continental moisture (Arabian sea, Bay of Bengal), regional moisture (Ganga basin), local moisture (at individual locations). The interpretation for the local moisture dynamics has been supported with Rose Plots for wind pattern analysis.
Isotopic database development	Achieved	Isotopic database has been developed for approximately 24000 samples =10000 (NIH) + 14000 (PRL)

Analysis and Results

- A total of 9800 samples of air moisture, groundwater, Upper Ganga Canal and precipitation were collected by NIH and out of these, about 8000 samples were analysed for stable isotopes of $\delta^{18}O$ and δD.
- The atmospheric water vapours received during SW monsoon period are always depleted as compared to the vapours received during non-monsoon period. The extent of depletion in isotopic composition of moisture and period over which this depletion continues, is directly linked with monsoon strength (intensity, episodes and duration). Therefore, isotopes may be used to track movement of monsoon vapours. Regional influx of moist vapour and the South-West monsoon transect was established.



South-West Monsoon Transect

- The isotopic analysis confirms the continental and altitude effects which were earlier deciphered by precipitation.
- The isotopic data analysis validates the impact of local moisture on rainfall and help in

resolving the moisture sources in different seasons.

- Roorkee receives air moisture from various sources such as Arabian Sea, Indian Sea, Mediterranean Sea (Western disturbance), local and regional sources.
- The isotopic composition of air moisture can be applied for finding the onset of monsoon.
- The isotopes of air moisture can be used for studying the climatological conditions.
- The study of groundwater samples on western and eastern side of Upper Ganga Canal reveals that major groundwater type is Ca^{2+}-Mg^{2+}- HCO_3^- .
- Upper Ganga Canal seepage to groundwater is more on eastern and south–east side of Upper Ganga Canal since for the same effect it is covering more distance on eastern side in comparison to western side. Further, the influence of Upper Ganga Canal on groundwater is found to decrease with the distance increasing away from the Upper Ganga Canal. The rate of decrease is observed to be rapid in western side as compared to the eastern side and south-eastern side. The higher interaction in the south-east direction is probably due to combination of topographic slope and geometry of the Upper Ganga Canal.
- Higher values of certain parameters such as Nitrate, Fluoride, Bicarbonate, hardness at certain hand pumps indicate the unfitness of water for drinking purpose due to some local contaminant. Hence, it is suggested that any groundwater source in the study area be analyzed /monitored before the use for domestic and drinking purposes.

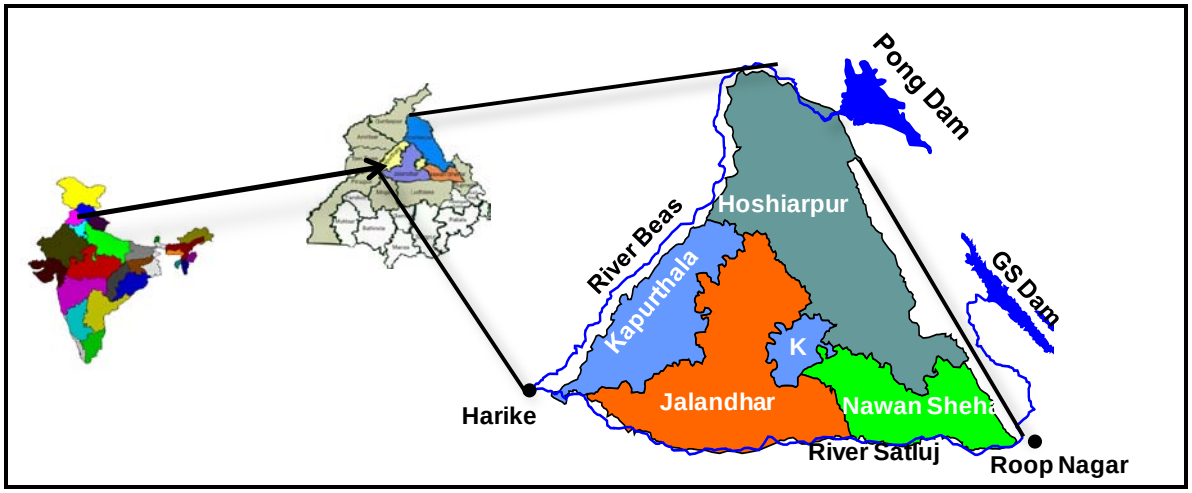
Results of the study have been published in 7 International journals, 4 National journals, 9 International conferences, 5 National conferences. One book and one book chapter were also published under this project. Project completion report has been submitted to DST, New Delhi.

9. PROJECT REFERENCE CODE: NIH/HID/HP-II/2008-13

Title of the Study	:	**Groundwater Dynamics of Bist-Doab Area, Punjab using Isotopes**
Study Team	:	M. S. Rao (PI) Sudhir Kumar S. K. Verma P. K. Garg Gopal Krishan CGWB Officials
Type of Study	:	Purpose Driven Study (HP-II)
Funding Agency	:	World Bank
Budget	:	121.79 lakhs
Date of Start	:	October 2008
Date of Completion	:	March 2014 (Completed)

Location Map

The Bist Doab is a triangular region and covers an area of 9060 km^2. The area lies between 30^{0}51' and 30^{0}04' N latitude and 74^{0}57' and 76^{0}40' E longitude. It comprises the districts of Hoshiarpur, Kapurthala, Jalandhar and Nawanshahar and part of the district of Roop Nagar of Punjab State, India. It is bounded by Shiwaliks in the north-east, Beas river in the north east-south west and Satluj river in south east-south west. The area is drained by the perennial rivers Satluj and Beas and their tributaries. They coalesce at the Harike. The climate of the area is influenced by the Himalayas in the north.



Study Objectives

Identifying groundwater recharge zones and recharge sources using groundwater dating and stable isotope techniques; groundwater modeling.

Statement of the Problem

The Bist-Doab region, the region between Satluj river and Beas river, experiences high amount of groundwater depletion due to increased agricultural activities. Hence, it is imperative to identify the recharge zones and recharge sources of groundwater.

Action Plan

Activity	2013-2014
Quarter ⟶	4th
Sample collection of groundwater, surface water, precipitation	✓
Surface water and groundwater data processing	✓
Identification of recharge zones and recharge sources	✓
Integration of water quality, stable and radioactive isotope data and field data along with modelling to develop a general scenario for groundwater flow in aquifers	✓
Publications and reporting in conferences	✓
Preparation of final report	✓

Objectives vis-à-vis Achievements

Objective	Status	Work Done
Identifying groundwater recharge zones and recharge sources using groundwater dating and stable isotope technique; and groundwater modelling	Recharge sources and zones for shallow and deep groundwater have been refined.	*Stable Isotopes & Environmental Tritium:* 716 samples (SW, GW and rain) have been collected from October 2012 to March 2013 making a total of 4477 samples (4477 for stable isotope and 170 for environmental tritium) collected during the entire study period. *Status of Sample Analysis:* Analysed 457 samples for stable isotopes and 28 samples for environmental tritium since last working group meeting. *Water Chemistry:* The groundwater samples collected during pre and post monsoon periods of 2011 have been analysed for water quality using Ion Chromatograph and interpretation of data has been carried out (these results will be presented in the working group meeting).
	Analysed	Analyses of water samples for stable isotopes, environmental tritium and water quality.

Analysis and Results

Analysis of water level data of Bist Doab region clearly depicted very high rate of groundwater depletion both in shallow and deep aquifers in central Bist Doab region. Using isotopes, groundwater recharge conditions have been mapped. The deeper aquifers, on which the irrigation sector is relied upon, are not getting recharged in Bist Doab plains. Over 60% of the groundwater recharge is taking place in Shiwalik-Kandi region and this recharge is taking a few decades for reaching to central Bist Doab region. Recharge of groundwater along the flood plain of the Beas river is supporting only the local area over a distance upto few kilometres from the river stretch.

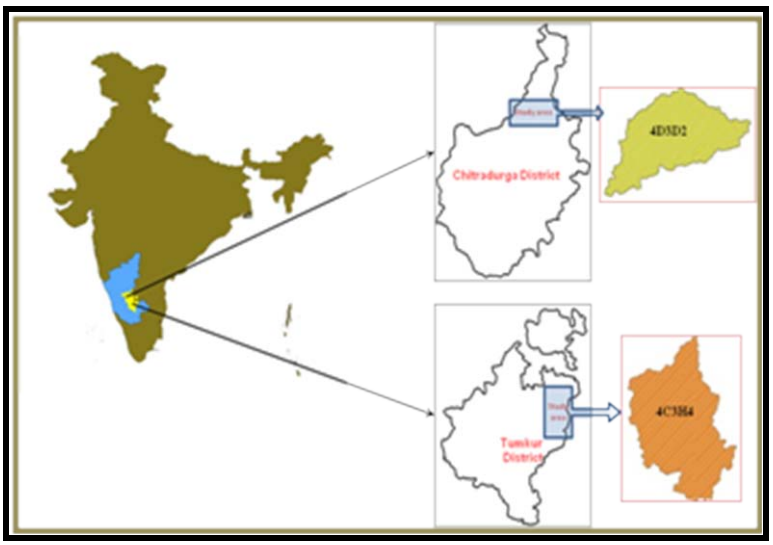
The pressure building on groundwater can be reduced to large extent through bypassing a component of the Beas river water through central Bist Doab region and also through trapping storm water of monsoon streams. A map of link canal to bypass the Beas river water through central Bist Doab region and sites for developing check-dams to trap the monsoon stream run-off has been provided in the detailed report. These steps along with some other conventional techniques (as detailed in the report) can rejuvenate the groundwater reserve to a large extent. If the measures to rejuvenate the groundwater in central Bist Doab plains are not timely taken up, the situation may worsen and can become irreversible.

Results of the study have been published in Journals (4) and Conferences (16). The final report has been prepared.

10. PROJECT REFERENCE CODE: NIH/HID/HP-II/2008-14

Title of the Study	:	**Groundwater Management in Over-Exploited Blocks of Chitradurga and Tumkur Districts of Karnataka**
Study Team	:	Sudhir Kumar (PI) J. V. Tyagi S. P. Rai Anupma Sharma B. K. Purandara C. Rangaraj
Type of Study	:	Purpose Driven Study (HP-II)
Funding Agency	:	World Bank
Budget	:	79.6 Lacs
Date of Start	:	October 2008
Date of Completion	:	March 2014

Location Map



Study Objectives

i) To analyze groundwater productivity at specific study sites including artificial recharge structures and an assessment of potential increases and their contribution to rural livelihood improvement

ii) To develop integrated understanding of hydrologic, social, economic, and institutional perspectives

iii) To improve stakeholder engagement and community participation for developing a common vision, goal and partnership for managing basin's groundwater resources

iv) To identify anthropogenic interventions and evaluate their likely impact for effective groundwater management

v) To arrive at a model for management and regulation of identified over-exploited blocks on an operational basis

Statement of the Problem

Today groundwater resources are exploited as a common pool resource in an open access framework by one and all. This has resulted in over-exploitation of groundwater resources leading to falling groundwater levels and deterioration of groundwater quality. There is an urgent need for formulations of guidelines for management of groundwater, particularly in hard rock areas, where water table is declining rapidly.

Analysis and Results

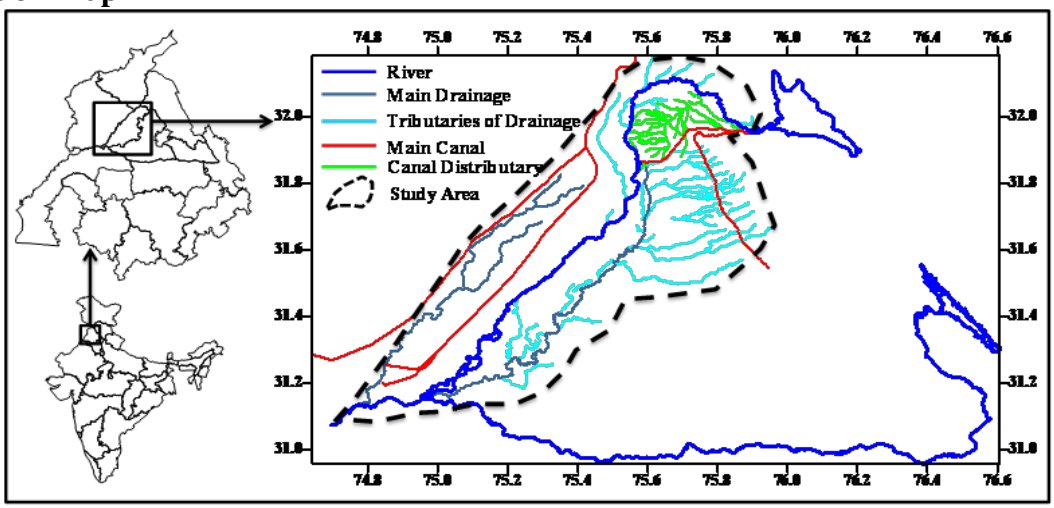
- Hydro-meteorological instruments (evaporation pan, soil moisture sensors and raingauge) and automatic groundwater level recorders were installed in the field. Evaporation rates vary from 2 mm to 8 mm per day in these watersheds. Rainfall is very erratic, both in space and time.
- GIS database has been prepared for both the watersheds including base map, drainage map, road map and water storage structures maps etc.
- Infiltration tests have been conducted at 16 locations in both the watersheds. Low infiltration rates observed in the bottom of tanks indicate chocking of tank beds.
- Water level data (depth to water level and reduced water level) and rainfall data have been collected for 14 observation wells in Chitradurga watershed (till 2011) and 15 in Tumkur watershed (upto 2011) and contours prepared. Water table fluctuates with the amount of rainfall.
- About 60 groundwater samples from Chitradurga and Tumkur watershed have been collected and analysed for stable isotopes of hydrogen and oxygen. The results indicate that irrigation tanks are not much recharging the groundwater.
- Resistivity survey has been conducted at 18 sites in both the watersheds. The results indicate availability of water in thin bands.
- Pump tests have been conducted at 4 locations. The results indicate low hydraulic conductivity.
- Socio-economic survey has also been conducted.
- A training course on “Hydrological Investigations and Water Management in Hard Rock areas” was organised in Bangalore during 18-22 March 2013.
- Isotopic studies carried out to determine the groundwater recharge from the irrigation tanks, indicated no recharge from the tanks.

Date of Completion: Completed

11. PROJECT REFERENCE CODE: NIH/HID/IAEA-1/2012-15

Title of the Study	:	**The Use of Environmental Isotopes to Assess Sustainability of Intensively Exploited Aquifer Systems in North Eastern Parts of Punjab, India**
Study Team	:	M. S. Rao (PI) C. P. Kumar S. P. Rai
Type of Study	:	Sponsored
Funding Agency	:	IAEA, Vienna
Budget	:	Euros 1500
Date of Start	:	September 2012
Date of Completion	:	August 2015

Location Map



Study Objectives

1. Assessment of depleting groundwater conditions in north-eastern parts of Punjab.
2. Identifying the regions where groundwater use has caused changes in chemical, stable isotopic composition and age of groundwater.
3. Identifying the areas where deep aquifers are getting modern recharge through their shallow aquifers.
4. Groundwater recharge/return-flow to the Beas river and Satluj river due to river water and groundwater interaction.
5. Assessment of artificial recharge measures.

Statement of the Problem

As per report of CGWB, 80% area of Punjab falls under over-exploited zone. The concentrated pumping has affected the natural groundwater conditions and flow regime. The falling water table has brought the agricultural productivity and economic conditions of the state to a plateau. Recent isotopic hydrological investigations have provided some clues on recharge conditions of groundwater diminishing zone in Bist doab. However, most of the isotope data in the earlier study was based on top aquifer and few data from a second aquifer, while the wells getting developed for irrigation and drinking needs have been entering into

the deeper aquifers. The doab region is underlain by hundreds of meters of thick alluvium. However, detailed study of groundwater age of deeper aquifer is yet to be mapped using ^{14}C dating. The present study is intended to assess the mid and long term sustainability of groundwater resources, especially in aquifers that have been providing large quantities of water over last few decades. The study region is an extended part of Bist doab region where groundwater is getting over-exploited.

Action Plan

Year	June 2014 to March 2015	Remarks
June 2014 to March 2015	Water sampling, analysis and data interpretation Report writing	Report preparation as per table below.

Activity Schedule (Quarterwise: June 2014 to March 2015)

Activity	1st	2nd	3rd
Review and synthesis of groundwater data, isotope data and hydro-chemical data, as on date	♦	♦	♦
Water sampling from piezometers and deep wells for water quality and stable isotope analysis	♦	♦	♦
Groundwater age dating investigations		♦	♦
Suggesting management measures to improve groundwater conditions in the region		♦	♦
Interim report		♦	♦

Objectives vis-à-vis Achievements

Objective	Status	Work Done
Assessment of depleting groundwater conditions in north-eastern parts of Punjab.	Under Progress	The water level data of the study area is continuously being monitored.
Identifying the regions where groundwater use has caused changes in chemical, stable isotopic composition and age of groundwater		Approximately 1000 samples have been collected and the analysis is in progress.
Identifying the areas where deep aquifers are getting modern recharge through their shallow aquifers		
Groundwater recharge/return-flow to the Beas river and Satluj river due to river water and groundwater interaction		
Assessment of artificial recharge measures		

Analysis and Results

In order to investigate groundwater and surface water interaction, groundwater sampling stations have been established at 3 cross-sections over a length of 2 km. along the Beas river - (i) stations in the northern side of Beas: Tangru, Damtal, Kathgarh, Mirthal, Jagatpur Kalan,

Dhaki, (ii) stations in the central side: Hargovindpur, Machrai, Ghuman, (iii) stations in the southern side; Govindwal, Fatehabad. About 1000 samples have been collected and the analysis work is in progress. The water level data from the Automatic Water Level Recorders installed in deep piezometers in the study area have been collected and the results will be presented during the working group meeting.

The progress of the project will also be presented at IAEA, Vienna in June, 2014.

Future Plan

- The water levels will be monitored regularly.
- The sampling will be continued for the analysis of chemical and isotopes to achieve the above objectives

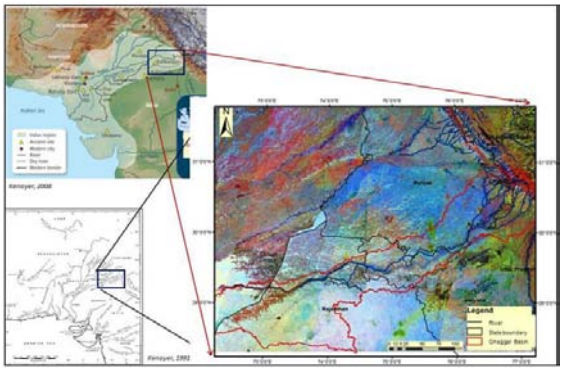
12. PROJECT REFERENCE CODE: NIH/HID/MOES/2012-15

Title of the Study : **The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates**

Study Team : S. P. Rai (PI)
M. S. Rao
Surjeet Singh
S. K. Verma
C. P. Kumar
Sudhir Kumar
V. K. Agarwal
Rajeev Gupta
S. L. Srivastava
Vishal Gupta
Mohar Singh

Type of Study : Sponsored
Funding Agency : MoES, Government of India
Budget : Rs. 210 Lakh
Date of Start : June 2012
Date of Completion : May 2015
Location Map

The study area covers the North Western India. However, Ghaghar basin has been selected to carry out detailed investigations, which covers the states of Himachal Pradesh, Punjab, Haryana and Rajasthan.



Land use: Agriculture dominated

Major problem of the area is declining of groundwater levels at a very fast rate, but at few places groundwater level is rising also.

Study Objectives

- Isotopic characterization ($\delta^{18}O$ and $\delta^{2}H$) of groundwater, stream and rain water
- Groundwater dating using Tritium and Carbon-14
- Measurement of Radon in groundwater
- Delineation of flow direction and recharge zones
- Identification of recharge source and zones of groundwater in the study area

Statement of the Problem

India is largest agricultural user of groundwater in the world. The last 40 years have seen a revolutionary shift from large scale surface water management to widespread groundwater abstraction, particularly in the northwestern states of Punjab, Haryana and Rajasthan. As a result of this, groundwater depletion of this region has become under the vulnerable condition

and a hotspot for groundwater management. The groundwater depletion rates in the states of northwestern India are reported highest in the world. This unmanaged use of groundwater becomes more challenging due to increasing demands from population and industrial developments under the climate change scenario. There is a major task to replenish the groundwater depletion through rainfall recharge. Therefore, this study has been taken-up to study groundwater dynamics in the region.

Action Plan

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Selection of study area	♦											
Literature survey	♦	♦	♦	♦	♦							
Collection of previous years data	♦	♦	♦	♦	♦							
Identification of data gaps	♦	♦	♦									
Selection of sites for stable isotope (δ^2H and $\delta^{18}O$) analysis	♦	♦	♦									
Selection of sites for radio- isotope (^3H and ^{14}C) analysis	♦	♦	♦									
Site selection and installation of raingauges	♦	♦	♦									
Measurement of δ^2H and $\delta^{18}O$ of rain, river and groundwater		♦	♦	♦	♦	♦	♦	♦	♦	♦		
Measurement of ^3H and ^{14}C activity of groundwater, rain and river		♦	♦	♦	♦	♦	♦	♦	♦	♦		
Measurement of radon in groundwater		♦	♦	♦	♦	♦	♦	♦	♦	♦		
Preparation of geological and hydrogeological maps of the study area				♦	♦	♦	♦	♦				
Preparation of water table and flow direction map on the basis of previous years data		♦	♦	♦	♦	♦						
Interpretation of isotopic data					♦	♦	♦	♦	♦	♦	♦	
Estimation of natural recharge to groundwater									♦	♦	♦	
Impact of climate change on groundwater			♦	♦	♦	♦	♦	♦	♦	♦	♦	

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Identification of recharge zones									♦	♦	♦	
First draft report										♦		
Second draft report											♦	
Final report												♦

Objectives vis-à-vis Achievements

Objectives	Achievements
• Isotopic characterization ($\delta^{18}O$ and $\delta^{2}H$) of groundwater, stream and rain water • Groundwater dating using the tritium and Carbon-14 • To decipher the recharge zone of springs falling in the study area • Measurement of Radon in groundwater • Delineation of flow direction and recharge zones • Identification of recharge source and zones of groundwater in the study area.	• Post-monsoon samples of groundwater, river and canal have been collected and laboratory analysis completed. • Enrichment completed for collected groundwater samples and further analysis is in progress. • For carbon dating, a proposal has been submitted to NERC, UK.

Analysis and Results

Isotopic Composition of Rainfall, River and Canal Water

The stable isotope data of precipitation of 12 locations of Punjab during the year 2009-2013 have been used to characterize the isotopic composition of precipitation. The $\delta^{18}O$ varies from -19.4‰ (minimum) to 9.8‰ (maximum) and $\delta^{2}H$ from -150.1‰ (minimum) to 59.1‰ (maximum). The local meteoric water line is

$\delta^{2}H = 7.9 * \delta^{18}O + 5.4$, $r^2 = 0.98$, n = 148

Ghaggar river samples have been collected from its origin near Nahan in Himachal Pradesh to downstream upto Sirsa in Haryana. The $\delta^{18}O$ of river varies from -7.3‰ to -5.3‰ and $\delta^{2}H$ varies between -50.6‰ to -43.8‰. The $\delta^{18}O$ in origin area (between Nahan to Panchkula) varies between -7.3‰ and -6.7‰ and between -50.6‰ and -46.4‰ for $\delta^{2}H$. Near Patiala and Sirsa, isotopic composition of river is found -6.1‰ and -5.3‰ for $\delta^{18}O$ and -49.8‰ to -43.8‰ for $\delta^{2}H$ respectively. The downstream samples show enrichment which is due to evaporative enrichment of river water and industrial effluent and waste water joining the Ghaggar river. The canal water samples were collected from various sites in the catchment. The isotopic variation of canal water are found between -12.1‰ and -11.5‰ for $\delta^{18}O$ and -80.9‰ and -74.9‰ for $\delta^{2}H$. The isotopic composition of canal water is depleted in comparison to Ghaggar river and local precipitation. The source of canal water is Bhakara dam, which is on Satluj river. The satluj river isotopic composition varies between -13.0‰ and -9.9‰ for $\delta^{18}O$ and -91.1‰ to -68.2‰ for $\delta^{2}H$.

The spatial variation of $\delta^{18}O$ values of groundwater of shallow depth show $\delta^{18}O$ varying between -4‰ and -12‰. The enriched $\delta^{18}O$ values are found in upper part of the catchment while depleted values in middle and lower part of the catchment. The depleted isotopic signature of groundwater in middle and lower part indicates recharge to groundwater through canal water. The depleted $\delta^{18}O$ are also found in the middle aquifer in the middle part of the basin. However, the areal extent of depleted water is lesser in comparison to the shallow aquifer. The patches of depleted groundwater (-8‰ or more than -8‰) are also found in deeper aquifer. However, the effect of canal recharge appears insignificant in deeper aquifer.

The environmental tritium activity has been measured for groundwater at different locations and it is found to vary between 0.3 TU and 8 TU. The tritium value of groundwater samples collected from shallow depths near Chandigarh and Rajpura area are varying from 5.2 TU to 6.1 TU and near Patiala and Samana, it is about 4.2 TU.

The electrical conductivity (EC) of Ghaghar river and canal water is found in the range of 400 μS/cm to 450 μS/cm and 200 μS/cm to 220 μS/cm, respectively. The canal and river water samples show low salt values than the desirable value of Indian & WHO Standards (782 μS/cm). EC ranges between 230 μS/cm and 10500 μS/cm in shallow aquifer, 260 μS/cm to 3900 μS/cm in middle aquifer and 420 μS/cm to 9500 μS/cm in deep aquifer, respectively. In shallow aquifer, EC ranges from 250 μS/cm to 2000 μS/cm in upper reaches of study area, 500 μS/cm to 1000 μS/cm in middle part of study area and 1000 μS/cm to 10500 μS/cm in lower part of study area. The southern part of the basin is more saline.

Future Plan

- Pre-monsoon sampling of groundwater for stable and radio isotope measurements, rainfall sampling to continue
- Analysis of water level data and estimation of volume of water withdrawn
- Preparation of hydrogeological map of the study area
- Estimation of canal recharge to groundwater

13. PROJECT REFERENCE CODE: NIH/HID/BGS/2013-14

Title of the Study : **Review of Groundwater Resources in the Indo-Gangetic Basin: A Case Study on Resilience of Groundwater in the Punjab to Withdrawal and Environmental Change**

Study Team : M. S. Rao (PI)
C. P. Kumar
Gopal Krishan
Type of Study : Sponsored
Funding Agency : BGS-DFID
Budget : £ 28,900
Date of Start : February 2013
Date of Completion : September 2014
Location Map: Indo-Gangetic basin (Punjab, Haryana, UP, Bihar and West Bengal)
Study Objectives

1. Overview of the occurrence and status of groundwater resources in the Indo-Gangetic Basin (IGB)
2. To carry out a case study examining the residence times of groundwater across a rainfall transect in heavily exploited, Punjab

Statement of the Problem

The Indo-Gangetic plains support one of the most populous areas on the earth. It is home to approximately one billion people. The economy, poverty and health of the region are highly diverse and include areas of extreme poverty as well as highly successful and growing economies. Exploiting easily accessible water resources for drinking water, agriculture and growing industries has been fundamental to the region's success and will continue to play a large part in its future. Despite the presence of the large rivers, groundwater is highly exploited across the basin. Within the Indo-Gangetic basin, groundwater condition has reached to most critical condition in Punjab. As per assessment of the Central Ground Water Board (2009), the stage of groundwater development of Punjab state is 170% leaving little scope for further development of dynamic resource except in few pockets. Gravity of the situation can be gauged from the fact that stage of groundwater utilization exceeded 300% in some parts of the north-east Punjab.

Considering these facts, it is proposed to prepare a report on groundwater availability in the Indo-Gangetic basin and to examine the case in detail across heavily exploited region of Punjab.

Action Plan

Year	June 2014 to September 2014	Remark
June 2014 to September 2014	Preparation of a status report on resilience of groundwater in Punjab to withdrawal and environmental change	Report preparation, as per table below.

Activity Schedule (June 2014 to September 2014)

Activity	(Jun 2014 –Sep 2014)
Recharge studies in unsaturated zone including sampling and analysis	♦
Analysis of isotopic and CFC, SF6, Noble gases (NIH-BGS)	♦
Water quality analysis of samples (NIH-BGS)	♦
First draft (NIH-BGS)	♦

Objectives vis-à-vis Achievements

Objective	Status	Work Done
Overview of the occurrence and status of groundwater resources in the Indo-Gangetic Basin (IGB)	Under Progress	The water level data of 20 years have been collected for UP, Bihar, WB, Assam.
To carry out a case study examining the residence times of groundwater across a rainfall transect in heavily exploited, Punjab		Samples from deep and shallow aquifers have been collected and analysed for cations, anions and isotopes.

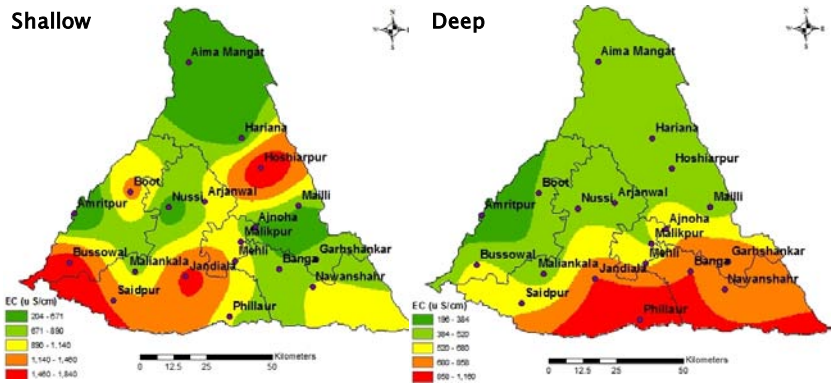
Analysis and Results

This project is broadly divided into two parts: (i) groundwater resilience in Ganga basin, and (ii) detailed case study in parts of Punjab (Bist-doab).

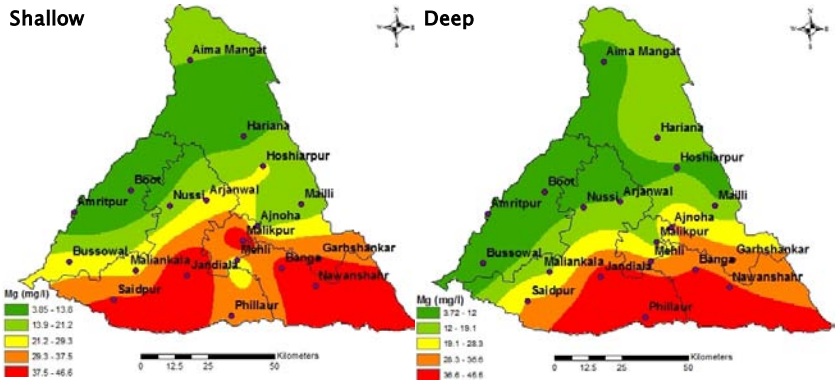
For the first part on groundwater resilience in Ganga basin: landuse maps, water level data of UP, Bihar, West Bengal and Assam have been procured and preparation of report is in progress. The radon sampling and analysis was also carried out in east coast of West-Bengal.

For the second part on detailed case study on Bist doab, Punjab: a total of 19 paired groundwater samples were collected from the deeper and shallow aquifers (tubewells and groundwater wells) on the basis of results obtained in the ongoing PDS study on Bist doab in two field visits along with the officials of BGS.

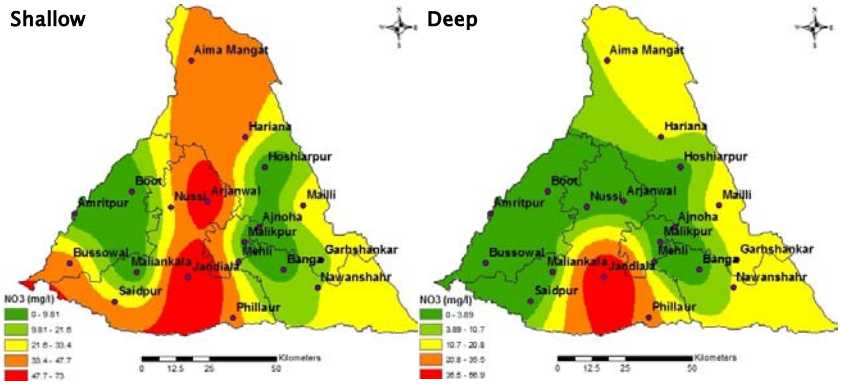
The hydro-chemical analysis of the study reveals that groundwater of the study area is very good in terms of trace metals, such as chromium, manganese and iron, however the shallow aquifer does show evidence of contamination from nitrate and trace elements including B, Zn, Pb and Cu at few sites. Uranium concentrations are high for both the shallow and deep aquifers (average concentrations >15 µg/L), however, WHO drinking water standards were exceeded in only 10% of sites investigated in this study. Arsenic concentrations were below 10µg/L on all occasions. The groundwater is well suited for irrigation based on the sodium absorption ratio.



EC map of shallow and deep aquifers



Mg^{2+} map of shallow and deep aquifers



NO_3^- map of shallow and deep aquifers

The results were also presented in the 1st review meeting conducted in New Delhi during November 4-8, 2013.

Publications

Gopal Krishan, D. J. Lapworth, M. S. Rao, C. P. Kumar, M. Smilovic and P. Semwal. 2014. Natural (Baseline) Groundwater Quality In The Bist-Doab Catchment, Punjab, India: A Pilot Study Comparing Shallow and Deep Aquifers. *International Journal of Earth Sciences and Engineering*, **7** (01): 16-26.

Alan Macdonald, Helen Bonsor, M. Someshwar Rao, Gopal Krishan, Frank Van Steenburgen, Kazi Ahmed, Mohammad Shamsudduha, Ajaya Dixit, Marcus Moench, 2013. Groundwater Topologies In the Indo Gangetic Basin, In Proc. of International Conference on Advances in Water Resources Development & Mangement held at Panjab University, Chandigarh during October 23-27, 2013.

Future Plan

The report writing work is in progress and will be submitted to funding agency by August, 2014.

14. PROJECT REFERENCE CODE: NIH/HID/IAEA-2/2012-15

Title of the Study : **Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques**

Study Team : S. P. Rai (PI)
R. V. Kale
M. S. Rao
C. P. Kumar
Sudhir Kumar
V. K. Agarwal
Vishal Gupta
Mohar Singh

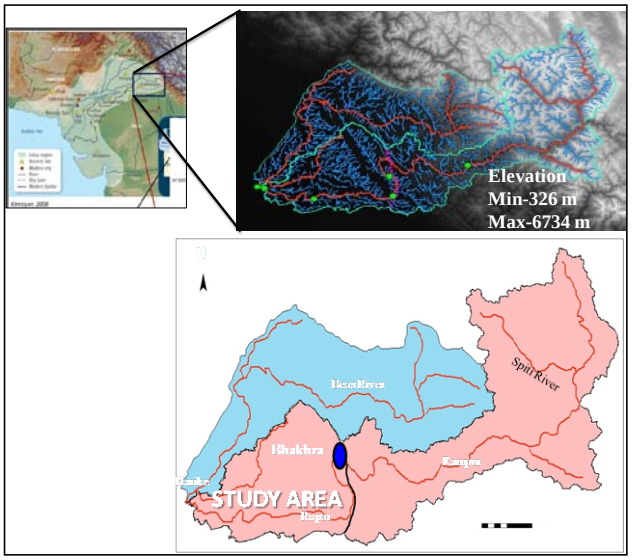
Type of Study : Sponsored

Funding Agency : IAEA, Vienna

Budget : 5000 Euro per year

Date of Start : October 2012

Date of Completion : September 2015



Location Map

The study area falls in the Punjab state of India. Groundwater levels in Punjab have reached to most critical condition. As per report of Central Ground Water Board, Government of India (2009), 80% area of Punjab state falls under over-exploited zone. With onset of Green Revolution during 1960s, the state rapidly adopted the green revolution technology and resulted in increased demand for irrigation water. The requirement of irrigation was met through development of irrigation canal network and development of tube wells. Between 1960 and 1999, the food grain production of Punjab increased from 3.16 to 22.22 million tones. During this period, number of tube wells increased from 0.60 million to 1.1 million, leading to over-exploitation of groundwater in most parts of the state. The concentrated pumping has affected the natural groundwater conditions and flow regime.

Study Objectives

- To develop thematic maps based on isotope and related information relevant to the evaluation and assessment of the quality of surface water
- Comparative study of recession characteristics of Satluj River with conceptual and isotopic model
- To assess the potential and limitations of the tracer techniques for routine application in hydrological studies

Statement of the Problem

The importance of Satluj river in Indian context is better understood from the fact that it continues to play a major role in the socio-economic development of north-western part of the country. The dependency of the states of Himachal Pradesh, Punjab, Haryana and Rajasthan on the resources of Satluj river for the sustenance and growth of agricultural and hydroelectric power sector is ever growing. In addition to several micro and mini projects, several mega projects are under way, particularly in the upper part of Satluj Basin. The runoff of Satluj river receives major contribution from snow/glacier, rainfall-runoff and groundwater/baseflow. The assessment of rainfall derived runoff and snow and glacier melt runoff have been carried out. However, contribution of the baseflow to river flow was overlooked and no major attempt has been made to assess the impact of baseflow contribution on discharge and quality of the river. Therefore, this study is a first attempt to understand the groundwater and river interaction in this part of the Satluj catchment.

Action Plan

Activity Schedule (Quarterwise: 2012-13, 2013-2014 and 2014-2015)

Activity	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Selection of study area			♦									
Literature survey			♦	♦	♦							
Collection of previous years' data				♦	♦							
Identification of data gaps				♦								
Selection of sites for stable isotope (δ^2H and $\delta^{18}O$) analysis					♦	♦	♦	♦				
Selection of sites for radio- isotope (^3H and ^{14}C) analysis			♦	♦	♦	♦	♦	♦	♦	♦		
Site selection and installation of raingauges			♦	♦	♦	♦						
Measurement of δ^2H and $\delta^{18}O$ of rain, river and groundwater				♦	♦	♦	♦	♦	♦	♦		
Measurement of ^3H and ^{14}C activity of groundwater, rain and river				♦	♦	♦	♦	♦	♦	♦		
Measurement of radon in groundwater								♦	♦	♦		
Preparation of geological and hydrogeological maps of the study area				♦	♦	♦	♦	♦				

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Preparation of water table and flow direction map on the basis of previous years' data				♦	♦	♦						
Interpretation of isotopic data					♦	♦	♦	♦	♦	♦	♦	
Application of conceptual model					♦	♦	♦	♦	♦	♦	♦	

Objectives vis-à-vis Achievements

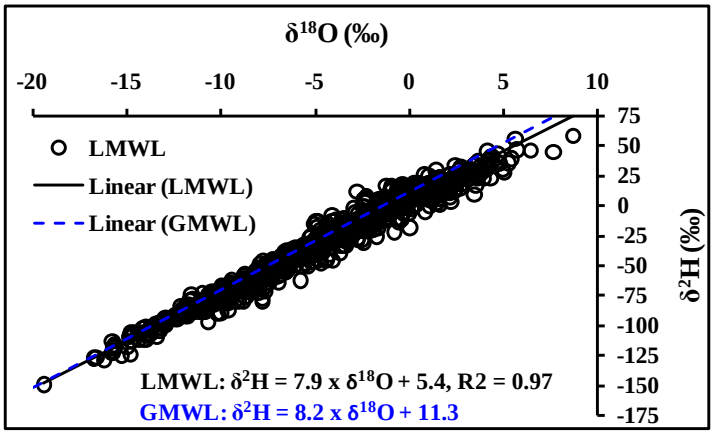
Objectives	Achievements
• Isotopic characterization ($\delta^{18}O$ and $\delta^{2}H$) of groundwater, stream and rain water • Groundwater dating using tritium and Carbon-14 • Comparative study of recession characteristics of Satluj river with conceptual and isotopic model • Delineation of flow direction and recharge zones • Comparative study of recession characteristics of Satluj river with conceptual and isotopic model	• Samples of groundwater, precipitation, river and canal collected for isotopic analysis • Groundwater samples for tritium analysis collected • Modelling in progress

Analysis and Results

Isotopic Composition of Precipitation

The isotopic composition of precipitation in the study area varies from -19.4‰ to 9.8‰ for $\delta^{18}O$ and -150.1‰ to 59.1‰ for $\delta^{2}H$. The $\delta^{18}O$- $\delta^{2}H$ bi plot of precipitation in the study area shows similarity with GMWL (Rozanski *et al.* 1993) and Indian Meteoric Water Line for the north region (IMWL- North) (Kumar *et al.* 2010). The slightly lower intercept may be due to local climate.

LMWL: $\delta^{2}H = 7.9 \times \delta^{18}O + 5.4$; $R^2 = 0.97$, n = 119
IMWL- North: $\delta^{2}H = 8.15 \times \delta^{18}O + 9.55$; $R^2 = 0.99$
GMWL: $\delta^{2}H = 8.17 \times \delta^{18}O + 11.27$; $R^2 = 0.99$

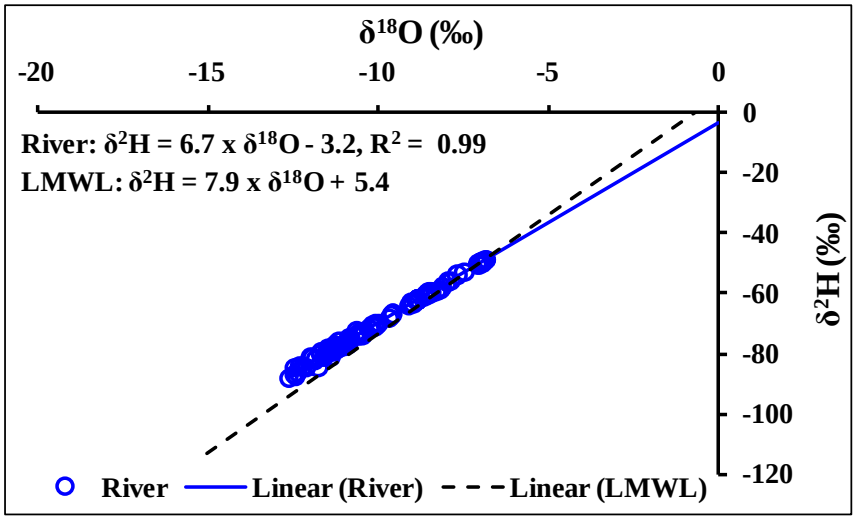


Isotopic composition of precipitation in study area

Isotopic Composition of River

The $\delta^{18}O$ of Satluj river varies between -12.7‰ to -6.8‰ and $\delta^{2}H$ varies from -87.9‰ to -48.5‰. The isotopic composition of river gets enriched as water moves from Ropar to Harike (downstream). The depleted isotopic composition of Satluj River at Ropar is due to major contribution from the higher Himalayas. As the river moves downstream, enrichment of $\delta^{18}O$ of river water is observed which may be due to contribution from groundwater. The regression lines derived for the river water is given below:

$\delta^{2}H = 6.7 \times \delta^{18}O - 3.2$; $R^2 = 0.99$, n = 98



Location map and isotopic characterization of river water in region

Isotopic Composition of Groundwater

The groundwater samples were collected from existing dug wells, hand pumps and tube wells. The depth of dug wells, hand pumps and tube wells represent different depths of water levels. The depths of open wells, dugwells, hand pumps and tube wells were collected from the sampling sites. The overall depth data indicate that hand pumps are bored up to depth of 80 m and tube wells below the 80 m depth.

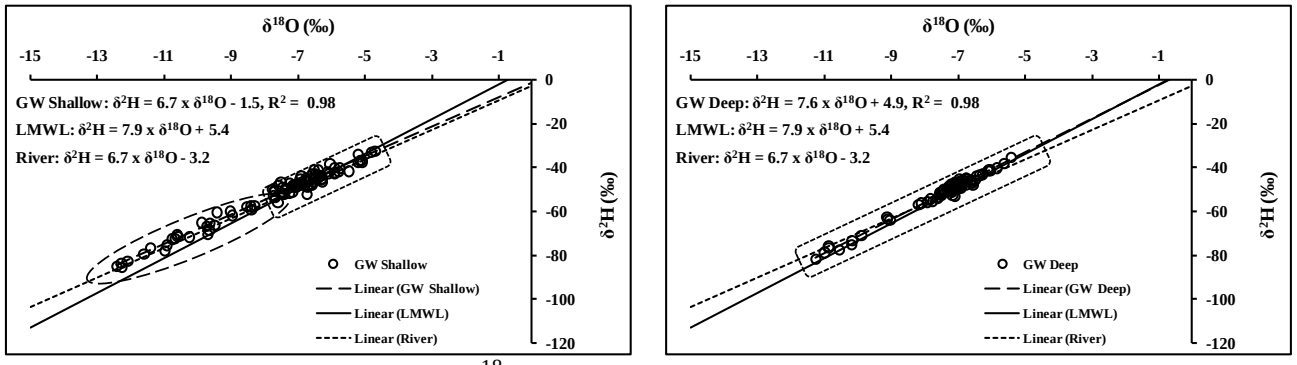
Open wells and Hand pumps = < 80 m
Tube wells of private farmers and Government = > 100 m

The oxygen isotope ratio ($\delta^{18}O$) of water samples up to depth of 80 m varied from -12.4‰ (minimum) to -4.7‰ (maximum) and hydrogen isotopic ratio ($\delta^{2}H$) from -85.1‰ (minimum) to -32.4‰ (maximum). The $\delta^{18}O$ of water samples below the depth of 100 m varied from -11.3‰ (minimum) to -5.4‰ (maximum) and $\delta^{2}H$ -81.6‰ (minimum) to -35.2‰ (maximum).

The $\delta^{18}O$ and $\delta^{2}H$ relationship for groundwater collected from depth zones of <80 m and >100 m depth has been developed. The regression analysis between $\delta^{18}O$ and $\delta^{2}H$ of the data of different depths gives the best fit line (BFL) as:

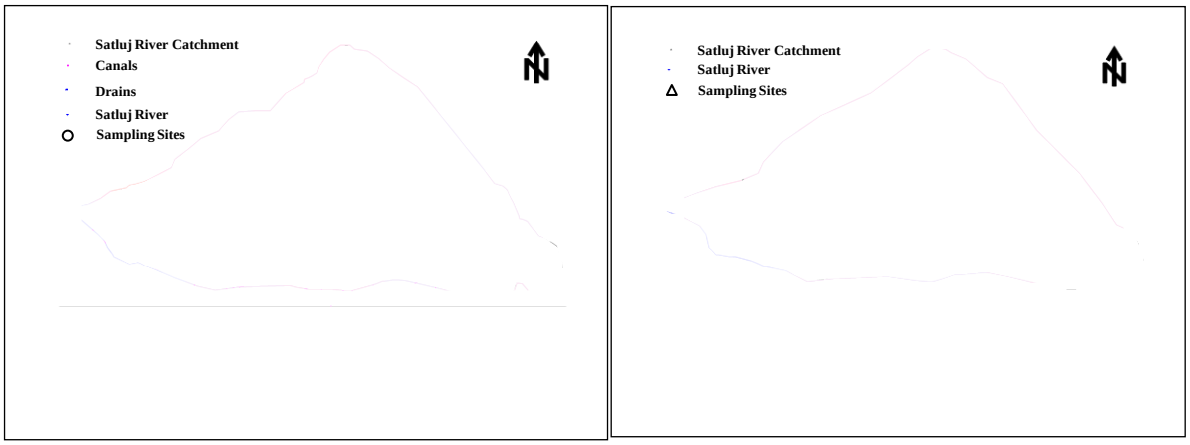
$\delta^{2}H = 6.7 * \delta^{18}O - 1.5$ (n = 96, $r^2 = 0.98$) (< 80 m)
$\delta^{2}H = 7.6 * \delta^{18}O + 4.9$ (n = 76, $r^2 = 0.92$) (>100 m)

where, n is the number of samples, r is the correlation coefficient.



Isotopic variation ($\delta^{18}O$) of groundwater in shallow aquifer

The spatial distribution of isotopic composition of shallow and deep groundwater is given in the figure below. Generally, shallow groundwater show enriched $\delta^{18}O$ and $\delta^{2}H$ values in the study area. However, at few locations, depleted values (more than -9‰) are also found due to possible recharge through river/canal. The deep aquifer shows almost similar isotopic composition throughout the study area which resembles the isotopic composition of precipitation.



Isotopic distribution of groundwater in shallow and deep aquifer

Future Plan

- Sampling of groundwater, rain and river water to continue
- Isotopic characterization of rain, river and groundwater
- Hydrochemical characteristics of groundwater and river
- Hydrograph separation to separate out baseflow component
- Identification of groundwater discharge and recharge zones
- Progress report and recommendations

15. PROJECT REFERENCE CODE: NIH/HID/IAEA-3/2013-15

Title of the Study	:	**Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains**
Study Team	:	Sudhir Kumar (PI) S. P. Rai S. D. Khobragade C. K. Jain P. K. Garg
Type of Study	:	Sponsored
Date of Start	:	May 2013
Date of Completion	:	April 2015

Progress: Same as at Project no. NIH/HID/INT/2013-15/2

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. Avinash Agarwal	Scientist F
4	Dr. R P Pandey	Scientist F
5	Dr. A K Lohani	Scientist F
6	Dr. Senthil Kumar	Scientist E
7	Dr. Sanjay Kumar	Scientist D
8	Smt. Archana Sarkar	Scientist D
9	Dr. Manohar Arora	Scientist D
10	Sri Digambar Singh	Scientist B
11	Sri J P Patra	Scientist B
12	Sri Naresh Kumar	PRA
13	Sri N K Bhatnagar	PRA
14	Sri R K Neema	PRA
15	Sri Hukum Singh	PRA
16	Sri Om Prakash	SRA
17	Sri S L Srivastava	SRA
18	Sri T R Sapra	RA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

WORK PROGRAMME OF SURFACE WATER HYDROLOGY DIVISION FOR THE YEAR 2014-15

S. No. & Ref. Code	Title	Study Team	Duration
Internal Studies			
1. NIH/SWD/NIH/11-14	Hydrological studies for upper Narmada basin.	J. P. Patra Rakesh Kumar Pankaj Mani T. R. Sapra	3 Years (April 2011 to March 2014)
2. NIH/SWHD/NIH/13-14	State-of-the-Art Report on Soil Erosion and Sediment Transport Modelling	J.V. Tyagi	1 year (4/13-3/14)
3. NIH/SWD/NIH/13-14	Suspended Sediment Flux Modelling in the largest sub-basin of Brahmaputra	Archana Sarkar Rakesh Kumar	1 year (April 2013 to March 2014)
4. NIH/SWD/NIH/12-15	Sedimentation Studies for Pong Reservoir, Himachal Pradesh	A. R. Senthil kumar Manohar Arora Suhas D Khobragade Avinash Agarwal Sanjay Jain	3 years (April 2012 to March 2015)
5. NIH/SWD/NIH/12-15	Study Of Hydro-Meteorological Droughts For Chitrakoot Bundelkhand Region In India	R.P. Pandey	3 years (April 2012 to March 2015)
6. NIH/SWD/NIH/13-16	Quantitative assessment of uncertainties in river discharge estimation	Sanjay Kumar Sharad Jain	3 Years (April 2013 to March 2016)
7. NIH/SWD/NIH/13-16	Evaluation and modeling of hydrological support system for watersheds of Garhwal, Uttarakhand hills.	Avinash Agarwal Manohar Arora RK Nema	3 Years (November 2013 to October 2016)
8. NIH/SWD/NIH/14-15	Estimation of Water Balance for Integrated Water Resources Management in Yerrakalva Pilot Basin, A.P.	J.V.Tyagi YRS Rao,	1 year (April 2014 to March 2015)
9. NIH/SWD/NIH/14-15	Status Report on “Impact of Anthropogenic and Climate Change on Sediment Load of Rivers”	Archana Sarkar	1 year (April 2014 to March 2015)
10. NIH/SWD/NIH/14-16	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar N.K. Bhatnagar Vaibhav Garg, Sc C, IIRS, Dehradun Rakesh Kumar	2 years (April 2014 to March 2016)
11. NIH/SWD/NIH/14-17	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora Rakesh Kumar	3years (May 2014 to March 2017)
12. NIH/SWD/NIH/14-17	Effect of climate change on evaporation at point scale	Digambar Singh A. R. Senthil kumar Manohar Arora	3years (June 2014 to March 2017)
13. NIH/SWD/NIH/14-17	Hydrological modelling, water availability analysis	J.P.Patra Dr. Rakesh Kumar Pankaj Mani	3years (April 2014 to March 2017)

1. PROJECT REFERENCE CODE: NIH/SWD/NIH/11-14

1. **Title of the study:** **Hydrological studies for upper Narmada basin.**
2. **Study group:** J. P. Patra, Sc. 'B'
   Dr. Rakesh Kumar, Sc. 'G' & Head
   Pankaj Mani, Sc. 'D', CFMS, Patna
   T. R. Sapra, SRA
3. **Duration of study:** 3 Years (April 2011 to March 2014)
4. **Type of study:** Internal.
5. **Location map**

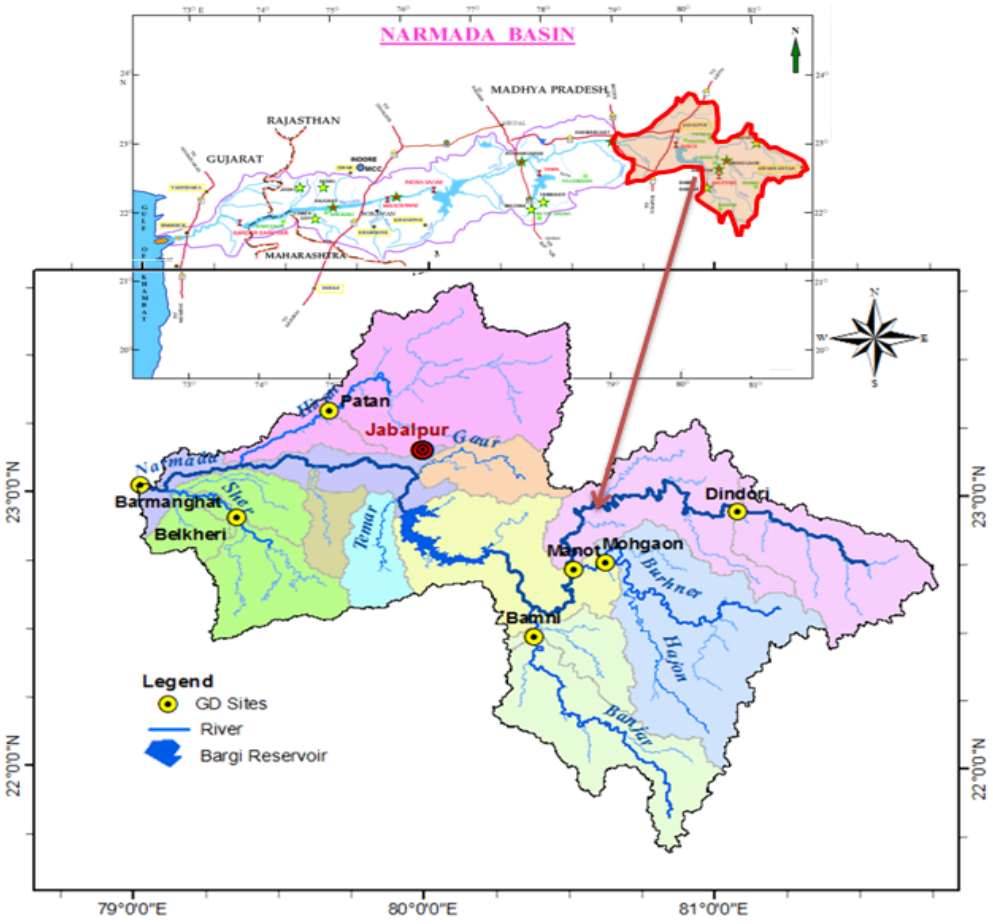


Fig. 1: Location map of study area.

6. **Study objectives:**

a) Estimation of dependable flows for some of the gauging sites.
b) Rainfall runoff modelling.
c) Estimation of floods for various return periods using L-moment for gauged and ungauged catchments.
d) Estimation of Standard Project Flood (SPF) and Probable Maximum Flood (PMF) for Bargi dam.
e) Dam break flood wave simulation.
f) Preparation of flood inundation maps for various dam break scenarios.

7. Statement of the problem

The Narmada is the largest west flowing and seventh largest river of India. The basin, edging between Vindya and Satpuda ranges, extends over an area of 98,796 km^2. The Narmada rises from a Kund at an elevation of 1057m from Amarkantak in the Maikal hill in Shahdol district of Madhya Pradesh. Bargi Dam is one of the first completed Dam out of the chain of 30 major dams to be constructed on Narmada River in Madhya Pradesh. The dam construction work started in 1974 and was completed in 1990 when the dam was filled to its complete capacity. The height of the dam is 69 m and length 5.4 km. The reservoir is about 75 km in length and 4.5 km width, spreading over 267.97 km^2 area.

Though probability of dam failure extremely low, its occurrences can imply catastrophic consequences in downstream, including loss of human lives, properties, natural resources and so on. Therefore, significant predictive data on hypothetical flood events such as flood flows, flow velocities, depths and flood wave arrival times at specific locations downstream of the dam become some the most important pieces of information for disaster preparedness. Moreover, the National Water Policy, 2002 recognized the unavailability of Emergency Action Plans (EAP) for majors dams and stressed upon preparation of EAP for all large dams. Dam break analysis plays a major role in preparing EAP. The preset study focus on dam break analysis of Bargi dam and resulting flood inundation mapping up to barmangath with a drainage area of 26, 453 km^2.

8. Approved action plan and timeline

Action	Time (month)						Status
	1-6	7-12	13-18	19-24	25-30	31-36	
Literature review Data collection							Completed
Processing and analysis of data							Completed
Modelling work							Completed
Reporting / Assessment of progress							Completed
Preparation final report							Completed

9. Role of team members

Sl No	Role / Action	Member/(s)
1	Data collection	JPP,TRS
2	Estimation of river flows of various dependability	RK
3	Estimation of basin parameters	JPP,PM
4	Estimation of floods for various return periods and PMF	RK, JPP
5	Hydrological modelling using HEC-HMS	JPP,RK
6	Dam Break analysis. Flood wave routing using MIKE-Flood and danger reach mapping	PM,JPP
7	Prepare flood inundation maps using ArcGIS	JPP,RK,PM

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

10. Brief Methodology

The river flow for some of the gauging sites for the upper Narmada river and its tributaries for various dependability are estimated. For estimating design floods the total basin area is divided into smaller size (Area < 5,000 km^2) sub-basins in order to apply unit hydrograph (UH) techniques. In this study different UH techniques such as in CWC-flood estimation report is used. The HEC-GeoHMS software is used for the delineation of basins, estimation of basin parameters then project is exported to HEC-HMS for rainfall-runoff modelling of various critical sequences of the rainfall depths. The rainfall of various return periods are estimated using L-moments based rainfall frequency analysis. Futher the PMP data is obtained from the IMD. HEC-HMS model is used for rainfall runoff modelling to obtained the inflow hydrographs at Bargi dam foe various return period and PMF. The Dam break analysis of Bargi dam for various failure scenarios is simulated using MIKE Flood and flood propagation along the river is analyzed. Further, the model output is used to prepare flood inundation maps of various scenarios.

11. Results achieved with progress/present status

The flow duration curves at seven gauging sites namely Dindori, Manot, Mohagaon, Bamni, Barmanghat, Belkari and Patan are developed for pre monsoon (March to May), monsoon (June to September), post monsoon (October to November) and winter (December to February) seasons. The equations of fitted flow duration curves with R^2 value for Barmanghat gauging sites are Figure 2.

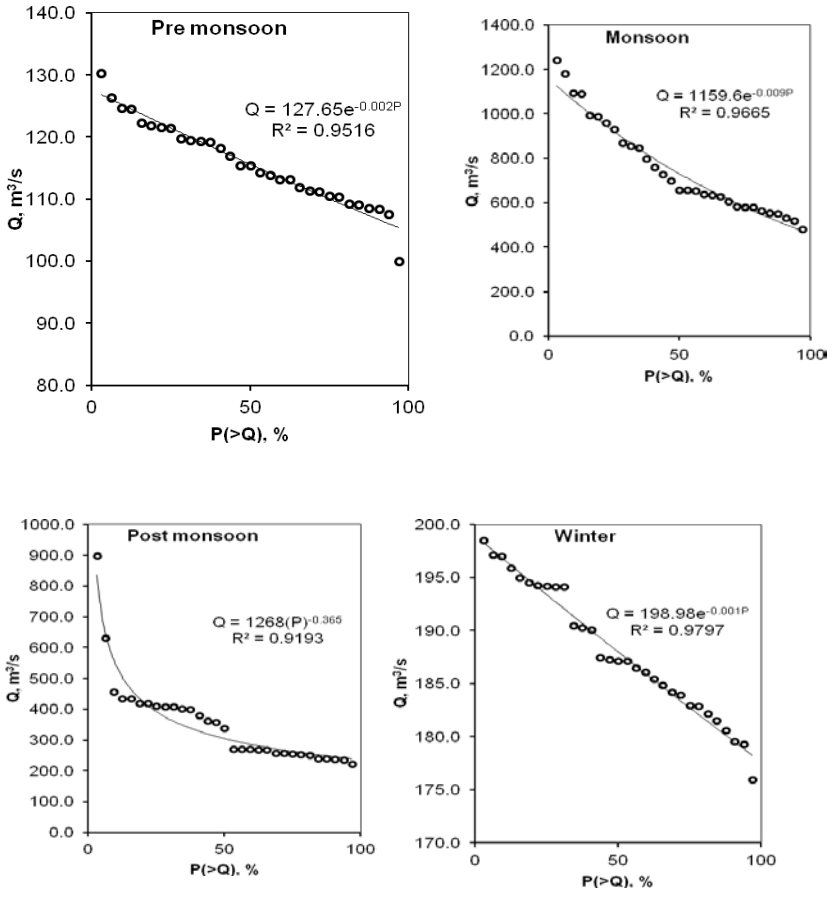


Fig. 2: Seasonal flow duration curves at Barmanghat

The catchment characteristics obtained from DEM using HEC-GeoHMS 5.0 are: Area of the catchment (A), Equivalent stream slope (S) and Length of the main stream (L). The catchment characteristics for four sub basins are given in Table 1. The parameters of UH has been derived using the above catchment characteristics and relationships given in the flood estimation report. The rainfall data available at nine raingauge station with thiessen polygon and their weights for the four sub catchments area shown in Figure 3.

Table 1 Catchment characteristics

SubBasin	A(km^2)	S(m/km)	L(km)	L_c(km)
Manot	4971.95	1.94	272.25	161.84
Manot to Bargi	3681.10	2.43	176.24	73.02
Burahnar	4012.50	2.56	174.02	88.18
Banjar	2522.14	1.46	171.20	91.27

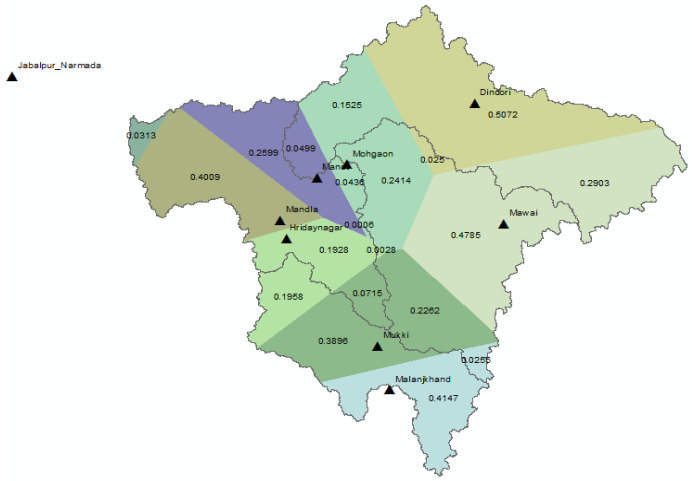


Fig. 3: Rain-gauge stations with Thiessen polygons

The 1 day and 2 day maximum rainfall for various return periods for these nine raingauge stations are estimated using L-moments based rainfall frequency analysis. The L-moments ratio diagram for Jabalpur for 1-day annual maximum rainfall is shown in figure 4 and 1-day maximum rainfall for various return periods are shown in table 2.

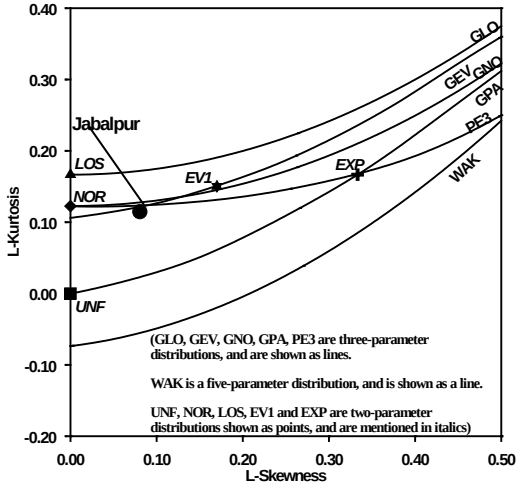


Fig. 4: L-moments ratio diagram for Jabalpur

Table 2 Rainfall for various return periods

	Return periods (year)		
Raingauge	**25**	**100**	**1000**
Malanjkhand	259.2	304.3	348.4
Mandla	190.3	242.2	355.2
Dindori	266.5	372.5	586.7
Hridayanagar	172.5	230.4	373.9
Manot	300.7	570.6	1801.7
Mawai	257.9	366.0	652.7
Mohgaon	177.4	223.7	322.5
Mukki	224.1	304.7	486.9
Jabalpur	383.9	408.1	419.9
Regional for 9 Rain-gauges	247.2	306.9	400.3

The inflows to Bargi dam for are estimated using HEC-HMS with inputs like developed SUH and estimated rainfall of various return periods etc. The inflow hydrograph due ta 1-day and 2-day maximum rainfall for various return period and PMP is shown in figure 5.

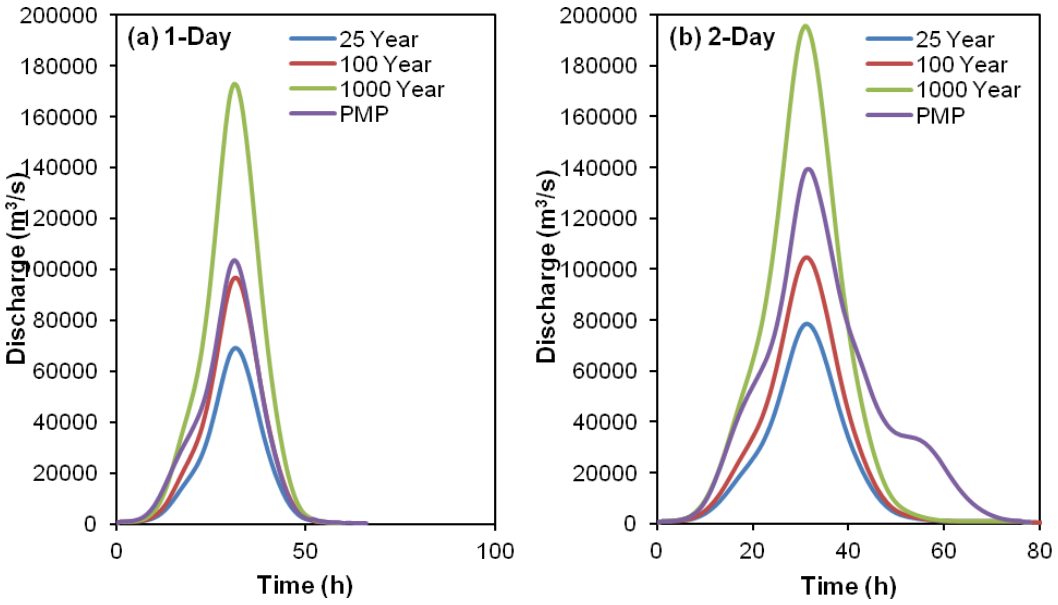


Fig. 5: Inflow hydrograph to Bargi dam

The Bargi dam is an earth and masonry composite dam, hence breach time of 2 hour has been assumed. The breach width is estimated based criteria of maximum of (i) dam width at foundation level, 73 m; (ii) width of 7 blocks, ~ 250 m, (iii) 2-5 times height of dam, i.e. 120-300 m. Thus breach width of 250 m is assumed. The trapezoidal shape of the breach section is assumed for earthfill dam with side slope of 1V:1H. The breach starts at top of dam (426.9 m) and the final breach level is 367.00 m i.e. river bed level has been considered. The gradual failure of the earthen dam has been simulated in MIKE 11 by linear failure mechanism in the present study. In dam break analysis it is assumed that the reservoir is at FRL when the inflow enters into the reservoir which in turn raises the water level above the top of the dam and thus the dam fails due to overtopping. The flood inundation maps due to dam break and inflow of various return period and PMF are shown in Figure 8.

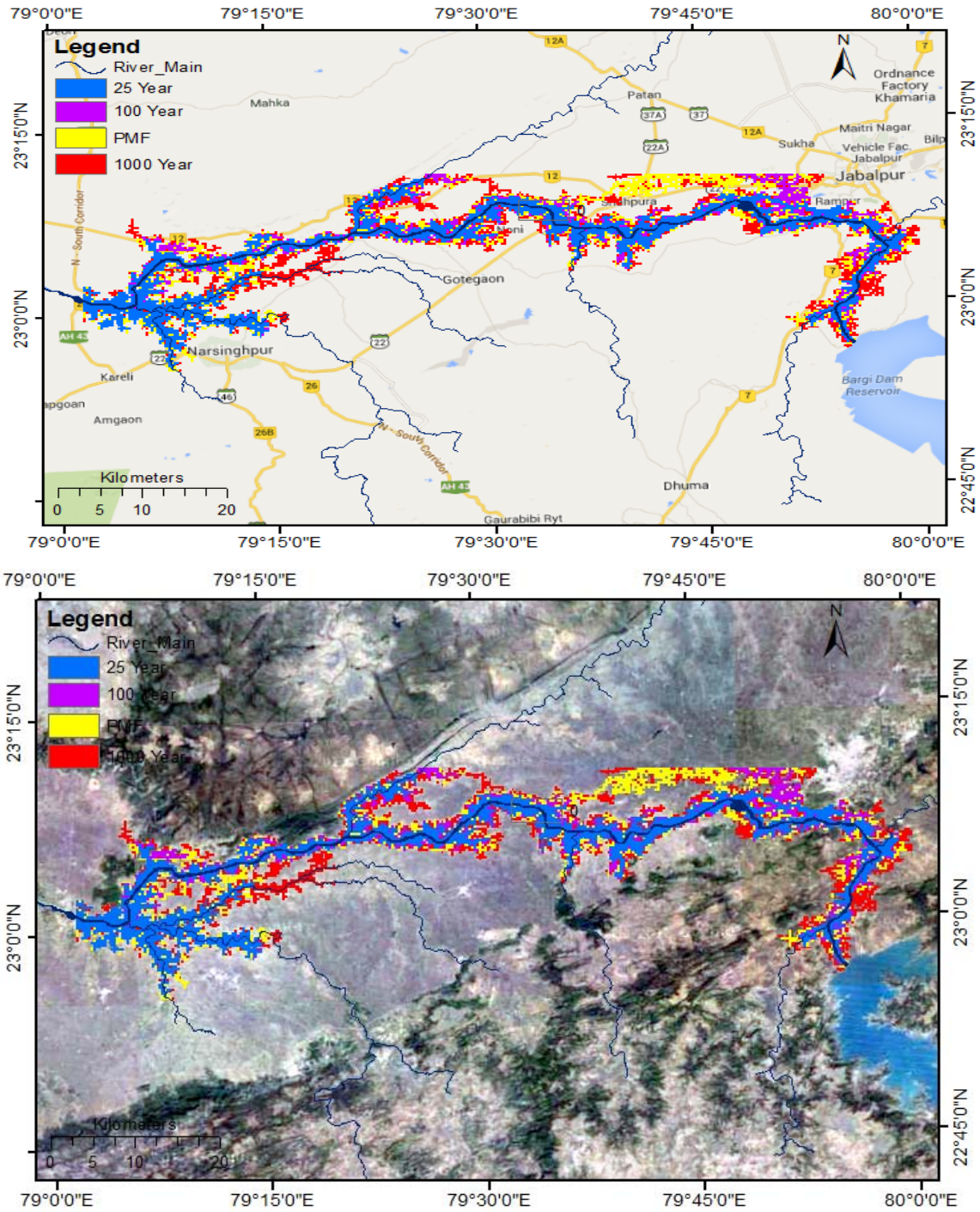


Fig. 8: Flood inundation maps due to dam beak. (a) Above Google maps and (b) Above Google earth

12. Action taken on comments of previous working group meeting

There were no specific comments

13. List of deliverables

Flood inundation maps, papers and reports.

14. Data collected/generated

- DEM of the study area is generated from SRTM and contour of SOI toposheets.

- Land use and land cover map is generated by classifying LANDSAT image.
- Daily rainfall for six raingauge stations i.e., Jabalpur, Mandla, Umaria, Balaghat, Narsinghpur and Seoni for the year 1970 to 2007 are collected from IMD. However the data set is having missing values at some stations.
- Stage and discharge at eight gaugiging sites namely, Bamni, Barmanghat, Belkhedi, Bijora, Dindori, Manot, Mohgaon and Patan for the period of 2000 to 2010 from CWC.
- River cross-sections at above gauging sites are also collected from CWC.
- Measured some river cross-sections during field survey.
- Salient features of dam such as height, length, top-width, elevation of river bed etc, spillway characteristics, and elevation of uncontrolled spillway crest with discharge coefficients are collected from office of Chief Engineer (Bargi), Rani Avantibai Pariyojana, NVDA, Jabalpur (MP)
- Elevation capacity and area capacity curve of the reservoir, Inflow and outflow data from 1990 to 2010 are also collected from office of Chief Engineer (Bargi), Rani Avantibai Pariyojana, NVDA, Jabalpur (MP).

15. Involvement of end users/beneficiaries

There has been discussion with the officials of Chief Engineer (Bargi), Rani Avantibai Pariyojana, NVDA, Bargi Hills, Jabalpur (M.P.) regarding need of this type of study.

2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/13-14

a) Title of the study: **State-of-the-Art Report on Soil Erosion and Sediment Transport Modelling**

b) Study group: J.V. Tyagi, Sc 'G'

c) Type of study: Internal

d) Date of start: April 2013

e) Scheduled date of completion: March, 2014

f) Objectives of the study:

The key objective of the state-of-the-art report is to provide a resource on soil erosion and sediment transport modelling for the use of potential model developers and model users to guide their erosion modelling applications at catchment scale.

g) Statement of the problems:

The National Water Mission document of National Action Plan on Climate Change (NAPCC) has identified various goals. The document also suggested various strategies for achieving these goals. The suggested strategies include "Research and studies on all aspects related to impact of climate change on water resources including quality aspects of water resources with active collaboration of all research organizations working in the area of climate change". One of the action points for R&D studies highlights the need of "Building a Universal Soil Loss model depicting erosion and sediment transport etc., proving the model based on sediment flow and reservoir sedimentation data, actuating the above model for changed rainfall regime and changed management practices". As a first step, the action plan of the activity module I.5 envisages preparation of a state-of-the-art report on soil erosion and sediment transport modeling and the work was entrusted to NIH. Accordingly, preparation of state-of-the-art report was taken up.

h) Methodology:

The work plan for the study consists of the following steps.

- Collection of literature from web resources, academic and R&D institutions on soil erosion and transport modeling.
- Thorough review of the collected literature and analysis of various methodologies.
- Compilation of the literature and preparation of the state-of-the-art report.

i) Time schedule:

Work plan	Time Schedule	Status
Collection of literature from web resources, academic and R&D institutions on soil erosion and transport modeling	April - Sept, 2013	Completed
Thorough review of the collected literature and analysis of various methodologies	Oct. – Dec. 2013	Completed
Compilation of the literature and preparation of the state-of-the-art report	Jan. – March 2014	Completed

j) Progress/ present status of the study

The report has been completed and submitted as per schedule.

k) Adopters of the study:

CWC, NIH, academic and other R&D institutes involved in implementation of the National Action Plan on Climate Change (NAPCC).

l) Deliverables

(i) State-of-the-art report on soil erosion and sediment transport modeling.

(ii) The report consists of various approaches and methodologies for estimating soil erosion and sediment transport from river basins.

m) Major items of equipment procured: Nil

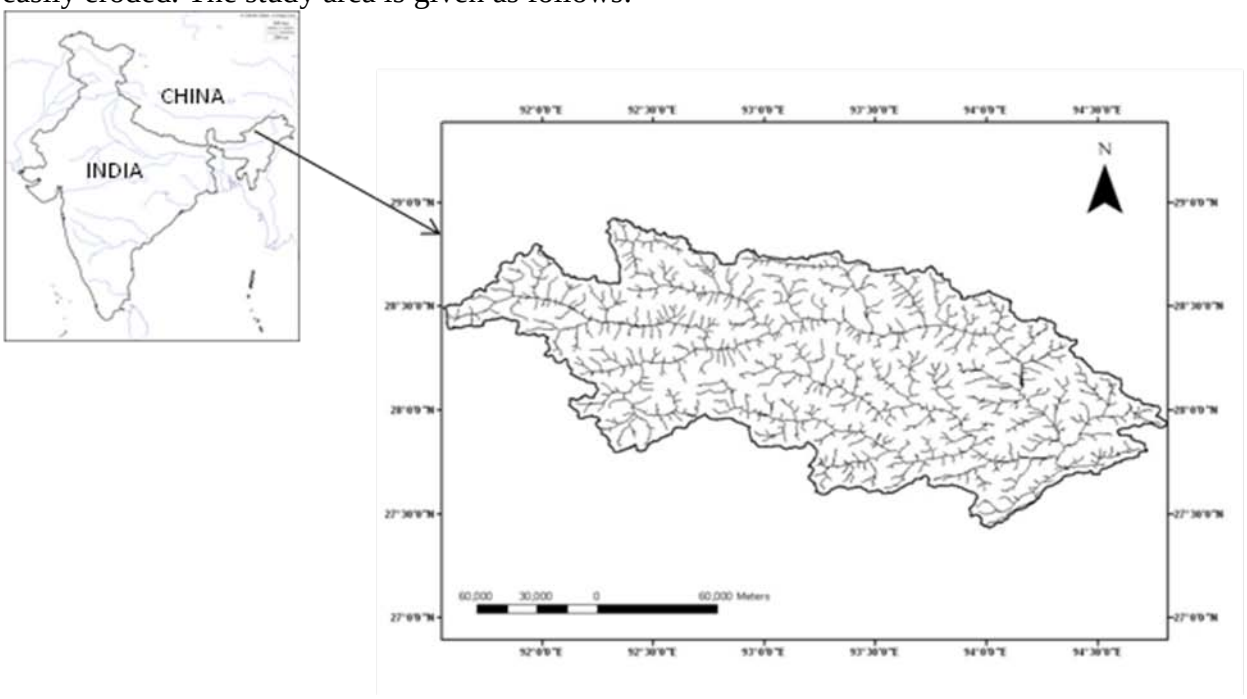
n) Lab facilities during the study: Nil.

3. PROJECT REFERENCE CODE: NIH/SWD/NIH/13-14

Title of the study:	**Suspended Sediment Flux Modelling in the largest sub-basin of Brahmaputra**
Name of the PI & Co-PI:	Archana Sarkar, Sc C Dr. Rakesh Kumar, Sc G & Head
Type of Study:	Internal
Date of Start:	1 April 2013
Scheduled date of completion:	31 March 2014
Nature of study:	Model development

Location Map:

The Subansiri River is the biggest north bank tributary of river Brahmaputra in India. It originates in Tibet beyond the Great Himalayan Range at an altitude of around 5340 m and joins the Brahmaputra in the plains of Assam State in India. The Subansiri River contributes about 10.7% of the total discharge of the river Brahmaputra at Pandu near Guwahati in India. The catchment area of Subansiri basin up to the outlet at Chouldhuaghat is approximately 26,419km^2 from SRTM data, of which about 10,237 km^2 (38.75%) lies in Tibet and the remaining 61.25% in India. The Sub-Himalayan range of Subansiri generally consists of soft sandstones and weathered rocks. During the period of May to October, the intensity of precipitation is high and sediment deposits at areas nearer to and along the foot hills are easily eroded. The study area is given as follows:



Study objectives:

i. Development of artificial neural network (ANN) based sediment flux simulation models for the Subansiri basin up to Chouldhuaghat gauging site on daily, ten-daily and monthly scales
ii. Development of conventional sediment rating curves (SRC) and multiple linear regression models (MLR) for sediment flux simulation with data similar to ANN models.
iii. Intercomparison of developed models
iv. Study of the effect of type of input data, length of input data, lagging of input data and scale of input data on the accuracy of sediment flux estimation in a large Himalayan River basin and also provides guidance on the types of tasks for which different types of input data may be preferable.

Statement of the problem

- "Hydrological modeling studies in Brahmaputra basin" is one of the thrust areas of "12th Five Year Plan"
- Rigorous assessment of sediment fluxes in rivers is required in a wide spectrum of problems such as design of reservoirs and dams; hydroelectric power generation and water supply; water quality and pollution and environmental impact assessment. The Subansiri River promises stupendous hydropower potential (22 projects having potential of 15,191 MW already proposed/in progress) for the country, therefore, accurate assessment of sediment flux is of prime importance.

End users/beneficiaries of the study

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

Approved Action plan and timeline

Year	April - June	July-Sept	Oct-Dec	Jan-March
2013-14	Data processing	Identification of ANN model architecture and preparation of input files	ANN model runs, development of SRC and MLR models	Interpretation of results, inter-comparison of models and preparation of report

Progress

Objectives	Achievements
April 2013- Sept 2013	
• Data processing	Completed
• Identification of ANN model architecture and preparation of input files	Completed
• ANN model runs, development of SRC and MLR models	Completed
• Interpretation of results, inter-comparison of models and preparation of draft report	Completed

Analysis and Results

Data Used

- Daily data of rainfall, rainfall intensity, temperature, snow cover area, discharge and suspended sediment concentration

Data Processing

- Based on the daily data, ten-daily and monthly data series have been prepared for ANN simulation

Results

Development of ANN Models

Various combinations of input data have been considered by adding input variables one by one for all the three different temporal scale models. For each combination of input variables, lagged input variables have been added up to previous two time steps. In this way, three groups of models were considered for daily sediment yield modelling and four groups of models were considered for both ten-daily as well as monthly sediment yield modelling. Within each group, three models have been considered based on lagged variables.

Daily ANN sediment yield simulation models with different input variables

ANN Model	Number of Input variables	Input Variables	Output Variable
Input variables with Rainfall and Mean Temperature only			
ANNSD-1	6	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, T_t,	S_t
ANNSD-2	12	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, T_t, T_{t-1}	S_t
ANNSD-3	18	RG_t, RA_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RA_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, T_t, T_{t-1}, T_{t-2}	S_t
Input variables with Rainfall, Mean Temperature, snow cover area and runoff (discharge)			
ANNSD-4	9	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, T_t, $SCA1_t$, $SCA2_t$, Q_t	S_t
ANNSD-5	18	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, T_t, T_{t-1}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, Q_t, Q_{t-1}	S_t
ANNSD-6	27	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, T_t, T_{t-1}, T_{t-2}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, $SCA1_{t-2}$, $SCA2_{t-2}$, Q_t, Q_{t-1}, Q_{t-2}	S_t
Input variables with Rainfall, Mean Temperature, snow cover area and runoff (discharge)			

ANNSD-7	10	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, T_t, $SCA1_t$, $SCA2_t$, Q_t, S_{t-1}	S_t
ANNSD-8	19	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, T_t, T_{t-1}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, Q_t, Q_{t-1}, S_{t-1}	S_t
ANNSD-9	29	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, T_t, T_{t-1}, T_{t-2}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, $SCA1_{t-2}$, $SCA2_{t-2}$, Q_t, Q_{t-1}, Q_{t-2}, S_{t-1}, S_{t-2}	S_t

Ten-Daily and monthly ANN sediment yield simulation models with different input variables

ANN Model	**No of Input variables**	**Input Variables**	**Output Variable**
Input variables with Rainfall and Mean Temperature only			
ANNST-1 ANNSM-1	6	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, T_t,	S_t
ANNST-2 ANNSM-2	12	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, T_t, T_{t-1}	S_t
ANNST-3 ANNSM-3	18	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, T_t, T_{t-1}, T_{t-2}	S_t
Input variables with Rainfall, Rainfall Intensity and Mean Temperature			
ANNST-4 ANNSM-4	11	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, T_t	S_t
ANNST-5 ANNSM-5	22	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, $RG\text{-}I_{t-1}$, $RR\text{-}I_{t-1}$, $R2\text{-}I_{t-1}$, $R5\text{-}I_{t-1}$, $R6\text{-}I_{t-1}$, T_t, T_{t-1}	S_t
ANNST-6 ANNSM-6	33	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, $RG\text{-}I_{t-1}$, $RR\text{-}I_{t-1}$, $R2\text{-}I_{t-1}$, $R5\text{-}I_{t-1}$, $R6\text{-}I_{t-1}$, $RG\text{-}I_{t-2}$, $RR\text{-}I_{t-2}$, $R2\text{-}I_{t-2}$, $R5\text{-}I_{t-2}$, $R6\text{-}I_{t-2}$, T_t, T_{t-1}, T_{t-2}	S_t
Input variables with Rainfall, Rainfall Intensity, Mean Temperature, snow cover area and runoff			
ANNST-7 ANNSM-7	14	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, T_t, $SCA1_t$, $SCA2_t$, Q_t	S_t

ANNST-8 ANNSM-8	28	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, $RG\text{-}I_{t-1}$, $RR\text{-}I_{t-1}$, $R2\text{-}I_{t-1}$, $R5\text{-}I_{t-1}$, $R6\text{-}I_{t-1}$, T_t, T_{t-1}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, Q_t, Q_{t-1}	S_t
ANNST-9 ANNSM-9	42	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, $RG\text{-}I_{t-1}$, $RR\text{-}I_{t-1}$, $R2\text{-}I_{t-1}$, $R5\text{-}I_{t-1}$, $R6\text{-}I_{t-1}$, $RG\text{-}I_{t-2}$, $RR\text{-}I_{t-2}$, $R2\text{-}I_{t-2}$, $R5\text{-}I_{t-2}$, $R6\text{-}I_{t-2}$, T_t, T_{t-1}, T_{t-2}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, $SCA1_{t-2}$, $SCA2_{t-2}$, Q_t, Q_{t-1}, Q_{t-2}	S_t
Input variables with Rainfall, Rainfall Intensity, Mean Temperature, snow cover area, runoff and previous Ten-day Sediment Yield			
ANNST-10 ANNSM-10	15	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, T_t, $SCA1_t$, $SCA2_t$, Q_t, S_{t-1}	S_t
ANNST-11 ANNST-11	29	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, $RG\text{-}I_{t-1}$, $RR\text{-}I_{t-1}$, $R2\text{-}I_{t-1}$, $R5\text{-}I_{t-1}$, $R6\text{-}I_{t-1}$, T_t, T_{t-1}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, Q_t, Q_{t-1}, S_{t-1}	S_t
ANNST-12 ANNST-12	44	RG_t, RR_t, $R2_t$, $R5_t$, $R6_t$, RG_{t-1}, RR_{t-1}, $R2_{t-1}$, $R5_{t-1}$, $R6_{t-1}$, RG_{t-2}, RR_{t-2}, $R2_{t-2}$, $R5_{t-2}$, $R6_{t-2}$, $RG\text{-}I_t$, $RR\text{-}I_t$, $R2\text{-}I_t$, $R5\text{-}I_t$, $R6\text{-}I_t$, $RG\text{-}I_{t-1}$, $RR\text{-}I_{t-1}$, $R2\text{-}I_{t-1}$, $R5\text{-}I_{t-1}$, $R6\text{-}I_{t-1}$, $RG\text{-}I_{t-2}$, $RR\text{-}I_{t-2}$, $R2\text{-}I_{t-2}$, $R5\text{-}I_{t-2}$, $R6\text{-}I_{t-2}$, T_t, T_{t-1}, T_{t-2}, $SCA1_t$, $SCA2_t$, $SCA1_{t-1}$, $SCA2_{t-1}$, $SCA1_{t-2}$, $SCA2_{t-2}$, Q_t, Q_{t-1}, Q_{t-2}, S_{t-1}, S_{t-2}	S_t

Performance indices of daily sediment yield ANN models

Model	**Training**			**Validation**			**Cross-Validation**		
	RMSE (mg /L)	**R**	**DC**	**RMSE (mg/ L)**	**R**	**DC**	**RMSE (mg /L)**	**R**	**DC**
Group I: Models with only rainfall and mean temperature as input									
ANN-SD1 (6,7,1)	65.852	0.618	0.381	66.361	0.784	0.524	57.124	0.737	0.515
ANN-SD2 (12,15,1)	**63.271**	**0.655**	**0.429**	**62.353**	**0.787**	**0.582**	**54.588**	**0.765**	**0.556**
ANN-SD3 (18,22,1)	60.894	0.687	0.547	64.267	0.785	0.552	56.497	0.751	0.526
Group II: Models with rainfall, mean temperature, snow cover area and discharge as input									
ANN-SD4 (9,11,1)	**56.39**	**0.748**	**0.550**	**55.709**	**0.855**	**0.664**	**47.221**	**0.829**	**0.666**
ANN-SD5 (18, 20,1)	56.61	0.737	0.543	58.129	0.805	0.636	47.896	0.813	0.659
ANN-SD6 (27,30,1)	55.76	0.746	0.556	56.394	0.818	0.657	47.654	0.807	0.660

Group III: Models with rainfall, mean temperature, snow cover area, discharge and previous day sediment concentration as input									
ANN-SD7 (10,13,1)	**19.861**	**0.971**	**0.944**	**23.000**	**0.975**	**0.948**	**16.988**	**0.984**	**0.968**
ANN-SD8 (19,23,1)	19.293	0.973	0.947	23.717	0.972	0.939	18.593	0.977	0.949
ANN-SD9 (29,30,1)	19.035	0.974	0.948	24.787	0.969	0.934	18.810	0.976	0.948

Comparative performance of daily sediment yield ANN and MLR models

Model	**Training**			**Validation**			**Cross-Validation**		
	RMSE (mg/L)	R	DC	RMSE (mg/L)	R	DC	RMSE (mg/L)	R	DC
MLR-SDI (ANN-SD2)	66.243 (63.271)	0.611 (0.655)	0.373 (0.429)	66.403 (62.353)	0.741 (0.787)	0.521 (0.582)	57.899 (54.588)	0.731 (0.765)	0.501 (0.556)
MLR-SDII (ANN-SD4)	63.645 (56.39)	0.649 (0.748)	0.422 (0.550)	56.439 (55.709)	0.815 (0.855)	0.658 (0.664)	52.506 (47.221)	0.770 (0.829)	0.590 (0.666)
MLR-SDIII (ANN-SD7)	21.181 (19.861)	0.967 (0.971)	0.936 (0.944)	23.743 (23.000)	0.971 (0.975)	0.943 (0.948)	17.729 (16.988)	0.979 (0.984)	0.957 (0.968)

Note: values in brackets are the indices values of corresponding ANN models.

Performance indices of ten-daily sediment yield ANN models

Model	**Training**			**Validation**			**Cross-Validation**		
	RMSE (mg/L)	**R**	**DC**	**RMSE (mg/L)**	**R**	**DC**	**RMSE (mg/L)**	**R**	**DC**
Group I: Models with only rainfall and mean temperature as input									
ANN-ST1	**50.75**	**0.783**	**0.612**	**49.321**	**0.897**	**0.722**	**48.716**	**0.855**	**0.673**
ANN-ST2	44.95	0.835	0.696	61.594	0.812	0.578	53.946	0.759	0.556
ANN-ST3	37.75	0.887	0.785	70.978	0.721	0.439	62.270	0.65	0.408
Group II: Models with rainfall, mean temperature and rainfall intensity as input									
ANN-ST4	**53.17**	**0.758**	**0.574**	**54.259**	**0.884**	**0.664**	**49.313**	**0.820**	**0.604**
ANN-ST5	51.39	0.798	0.602	75.658	0.867	0.348	106.70	0.798	-0.749
ANN-ST6	57.03	0.775	0.51	112.167	0.871	-0.415	150.31	0.799	-2.45
Group III: Models with rainfall, mean temperature, rainfall intensity, snow cover area &discharge as input									
ANN-ST7	**48.86**	**0.80**	**0.64**	**42.183**	**0.899**	**0.790**	**43.772**	**0.847**	**0.696**
ANN-ST8	60.53	0.682	0.448	46.718	0.888	0.746	48.781	0.809	0.638
ANN-ST9	60.05	0.684	0.457	60.356	0.837	0.595	45.875	0.832	0.679

Group IV: Models with rainfall, mean temperature, rainfall intensity, snow cover area, discharge and previous 10-day sediment concentration as input									
ANN-ST10	**28.5**	**0.937**	**0.878**	**41.343**	**0.907**	**0.805**	**25.288**	**0.955**	**0.902**
ANN-ST11	29.86	0.931	0.866	48.693	0.876	0.736	43.212	0.893	0.715
ANN-ST12	23.77	0.946	0.815	51.553	0.859	0.704	43.440	0.876	0.715

Comparative performance of ten-daily sediment yield ANN and MLR models

Model	**Training**			**Validation**			**Cross-Validation**		
	RMSE	**R**	**DC**	**RMSE**	**R**	**DC**	**RMSE**	**R**	**DC**
MLR-STI (ANN-ST1)	58.133 (50.75)	0.698 (0.783)	0.487 (0.612)	55.338 (49.321)	0.858 (0.897)	0.705 (0.722)	45.394 (48.716)	0.804 (0.855)	0.623 (0.673)
MLR-STII (ANN-ST4)	56.251 (53.17)	0.721 (0.758)	0.520 (0.574)	59.725 (54.259)	0.877 (0.884)	0.618 (0.664)	50.544 (49.313)	0.810 (0.820)	0.626 (0.604)
MLR-STIII (ANN-ST7)	54.393 (48.86)	0.742 (0.80)	0.551 (0.64)	45.923 (42.183)	0.892 (0.899)	0.758 (0.790)	44.040 (43.772)	0.835 (0.847)	0.682 (0.696)
MLR-STIV (ANN-ST10)	25.929 (28.5)	0.948 (0.937)	0.898 (0.878)	42.338 (41.343)	0.889 (0.907)	0.797 (0.805)	28.042 (25.288)	0.942 (0.955)	0.875 (0.902)

Performance indices of monthly sediment yield ANN models

Model	**Training**			**Validation**			**Cross-Validation**		
	RMSE (mg/L)	**R**	**DC**	**RMSE (mg/L)**	**R**	**DC**	**RMSE (mg/L)**	**R**	**DC**
Group I: Models with only rainfall and mean temperature as input									
ANN-SM1	**46.471**	**0.808**	**0.654**	**38.539**	**0.909**	**0.809**	**38.549**	**0.912**	**0.683**
ANN-SM2	47.255	0.808	0.651	69.461	0.801	0.407	40.128	0.901	0.634
ANN-SM3	48.786	0.795	0.628	45.626	0.866	0.737	43.968	0.854	0.649
Group II: Models with rainfall, mean temperature and rainfall intensity as input									
ANN-SM4	**44.063**	**0.846**	**0.743**	**36.070**	**0.959**	**0.859**	**47.384**	**0.807**	**0.632**
ANN-SM5	54.986	0.727	0.527	58.346	0.846	0.588	52.933	0.765	0.571
ANN-SM6	43.489	0.911	0.828	37.288	0.946	0.849	53.629	0.792	0.619
Group III: Models with rainfall, mean temperature, rainfall intensity, snow cover area and discharge as input									
ANN-SM7	**41.960**	**0.858**	**0.749**	**39.106**	**0.934**	**0.799**	**41.549**	**0.854**	**0.714**
ANN-SM8	48.375	0.796	0.634	67.066	0.773	0.463	45.624	0.846	0.687
ANN-SM9	46.251	0.816	0.665	52.871	0.851	0.664	49.348	0.789	0.593
Group IV: Models with rainfall, mean temperature, rainfall intensity, snow cover area, discharge and previous month sediment concentration as input									
ANN-SM10	**24.52**	**0.951**	**0.906**	**40.664**	**0.892**	**0.766**	**37.086**	**0.902**	**0.774**
ANN-SM8	25.62	0.947	0.897	39.353	0.909	0.814	36.820	0.891	0.692
ANN-SM9	25.84	0.947	0.895	40.905	0.927	0.756	37.762	0.896	0.685

Comparative performance of monthly sediment yield ANN and MLR models

Model	Training			Validation			Cross-Validation		
	RMSE (mg/L)	**R**	**DC**	**RMSE (mg/L)**	**R**	**DC**	**RMSE (mg/L)**	**R**	**DC**
MLR-SMI (ANN-SM1)	46.967 (46.471)	0.786 (0.808)	0.617 (0.654)	39.349 (38.539)	0.899 (0.909)	0.787 (0.809)	51.584 (38.549)	0.782 (0.912)	0.563 (0.683)
MLR-SMII (ANN-SM4)	44.129 (44.063)	0.830 (0.846)	0.689 (0.743)	38.275 (36.070)	0.933 (0.959)	0.836 (0.859)	60.088 (47.384)	0.677 (0.807)	0.408 (0.632)
MLR-SMIII (ANN-SM7)	42.176 (41.960)	0.854 (0.858)	0.729 (0.749)	40.340 (39.106)	0.912 (0.934)	0.791 (0.799)	45.829 (41.549)	0.848 (0.854)	0.656 (0.714)
MLR-SMIV (ANN-SM10)	27.185 (24.52)	0.939 (0.951)	0.882 (0.906)	50.930 (40.664)	0.894 (0.892)	0.663 (0.766)	45.459 (37.086)	0.885 (0.902)	0.661 (0.774)

Note: values in brackets are the indices values of corresponding ANN models.

EXPECTED ADOPTERS

State Water Resources Dept and other agencies dealing with Hydropower projects.

DELIVERABLES

Report and Research papers

4. PROJECT REFERENCE CODE: NIH/SWD/NIH/12-15

Title of the study: **Sedimentation Studies for Pong Reservoir, Himachal Pradesh**

Study Group: Dr. A. R. Senthil kumar Sc E
Dr. Manohar Arora, Sc C
Dr. Suhas D Khobragade, Sc E, HID
Dr. Avinash Agarwal, Sc, F
Dr. Sanjay Jain, Sc F, WRSD

Date of start: 1 April 2012
Duration of the study: 3 Years
Whether externally funded or not: No

OBJECTIVES OF THE STUDY:

1. To develop a sediment yield model for the catchment area
2. To generate rainfall and runoff series for the future periods
3. To compute the sediment yield based on the generated rainfall and runoff series
4. To predict elevation-area-capacity curve

BRIEF METHODOLOGY:

Sediment yield model

Multiple Linear regression (MLR) and ANN models are developed to simulate the sediment yield for the catchment of Beas river up to Pong reservoir based on the historical data of rainfall, runoff and sediment yield

Generation of rainfall and runoff series

The data of rainfall and runoff for future 25, 50, 75 and 100 years are generated by the time series modelling with available data of rainfall and runoff series.

Computation of sediment yield and consolidated sediment volume

The developed sediment yield model is applied to compute the sediment volume for future 25, 50, 75 and 100 years. The unit weight of deposited sediment in the reservoir is computed from particle size distribution of suspended sediment concentration, hydrographic survey and porosity of uniformly distributed sediment in the reservoir. The consolidated unit weights of the sediment are arrived at by empirical equation as well as statistical methods. The consolidated unit weights computed by different methods are used to compute the possible range of sediment volume expected to be deposited in the reservoir for the future 25, 50, 75 and 100 years.

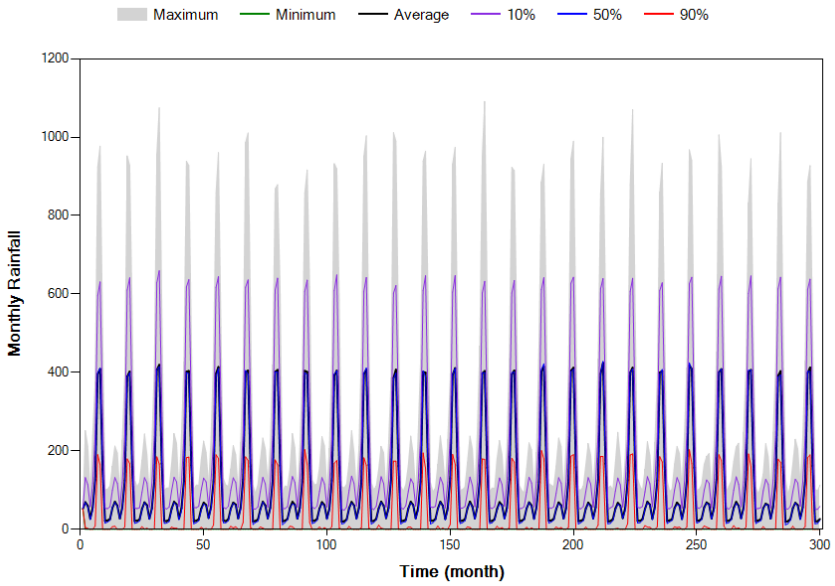
Revision of elevation-area-capacity table

The computed sediment volume for future periods is distributed in the reservoir by empirical area reduction method.

Results achieved with progress/present status

The monthly rainfall at Dehra Gopipur, Haripur, Nangal Chowk and Pong dam and monthly flow volume and sediment yield at Jwala Mukhi from 1987 to 2009 are used to develop ANN model to simulate the sediment load. The feed forward ANN is trained with input vector selected from the data as mentioned above. The monthly data from 1987 to 2007 are considered for the training of the model and data from 2008 to 2009 are considered for the validation of the model. The ANN model with input vector of flowvol(t), raindehra(t), rainhari(t), rainnangch(t), rainpondam(t) and the structure of 5-2-1 is the best model among the all. The monthly rainfall at Dehra Gopipur, Haripur, Nangal Chowk and Pong dam and monthly flow volume at Jwala Mukhi for future 25, 50, 75 and 100 years are generated by using time series modelling. The best ANN model is used to simulate the sediment load for future 25, 50, 75 and 100 years using the generated series of rainfall and flow volume. The uncertainty in the simulated series of sediment load is addressed by generating ensembles of input series and determining the sufficient number of parameter sets of the model by boots trap method.

The uncertainty analysis of generated data series of rainfall at Dehra Gopipur, Haripur, Nangal Chowk and Pong dam, flow volume at Jwala Mukhi for future 25, 50, 75 and 100 years is carried out. The uncertainty in the generated data series is determined by finding bandwidth of probable values of a particular series. The 1000 ensembles of rainfall at Dehra Gopipur, Haripur, Nangal Chowk and Pong dam, flow volume at Jwala Mukhi for 25, 50, 75 and 100 years are generated by changing the seed of uniformly distributed random number. The 10, 50 and 90 percent probable generated series of rainfall and flow volume is found from the ensembles of the series. These values address the uncertainty in the generated data. The 10, 50 and 90 percent probable series of rainfall at Dehra Gopipur for 25 years is presented in the following figure. The uncertainty in the model is addressed by developing ANN ensembles by boots trap method. Boots trap runs is being carried out with the historical monthly rainfall and flow volume. The band width of probable sediment yield is simulated from the ANN ensembles by boots trap method. The average probable sediment yield will be used for the revision of elevation-area-capacity table for the reservoirs.



Expected date of completion: 31 March 2015.

5. PROJECT REFERENCE CODE: NIH/SWD/NIH/12-15

Title of the study: **Study of Hydro-Meteorological Droughts for Chitrakoot Bundelkhand Region in India**

Name of PI: Dr. R.P. Pandey, Scientist F
Type of study: Internally Funded
Project Duration: 3-years
Date of start: April 2012
Scheduled Date of Completion: March. 2015

OBJECTIVES OF THE STUDY:

Major objective of the study is to quantify water scarcity during droughts and to identify possible options for augmenting water supply and minimizing crop loss due to droughts. The specific objectives of this project are to:

a) Assessment of drought frequency, duration and severity in Bubdelkhand.
b) Quantification of surface water and groundwater availability.
c) Assessment of total water demands for domestic, industries and agriculture.
d) Assessment of supplemental irrigation to minimize crop loss due to dryspells and droughts.
e) Delineation of zones vulnerable to different degree of drought severity.
f) To suggest an area specific plan for water management in Paisuni Basin,

Study Area: <u>Paisuni (Mandakini) Basin in Chitrakoot District</u>

Study area belongs to the part of Bundelkhand region in India (Fig. 1). Mean annual rainfall in the basin is about 1039 mm and mean annual potential evapotranspiration is about 1950 mm. Statement of problems of the study area is as follows:

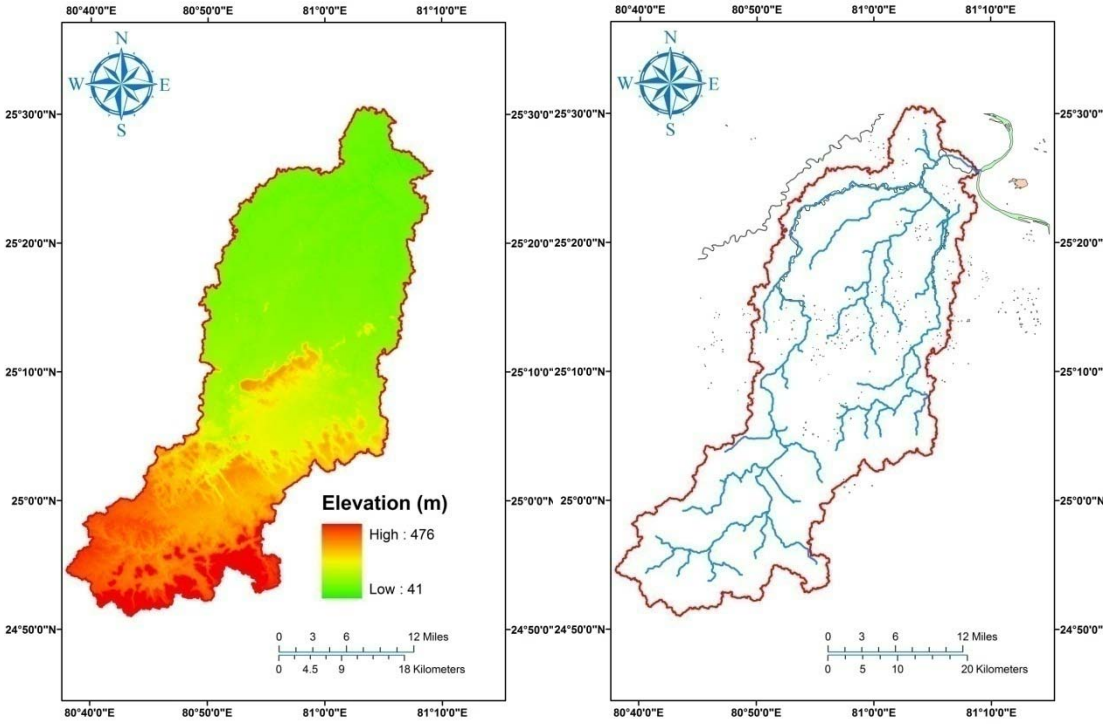
- Paisuni basin in Chitrakoot faces recurrent droughts of with average frequency of once in five years (greater severity).
- Frequent failures of crops are reported in the basin due to droughts.
- Present sources of drinking water supply are not sufficient to meet the demand during summer. Sever water shortages emerge during drought period
- In recent past during 2004- 2008 and 2010, it experienced acute water scarcity due to persistent drought situation in the basin.

Ground water availability in Manikpur, Pahari and Chitrakoot blocks are limited and it does not meet the demands. The Manikpur block appears to be more vulnerable to water shortages in summer months.

PROGRESS OF PROPOSED STUDY:

- Collected data/information from various sources and conducted field investigations in the study areas.
- Prepared base maps of drainage, land-use, DEM, ground water aspect map etc. using GIS.

- Analyzed rainfall data to determine frequency and severity of droughts in past decades and their impacts reported in administrative documented.
- Applied and compared SPI and EDI with A New Methodology (named as SDI, simple drought index) to assess attributes of drought events.
- Analyzed critical dry spell fro past 50 year data and estimated supplemental irrigation requirement for crop saving during CDS and drought.
- Prepared map for demarcation water deficit zones in study area in the form of different clusters of villages for water supply planning.



DEM Map **Drainage Map**

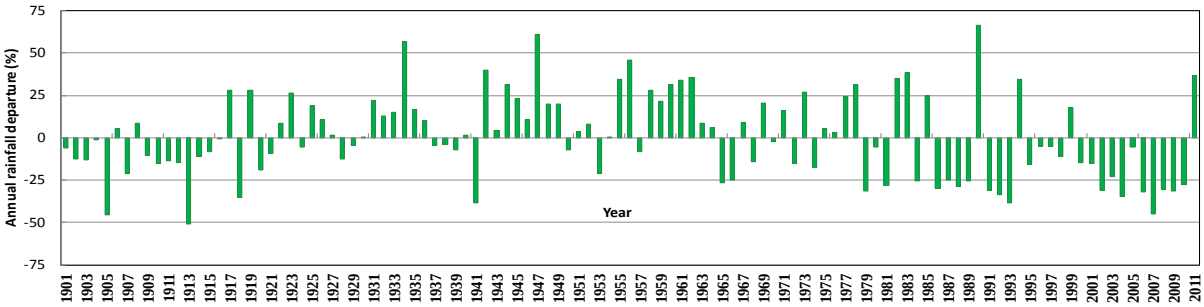


Table : Results of Critical Dry Spell Analysis in Paisuni basin covering Chitrakoot distt. UP and Part of Satna distt. MP

S. No	Station	Ist Critical Dry Spell			IInd Critical Dry Spell			IIIrd Critical Dry Spell			Longest duration of CDS
		Start mean date	End Mean Date	Duration	Start Mean Date	End Mean Date	Duration	Start Mean Date	End Mean Date	duration	
	1	**2**	**3**		**4**	**5**		**6**	**7**		**8**
1	Mau	17 July	3 Aug	18	12 Aug	23 Aug	11	5 Sep	21 Sep	17	45 (1983)
2	Karwi	18 July	2 Aug	16	9 Aug	26 Aug	18	-	-		28 (2002)
3	Satna	22 July	4 Aug	17	4 Aug	19 Aug	16	27 Aug	7 Sep	11	26 (1974)

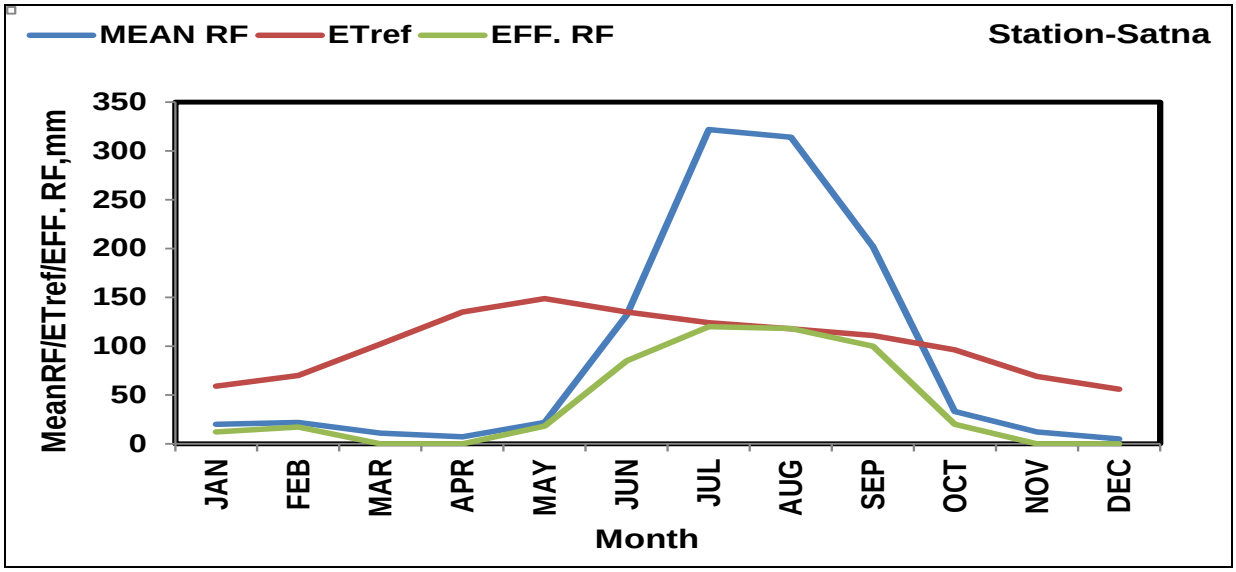


Fig: Distribution of monthly rainfall and Evapotranspiration

Table: Estimation of Crop Water Requirement

S. No.	Name of crop	Crop duration	Sowing time	Total Crop Water requirement (mm)
	1	**2**	**3**	**4**
1	Paddy (Kharif)	97 days	1-Jul	487
2	Soybean (Kharif)	110 days	30-Jun	411
3	Maize (Kharif)	110days	1-Jul	348
4	Wheat (Rabi)	120days	5-Nov	342

Table: Comparison of results of SDI with SPI and EDI

Year	Month	Rainfall	Monthly Av. RF	SDI-Identification	Weighted Departure	SPI 3 Month	EDI Monthly
2006	Jan	0	20	Drought-50	-2.13	-1.99	0.57
2006	Feb	20	22	Drought-2m	-0.21	-0.43	0.48
2006	Mar	34.2	11	1	2.47	0.31	0.85
2006	Apr	23.8	7	1	1.79	1.17	1.18
2006	May	25	22	1	0.32	1.19	0.62
2006	Jun	42.5	132	Drought-50	-9.54	-0.4	-0.69
2006	Jul	435.6	322	1	12.11	0.27	0.37
2006	Aug	171.5	314	1	-15.19	-0.39	-0.63
2006	Sep	44.9	202	Drought-50	-16.75	-0.64	-1.29
2006	Oct	11.5	33	Drought-50	-2.29	-1.57	-1.31
2006	Nov	0.6	12	Drought-2m	-1.22	-1.71	-1.46
2006	Dec	0	5	Drought-2m	-0.53	-0.86	-1.44
2007	Jan	0	20	Drought-50	-2.13	-1.74	-1.78
2007	Feb	71.2	22	1	5.25	0.75	-0.67
2007	Mar	25	11	1	1.49	1.04	-0.5
2007	Apr	1.8	7	1	-0.55	1.52	-0.67
2007	May	2.9	22	Drought-50	-2.04	0.08	-0.87

Proposed work plan for remaining part of the year 2013-14

- Classification of zones vulnerable to drought and water scarcity (preparation of vulnerability maps and their physical verification with ground truth).
- Assessment of surface water (Stream flow & Storages) and groundwater availability, (recharge/aquifer storages) at monthly time step.
- Assessment of water demand for domestic, industry and agriculture at monthly time step.

Time Schedule

Item of work plan	Time Schedule
Field survey & data collection from study area	April-June, 2012
Procurement of meteorological data and stream flow data from IMD and CWC respectively..	April –Sept. 2012
Preparation of base maps	June –December 2012
Mid-term field investigations and crop survey	September 2012 – January 3013
Analysis of Rainfall Temperature, evaporation records	June 2012 –March 2013
Analysis of dry spells & regional drought characteristics	April 2013-Dec 2013
Preparation of drought vulnerability maps	January 2014- June 2014
Assessment of surface and groundwater availability and total demand	April 2014 -Dec 2014
Preparation of plan for water augmentation and storage requirements	January –February 2014
Preparation of report	January- March 2015

List of deliverables (e.g. equipment, papers, reports, softwares, manuals, brochures, flyers, training programmes, users' interaction workshops)

1. This study will yield suitable approach to quantify drought attributes, area specific assessment of water availability, demand and magnitude of deficit.
2. Two training courses each for one week duration will be organized to disseminate the knowledge and output of the study during 2013-14 and 2014-15.

ORGANIZED FOLLOWING TRAINING COURSE

1. Organized one Training course on "Drought Disaster Risk Assessment and Management" March 10-14, 2014 at NIH, Roorkee. It was sponsored by National Institute of Disaster Management, New Delhi.
2. Organized one Training course on "*Drought Monitoring and Mitigation"*, under Hydrology Project-II during *March 24-25, 2014, at Chennai,* for the officers of Department of Water Resources Govt. of Tamil Nadu.

ORGANIZED BRAINSTORMING SESSION

1. Brainstorming Session on "Hydrological Aspects of Cloudburst & Flash Floods in Himalayas" January 10, 2014, New Delhi in collaboration with Indian Association of Hydrologists.

RESEARCH PAPERS PUBLISHED (October 2013-March 2014)

International Journal

1. Jain, Vinit Kumar; Manoj Kumar Jain, and **Rajendra Prasad Pandey** (2013) Effect of the Length of Streamflow Record on Truncation Level for Assessment of Streamflow Drought Characteristics, Jour. of Hydrologic Engineering, ASCE, doi:10.1061/(ASCE)HE.1943-5584.0000922. Published online on 17 Oct., 2013.
2. Mishra S.K., Rawat Soban, **Pandey R.P**., Jain M.K. and Chaube U.C. (2014). Relation Between Runoff Curve Number and PET. Journal of Hydrologic Engineering, ASCE, Vol. 19 No. 2, pp.355-365. (Published Feb. 2014 issue), *DOI*:*10.1061/(ASCE)HE.1943-5584.0000780*.

National Journal

3. Alpana Dubey, Deva Kant, Omkar Singh and **R.P. Pandey** (2013). A comparative study of environmental flow requirement approaches using hydrological index methods. Journal of Indian Water Resources society, vol. 33, No.3, pp 20-27

National conference

4. **Pandey R.P.,** Rakesh Kumar, Ashish Pandey and R.D. Singh (2013). "Relating regional climate and drought characteristics". **Key Note Paper** presented and published in the proceedings of National Conference on "Recent Trends and Innovation in Civil Engineering" held during 15-16 Nov., 2013 at BRCM College of Engineering and Technology, Bahal, Bhiwani (Haryana) , p. 108-119.

6. PROJECT REFERENCE CODE: NIH/SWD/NIH/13-16

Title of Study: **Quantitative assessment of uncertainties in river discharge estimation.**

Study Group: Sanjay Kumar, Sc-D, PI
Sharad Jain, Sc-G, Co-PI

Type of Study: Internal

Start Date: April, 2013

Scheduled date of completion: March, 2016

Objectives of the study:

The objectives of the study are:

1. To estimate uncertainty in river discharge observations.
2. To estimate uncertainty in the stage-discharge (rating) relationship.
3. To estimate uncertainty in stage- discharge relationship using slope as a parameter (back water effects).

Statement of the problem:

The uncertainty in the river discharge measurement and estimation is caused by different sources of errors. These mainly includes uncertainty in (a) observations of river stage and discharge used to parameterize the rating curve, (b) presence of unsteady flow conditions, and (c) interpolation and extrapolation errors of the rating curves. The study will provide a framework for analyzing and quantifying the uncertainty in the (i) river flow data (ii) stage-discharge relationship and (iii) stage-slope-discharge relations (for backwater effects) based on the ISO documents GUM (Guides to the expression of Uncertainty in Measurement), HUG (Hydrometric Uncertainty Guidance), ISO 773, 5168, 7066 and 768. The study will also examine various hydraulic factors controlling the flow at a cross section in the river and provides an understanding of independent variables that describes relations among stage, discharge and other parameters specifically discharge measurement under back water effects.

End users/beneficiaries of the study: Academicians, state and central government departments BIS, ISO.

Action plan and timeline:

S.N.	Major Activities	1st Year		2nd Year		3rd Year
1	Literature review including related various ISO standards					
2	Estimation of uncertainty in river discharge measurements (Interim Report-1)					
3	Estimation of uncertainty in stage-discharge (rating) relationship using					

	slope as a parameter (back water effects) (Interim Report-2)						
4	**Estimation of uncertainty in stage-discharge (rating) relationship. (Interim Report-3)**						
5	**Preparation of final report**						

Methodology:

Statistical methods/tools and the procedures described in various ISO documents (GUM, HUG) will be used for the estimation of river discharge uncertainties. The uncertainty in discharge measurement (assuming velocity area method) will be quantified as per the ISO 748 which provides the magnitude of these errors at 95% confidence level. The GUM defines the law of propagation of errors for combining uncertainties from several sources and HUG described it for different types of mathematical expressions generally used in hydrometry. This is illustrated by considering the quantity Q as a function of several measured quantities x, y, z . The error δQ in Q due to errors δx, δy, δz…. in x, y, z…., respectively, is given by

$$\delta Q = \frac{\partial Q}{\partial x}\delta x + \frac{\partial Q}{\partial y}\delta y + \frac{\partial Q}{\partial z}\delta z + \cdots$$

The uncertainty of a discharge measurement determined from a stage-fall-discharge rating function (as opposed to a gauged discharge which is determined from a current meter) shall be evaluated using statistical equations based on law of propagation of errors described above. Let X_{rd} be the uncertainty in the recorded discharge, the above error equation is then modified for uncertainty in discharge compution using stage-fall-discharge relationship as

$$X_{rd} = \pm(X_{\alpha}{}^2 + \beta^2 X^2 h_{u/s\text{-}h0} + \gamma^2 X^2_{hu/s\text{-}hd/s})^{1/2}$$

In practice, X_{α} is the standard error of the mean relation ($S_{mr)}$. $Xh_{u/s\text{-}h0}$ is the standard error of upstream gauge and $X_{h\ u/s\text{-}h\ d/s}$ is the standard error of fall between the u/s and d/s gauges.

Progress:

(i) As required by ISO/BIS the NWIP and the working draft of the revised ISO 9123 with updated uncertainty clause has been submitted to BIS/ISO for consideration.

(ii) It has been resolved that the working draft of the ISO 9123 will be circulated to SC1 members for call of experts.

(iii)The draft revision uploaded on ISO website for circulation to member bodies for comments.

Data requirements:

Stage and discharge data. Possible sources would be from literature, ISO documents, field organization.

Deliverables: Revised ISO document**,** Research papers and Report

7. PROJECT REFERENCE CODE: NIH/SWD/NIH/13-16

Title of the study	**Evaluation and modeling of hydrological support system for watersheds of Garhwal, Uttarakhand hills.**
Name of PI, Co-PI, & their affiliation	Dr. Avinash Agarwal (PI) Dr. Manohar Arora (Co PI) R K Nema (PRA)
Type of study	Internal funded
Date of start	Nov. 2013
Schedule date of completion	Nov. 2013 to Oct. 2016 (3 Years)

Role of team members

Dr. Avinash Agarwal (PI): Field visits, collection of electronic data, processing and plotting of data. Analysis of rainfall, runoff spring flow data. Development of implement-able technology for water availability and transfer. Progress, presentation and final reporting.

Dr. Manohar Arora (Co PI): Field visits. Assessing in collection of electronic data and in development of implement able technology for water availability analysis. Presenting the progress of work when required. Transfer of technology

Sh. R K Nema (PRA): Field visits. Collection of tabulated data. Keeping the record of skilled and unskilled daily wages. Proper running of all field instrument and observatory. Visits of the sites for its proper up date. Assessing in transfer of technology

Location of study area

Study area of this project lies in 'Western Himalaya' agro-ecological region of the Sub-humid ecosystem at elevation of 720 m to 2350 m. Climate in this region is warm with air temperature 3^{o}C to 35^{o}C sub-humid to humid and per-humid with average annual rainfall 900 mm to 1200 mm respectively for Chandrabhaga and Danda watersheds (Uttarakhand). Reliable source of water in the watersheds is only the existing springs in the watersheds.

Objectives of the study:

- Identification and development of river gauging sites. Installation of equipments for long term data base.
- Development of rainfall-runoff-suspended sediment yield model using satellite and general soil information.
- Classification of short and long term springs and development of spring flow model using topographic, hydrologic information such as hydraulic conductivity and effective porosity along with the recession characteristics of fractured soil media.
- Rejuvenation of few selected springs through woven wire check dams/infiltration tanks and to study changes in flow.
- Impact of climatic variability on runoff and spring flows.

Statement of the problem:

The monitoring continued with a network of instrumentation for watersheds (Chandrabhaga, Danda) with Rainfall (08 locations), runoff (3 locations), AWS One location for rainfall, temperature, humidity, wind speed & direction incoming radiation, pan evaporation and soil moisture (different depths), soil temperature (two depths). Daily spring flow of around twenty locations in each watershed is measured. The spring flow models will be developed considering topographic and hydrologic information. Since the quantity of spring flow is the need of the time, a long term spring flow record of few springs will be developed for climatic variability of the springs and for evaluation of spring flow with time. The suspended sediment sampling of monsoon period will add to the information to sediment yield from the hilly watershed.

Recommendation and suggestions in previous meeting of working group

Discussions were held with no specific comment/recommendation. The project was approved.	
▪ .Nil	▪

Analysis of results

(a) Maintenance and up keeping of installed equipments.
(b) The collected data for the period under processing.
(c) Relative spring flow performance and springshed demarcation and area.

Results in brief

- Maintenance and up keeping of installed equipments.
- Rainfall runoff and spring Flow analysis.
  Spring classification is done on he bases of spring discharge using Meinzer's classification. The relative performance of springs is estimated by four methods viz. (1) Based on spring flow variability, (2) Based on normalized mass spring flow, (3) Based on rainfall spring flow lag and (4) Based on spring flow gradient.

  Springsheds for the springs of watersheds are defined and the springshed area has been estimated.
- The data collected up to June 2013 is utilized for analysis.

List of deliverables	Hydro-meteorological data, papers and report for small watershed of Uttarakhand.
Major items of equipment procured	Nil
Lab facilities used during the study	Nil
Data procured and /or generated	The data hub for the watersheds has been updated.
Study benefits/impacts	Hill habitat, State Government and other agencies.
Specific linkage with institutions and/or end-users/ beneficiaries	Village wise interactive workshops in the watershed are proposed

Shot comings/ difficulties Nil

Future plan Model development

Study concluded

Title of the study: Climatic variability analysis and its impact on Himalayan watershed in Uttarakhand.

Study area of the study are Chandrabhaga and Danda watersheds of Uttarakhand that lies in 'Western Himalaya' agro-ecological region of the Sub-humid to humid ecosystem at an elevation of 720 m to 2350 m respectively. Climate of this region is warm with air temperature 3^{o}C to 35^{o}C with average annual rainfall 900 mm to 1200 mm. Reliable source of water during non monsoon period in the watersheds is only through existing springs. The objective of the study in brief is the development of rainfall-runoff, rainfall-spring flow relationships and assessment of climatic variability and its impact on runoff and spring flow. Another objective is the creation of a centralized database for watershed for the benefit of the users. The watersheds of the study area are shown in *figure 1*.

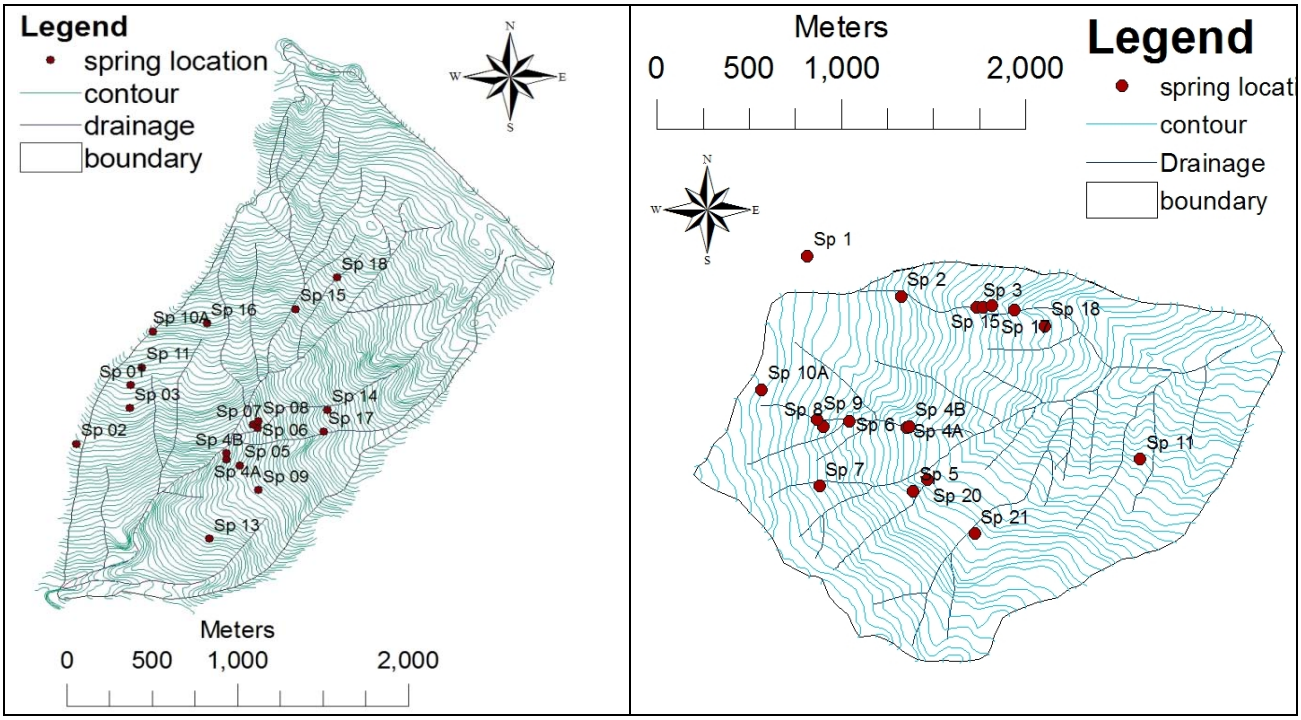


Figure 1: Chandrabhaga and Danda watersheds with springs of the watershed.

Monitoring of watersheds continued with a network of instrumentation over the watersheds (Chandrabhaga, Danda) with automatic weather station, automatic rain gauges, v-notches and with manual recording of daily spring flow of around twenty locations in each watershed. The spring flow in the watershed is important and is major source of available water during the periods of unavailability of rain water.

It can be seen that all the springs in Chandrabhaga and Danda watersheds flows through out the year. A fast decay of flow of springs for the post rains period suggests that the springs of the area are fast responding. The cumulative spring flow of the watersheds indicated a linear response with accumulative rainfall for the period June to September. A

non-linear response is observed for periods September to January and January to February due to non-monsoon period and winter rains respectively. The spring-rainfall lag time which also reflects the time of concentration of the spring flow were studied in order to understand the behavior response of the springs of the area. The spring-rainfall lag has been identified considering daily data and by converted monthly data. Different springs of watersheds indicated a lag of 1 to 30 days and 0 to 2 months. The spring–rainfall lag correlation ratio and lag for different spring has been related for both the watersheds (*figure 2*). It can be seen that the ratio of minimum to maximum correlation decreases with increase in spring-rainfall time lag in days. The same holds good for both the watersheds. The exponential decay relationship was found existing between the two variables and the obtained equations are below as;

Chandrabhaga watershed

$y_{(Chand)} = 0.8764\ e^{-0.0232x}$ $r^2 = .4985$

Danda watershed

$y_{(Danda)} = 0.7314e^{-0.0432x}$ $r^2 = .5132$

Spring flow yield and rainfall indicated alog and second order polynomial relationships between the two for the springs of the watersheds on water year (June to May) basis below as;

Chandrabhaga watershed

Log relationship:

$TSp = 4293 \ln(TRa) - 263981$ $r^2=0.67$

Second order polynomial relationship:

$TSp = -0.0082TRa^2 + 22.08TRa - 7564$ $r^2=0.77$

Danda watershed

Log relationship:

$TSp = 3726.8 \ln(TRa) - 18617$ $r^2=0.65$

Second order polynomial relationship:

$TSp = 0.0072TRa^2 - 3.352TRa - 3967$ $r^2=0.83$

The log relationships for the watersheds are almost similar in nature with correlation 0.67 and 0.65 respectively for Chandrabhaga and Danda (*figure 3*). The relationship suggests that the total spring flow increases with total amount of rainfall. In principal the relationships supports that for an a rainfall below average the spring flows will be minimum, for average rainfall the spring flow will be average and for above average rainfall the flows of the spring will be maximum. The correlation for the second order polynomial is better than log form and is respectively 0.77 and 0.83 for Chandrabhaga and Danda watersheds.

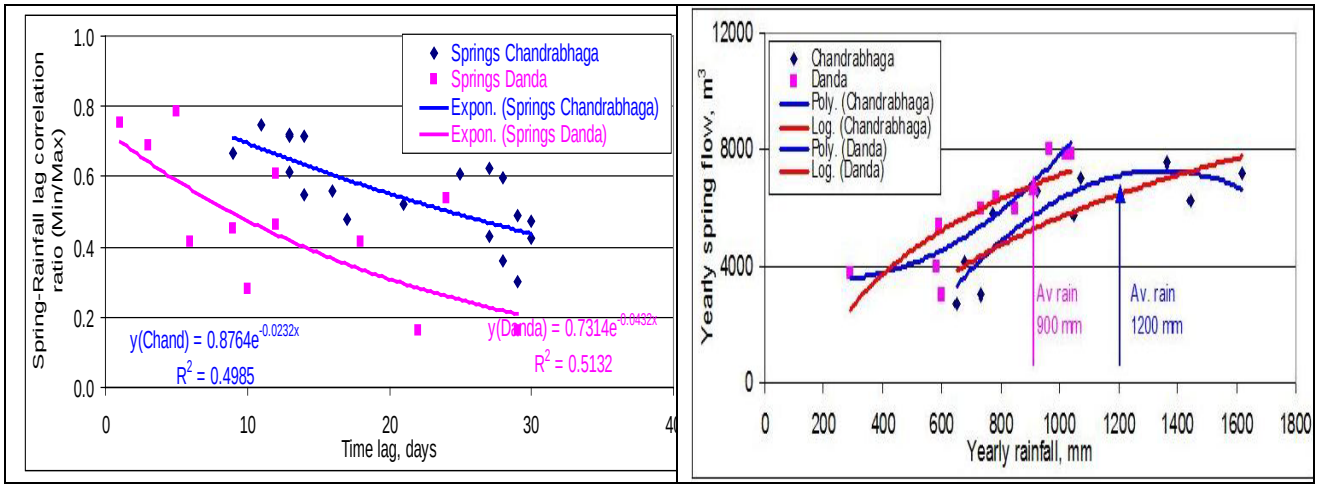


Figure 2: Relationship between spring–rainfall lag correlation ratio and spring-rainfall time lag for watersheds.	Figure 3. Relationship between total yearly rainfall and total yearly spring flow for watersheds.

The master recession curves are determined from the plot of dQ/dt against Q. The graphical analysis of $Q_{t+\Delta t}$ against Q_t or the equivalent form of dQ/dt against Q represents the upper and lower observed recession rates representing maximum and minimum recession rates. The plots so obtained are sensitive to the quality of the data as well as the selected time interval. The upper and lower envelops for the recession rates for the springs of Chandrabhaga are approximated considering monthly time interval and shown in *figure 4*. The approximated maximum recession rate, average recession rate and the lowest recession rate respectively for Chandrabhaga and Danda springs are given in *table 1*. The basis can be adopted for further classification and analysis of springs.

Table 1: The recession rates for the springs of Chandrabhaga and Danda watersheds.

Recession rates	Springs of Chandrabhaga	Springs of Chandrabhaga
Maximum	3.1414	3.1414
Average	0.9711	1.0843
Minimum	0.2563	0.2563

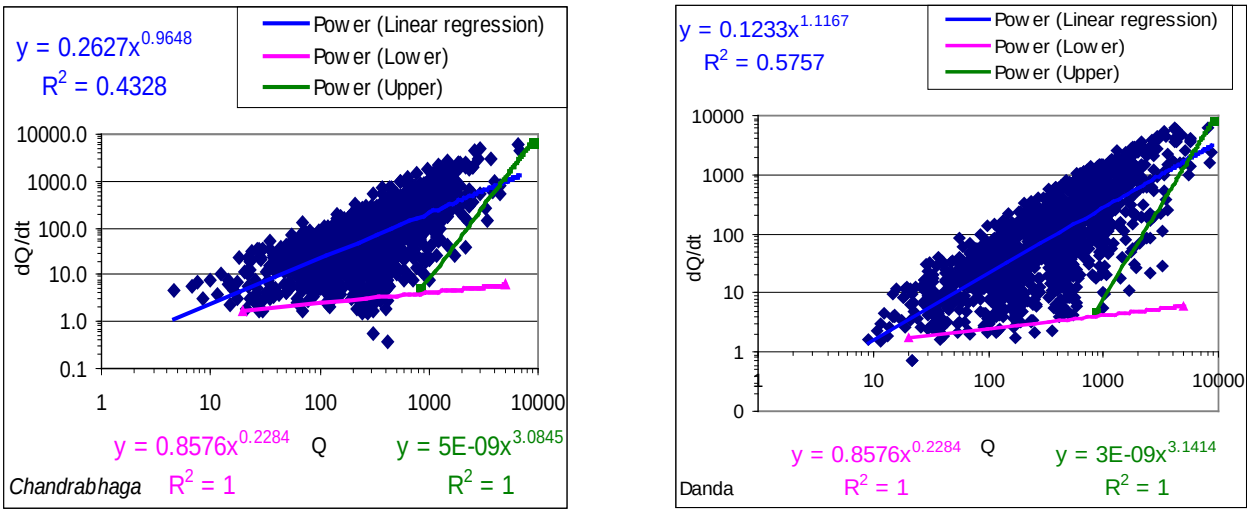


Figure 4: Upper and lower recession envelops for the springs of Chandrabhaga and Danda watersheds.

Springshed demarcation and development is subjected to geological similarity with in the watershed and is attempted with a new concept by delineating the boundaries of a spring subjected to conditions as; (1) The flow in the aquifer can not cross the stream path which is normally the lineament and also the other lineaments that are not along the defined visible stream paths present in the watershed, (2) The flow in the aquifer follows the same flow path that is defined by on the surface for surface flow as flow direction based on the topography, (3) The spring shed normally will not cross the well defined sub watershed boundaries, (4) The delineated spring shed boundaries can be corrected and adjusted subjected to condition as; (a) The area of the spring shed must follow the exponential relationship with maximum spring flow, (b) The spring shed area/relief must follow the exponential relationship with maximum spring flow. The delineated spring shed for a single or for a group of springs of the Chandrabhaga and Danda watersheds are reported in ***figure 5*.**

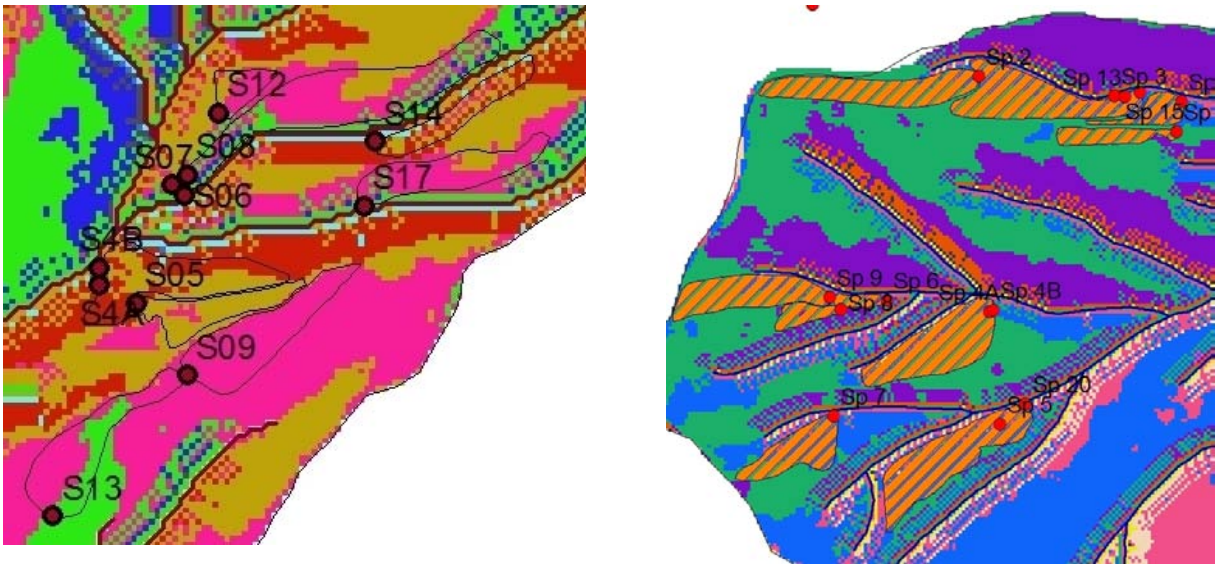


Figure 5: The delineated springsheds for the springs of Chandrabhaga and Danda watersheds.

8. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-15

1. Title of the Project: **Estimation of Water Balance for Integrated Water Resources Management in Yerrakalva Pilot Basin, A.P**.

2. Thrust Area under XII five year Plan: Integrated Water Resources Development & Management

3. Project Team: Dr. J.V.Tyagi, Sc 'G', SWH Div. (PI)

Dr. YRS Rao, Sc 'F', DRC, Kakinada (Co-PI)

4. Objectives of the study:

(i) To calibrate and validate SWAT model on Yerrakalva pilot basin
(ii)To compute water balance components of the hydrologic cycle for the basin

5. Statement of the problem:

Under 12th five-year plan program, NIH has taken up Pilot Basin Studies (PBS) for Integrated Water Resources Management (IWRM) in Yerrakalva river basin in coastal Andhra Pradesh. The program involves detailed studies on various components of the hydrologic cycle including water balance study of the basin. A water balance study quantifies the components of the hydrologic cycle at the catchment scale. The components of water balance of a basin are influenced by climate, the physical characteristics of the watershed such as morphology, land use and soil. Therefore, understanding the relationship between these physical parameters and hydrological components are very essential for integrated water resources management. This provides the most fundamental information about the hydrology of a watershed and is necessary to assess the importance of climate and land cover in determining water availability. In addition to providing a baseline understanding of the hydrologic processes occurring within a catchment, the water balance components can be compared over long periods of time to track the hydrologic response of a catchment to climatic and land cover variability. Therefore, the present study has been taken up for estimation of water balance and water yield in Yerrakalva river catchment which is critical to long term sustainable management of water resources in the basin.

6. Study area:

The Yerrakalva River rises in the eastern slopes of the eastern ghats at the boarder of West Godavari and Khammam districts. It enters into West Godavari district after 6.4 km run in Khammam district and runs in West Godavari district for about 180 km and joins the Upputeru river, which takes off from the Kolleru lake and falls into Bay of Bengal. Yerrakalva enters the Godavari western delta near Nandamuru aquiduct of Tadepalligudem Mandal. The catchment area of the river is 2725.03 Sq km of which 2330.10 Sq km spreads in upland and 394.93 Sq km in delta (Fig. 1). The study area gets rain during both Southwest and Northeast monsoons. The annual normal rainfall in the basin is around 1078mm.

7. Present state of art:

Major hydrological processes can be quantified with the help of water balance equations. Since the hydrologic processes are very complex, watershed models are widely used for proper comprehension of water balance components. The models based on explicit catchment water balance modelling are numbered in the hundreds and new models are still being presented. The watershed models partition rainfall into various hydrological processes such as surface runoff, evapotranspiration, percolation, lateral flow and base flow etc. with

the constraint to account for all water entering, leaving and being stored in a catchment. This adaptation of the principle of conservation of mass constrains the potential for error.

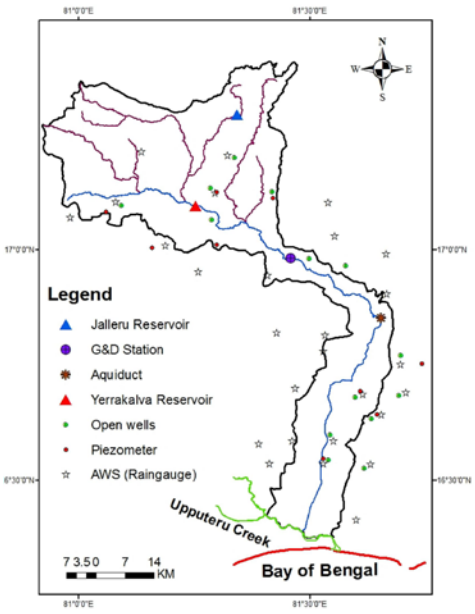


Fig. 1: study area

8. Methodology

SWAT, one of the most recent models developed by the USDA, will be used to analyse and quantify the water balance of the Yerrakalva river basin. The model has been chosen as SWAT is an integrated river basin scale, physically based, continuous-time, long-term simulation, distributed watershed model. Also, its suitability to different parts of the world has been well established. The SWAT model uses physically based inputs such as weather variables, soil properties, topography, land use characteristics and land-management practices occurring in the catchment. In SWAT, a basin is delineated into sub-basins, which are then further subdivided into HRUs based on the homogeneous land use, soil types and topographical characteristics. The major components of SWAT can be grouped into two categories (i) land phase of the hydrologic cycle that controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub-basin, and (ii) routing phase of the hydrologic cycle that defines the movement of water, sediments, etc. through the channel network of the watershed to the outlet. The physical processes associated with water flow, sediment transport, crop growth, nutrient cycling, etc. are directly modelled by SWAT. The hydrologic cycle as simulated by SWAT is based on the water balance equation. Model outputs all water balance components (surface runoff, evaporation, lateral flow, recharge, percolation, sediment yield, etc.) at the level of each watershed and are available at daily, monthly or annual time steps.

9. Research Outcome from the project:

(i) Quantification of water balance components of the catchment
(ii)Long term average estimates of catchment water yield
(iii) Technical publications in the form of report and research paper

10. Cost estimates

(a) Total cost of the project: Rs. 1,50,000/-

(b) Source of funding: Internal (Plan funds)
(c) Subhead-wise abstract of the cost:

S. No.	Sub-head	Amount (Rupees)
1.	Salary	-
2.	Travelling expenditure	1,00,000/-
3.	Infrastructure/equipment	-
4.	Experimental charges	25,000/-
5.	Misc. Expenditure	25,000/-
	Grand Total	**1,50,000/-**

(d) Justification for the subhead-wise abstract of the cost: Travelling expenditure of Rs. 1,00,000/- is required for field visits of PI, Co-PI and staff of DRC Kakinada to the study area and for data collection from the field departments. Also, some field experiments and collection of soil samples will be carried out for determination of model parameter values.

11. Work schedule:

(a) Probable date of commencement of the project: April 2014
(b) Duration of the project: One year
(c) Stages of work and milestone:

S. No.	Work Element	1st Qtr 2014	2nd Qtr 2014	3rd Qtr 2014	4th Qtr 2014	Status
1.	Collection of daily hydro-meteorological data & Processing					
2.	Field experiments, collection of soil samples and lab analysis					
3.	Preparation of spatial data base for SWAT viz. DEM, soil map and land use map					
4.	Preparation of attribute data base					
5.	Setting up of SWAT model					
6.	Calibration and validation of model					
7.	Analysis of model output and water balance					
8.	Report preparation					

9. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-15

1.	**Title of the study:**	**Status Report on "Impact of Anthropogenic and climate Change on Sediment Load of Rivers"**
2.	**Name of the PI:**	Dr Archana Sarkar, Sc C
3.	**Type of Study:**	Internal
4.	**Date of Start:**	1 April 2014
5.	**Scheduled date of completion:**	31 March 2015
6	**Nature of study:**	Review
7.	**Location Map:**	---
8.	**Study objectives:**	

1. Literature review
2. Preparation of status report

9. **Statement of the problem**

The sediment load of a river represents a key component of its hydrology, and in turn exerts an important influence on its aquatic ecology, its morphology and the exploitation of its water resources. Changes in the sediment loads of rivers can therefore have wide-ranging environmental and social and economic implications. There is growing evidence (reported by various authors for different rivers of the world) that the sediment loads of many rivers of the world, especially Asian rivers have changed significantly in recent years due to many reasons, including anthropogenic as well as climate change impact). Therefore, it is required to carry out a comprehensive up to date review of all such studies and prepare a status report.

10. End users/beneficiaries of the study

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

11. Methodology

Review of literature from research papers, reports and books.

12. Action plan and timeline

Year	April - June	July-Sept	Oct-Dec	Jan-March
2014-15	Literature Review	Literature Review	Literature Review	Preparation of status report

13. Data requirements: --

14. Deliverables:

i) Status Report

15. Adopters of the results of the study and their feedback: Water Resources Department

10. PROJECT REFERENCE CODE: NIH/SWD/NIH/13-16

1.	**Title of the study:**	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State
2.	**Name of the PI & Co-PI:**	Dr. Archana Sarkar, Sc C, (PI) Sh. N.K. Bhatnagar, PRA Dr. Vaibhav Garg, Sc C, IIRS, Dehradun Dr. Rakesh Kumar, Sc G & Head
3.	**Type of Study:**	Internal
4.	**Date of Start:**	1 April 2014
5.	**Scheduled date of completion:**	31 March 2016
6.	**Nature of study:**	Scientific Analysis
7.	**Location Map:**	

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".

8. Study Objectives:

Procurement of additional rainfall data of the available rain gauge stations in Uttarakhand State from various agencies and processing of rainfall data.
Spatio-temporal trend analysis of historical rainfall data.

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.

Comparison of rainfall data from various sources.

9. 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.

10. End users/beneficiaries of the study

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

11. Methodology

Trend analysis of historical rainfall data

The objective of a trend analysis is to find out whether a given time series shows an increasing or decreasing tendency over a given period of observation. Confirmatory method of data analysis detects the trends present in a time series and also estimates the rate of the identified trends. Both parametric and non-parametric methods of statistical trend analysis have been extensively used for detection of linear trends in climatic data series. However, form of test and the underlying sample distribution assumptions vary according to the objective of trend analysis. In the present study, linear trends will be estimated using the three methods: linear regression, Mann-Kendall test and Sen's slope estimator considering the advantages and disadvantages of the three methods.

Comparison of rainfall data from different sources

Comparison of rainfall data from two different sources, viz TRMM satellite data products and APHRODITE high resolution gridded re-analysis data will be carried out considering observed rain gauge data as base data.

12. 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
2015-16	Downloading of TRMM satellite data and APHRODITE data	Processing of downloaded data	Analysis and comparison of data from different sources	Interpretation of results and preparation of final report

13. Data requirements

Rainfall data at different temporal scales from different sources for the Uttarakhand State.

14. Deliverables:

Research papers and report.

15. Adopters of the results of the study and their feedback: Water Resources Department

11. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

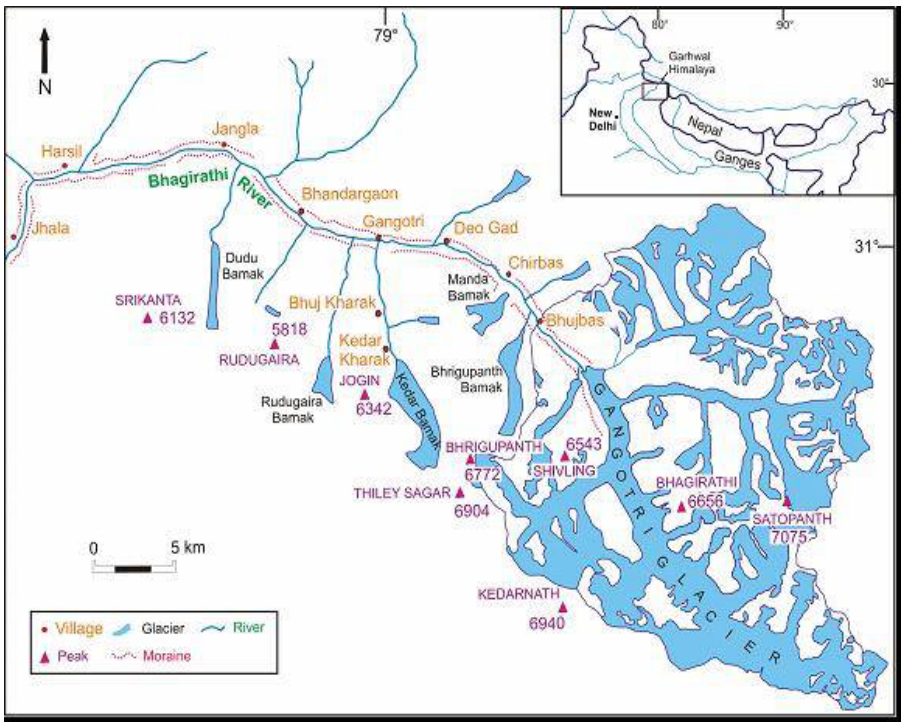
Title of the Study: **Monitoring and modelling of streamflow for the Gangotri Glacier**

Study Group: Dr Manohar Arora Sc 'C'
Rakesh Kumar Sc 'G'

Role of Team Members:

1. **Dr . Manohar Arora, Scientist C& PI:** Conduction field investigations, analyzing data/information, report preparation and overall responsible for the study completion.
2. **Dr Rakesh Kumar, Scientist F &** Co-PI: Guidance in development of methodology, modelling and structuring of report.

Type of Study: Sponsored
Date of start: 01.5. 2014
Scheduled date of completion: 31.03.2017
Location Map:



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.

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.

Approved action plan:

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

Objectives vis a vis Achievements:

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 collection and field investigations for the summer 2014 have been initiated.

Recommendations of Working Group/TAC/GB:
The study may be continued for long term to link with climate change.

Analysis and Results:
The Department of Science and Technology has sponsored this study. This is the first year and the investigations were started on 17th May 2014.

Adopters of the results of the study and their feedback:
The study is a sponsored study and the results will be disseminated by DST.

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.
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.
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.
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.
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.

12. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

1.	**Title of the study:**	**Effect of climate change on evaporation at point scale**
2.	**Name of the PI & Co-PI:**	Sh. Digambar Singh, Sc B Dr. A. R. Senthil kumar, Sc E Dr. Manohar Arora, Sc D
3.	**Type of Study:**	Internal
4.	**Date of Start:**	1 June 2014
5.	**Scheduled date of completion:**	31 March 2017
6	**Nature of study:**	Technique development

7. **Location Map:**

The temperature, rainfall, humidity and evaporation data of NIH observatory or suitable site would be used for carrying out the analysis.

8. Study objectives:

i. To develop evaporation model by empirical and soft computing techniques
ii. To downscale the data of temperature, rainfall and humidity from GCM model
iii. To determine the effect of climate variables on evaporation by using the downscaled data

9. **Statement of the problem**

Increased atmospheric concentration of carbon dioxide and other trace gases, as well as anthropogenic activities will increase the occurrence of extreme events of climatic variables such as rainfall and temperature. Ultimately, this will increase or decrease the evaporation of region. So the estimation of increase or decrease in evaporation due to different climate change scenarios is most important in the future planning of the cropping pattern of the region.

10. End users/beneficiaries of the study

Agriculture department for the planning of the cropping pattern.

11. Methodology

Evaporation model

Multiple Linear regression (MLR) and soft computing techniques would be applied to model the evaporation with rainfall, temperature and humidity as input vectors.

Development of climate scenarios

The prediction of rainfall, minimum and maximum temperature and humidity for future is possible by considering the statistical properties of the time series. The weather generators, considering the future carbon emissions, radiation and effects of green house gases, have been developed to generate the time series by fitting a distribution to the times series and by using the properties of distribution of the times series. The different scenarios of climatic conditions such as A1F1, B1 and baseline can be obtained from SDSM (**Statistical DownScaling Model)** from UK/PRECIS from IITM, Pune. The best models developed by soft computing techniques to simulate the evaporation from historical values of rainfall,

maximum and minimum temperature and humidity at the site can be utilized to generate the evaporation from the generated values of rainfall and maximum and minimum temperature and humidity for different climatic scenarios as mentioned above. The falling and rising values of evaporation from the different climate scenarios would give an idea to the official dealing with the planning of cropping pattern.

12. Action plan and timeline

Year	April - June	July-Sept	Oct-Dec	Jan-March
2014-15	Literature review, Data collection and compilation	Literature review, Data collection, compilation and processing	Development of model for evaporation by empirical and soft computing techniques	Development of model for evaporation by empirical and soft computing techniques
2015-16	Development of model for evaporation by empirical and soft computing techniques	Development of climate scenarios from SDSM/PRECIS	Development of climate scenarios from SDSM/PRECIS	Development of climate scenarios from SDSM/PRECIS
2016-17	Simulation of evaporation by considering the climate scenarios	Simulation of evaporation by considering the climate scenarios	Simulation of evaporation by considering the climate scenarios	Writing of final report

13. Data requirements

a. Maximum and minimum temperature
b. Rainfall
c. Humidity
d. Pan evaporation

14. Deliverables:

i) Future series of rainfall, maximum and minimum temperature and humidity
ii) Trend of future evaporation
iii) Comprehensive report giving data, maps and results
iv) Research papers

15. Adopters of the results of the study and their feedback: Agriculture department of the concerned region

13. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

1. **Thrust area under XII five year Plan**

   Hydrological modelling, water availability analysis

2. **Project team:**
   a. Project Investigator: J.P.Patra, Sc. – B
   b. Project Co-Investigator: Dr. Rakesh Kumar, Sc. – G & Head
      Pankaj Mani, Sc – D, CFMS Patna

3. **Title of the Project:**

   Hydrological modelling of Brahmani Baitarani river basin using eWater Source platform.

4. **Objectives**
   a. Statistical and trend analysis of rainfall and river discharge in the Brahmani Baitarani river basin.
   b. Development of rainfall runoff model for Brahmani Baitarani river basin using eWater source platform.
   c. Investigation of implications of different rainfall inputs on rainfall–runoff simulation.
   d. Test the applicability of the eWater source modelling platform in Brahmani Baitarani river basin by generating hydrological time series.

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

   The eWater source is Australia's first national river basin scale water modelling system. The source modelling platform has been developed to take a holistic approach to water management including human and ecological impacts. This includes integrating policy, addressing water savings and sharing for a whole river and connected groundwater systems including cities, agricultural and environmental demands. In the India-Australia Water Science and Technology Partnership programme, Australia is collaborating with the Ministry of Water Resources to pilot the source river basin modelling platform in India. The MoWR, GOI is planning to develop an Integrated Water Resources Management (IWRM) plan for Brahmani Baitarani basin using the source river basin modelling platform. Hence, the present study has been formulated to develop a rainfall runoff model for Brahmani Baitarani river basin in source platform and test its applicability by generating hydrological time series.

6. **Methodology**

   The Brahmani Baitarni basin (Fig. 1) extends over states of Odisha, Jharkhand and Chhattisgarh with catchment area of about 51,822 km^2. The basin is bounded by the Chhotanagpur Plateau on the north, by the ridge separating it from Mahanadi basin on the west and the south and by the Bay of Bengal on the east. The Brahmani known as South Koel in its upper reaches rises near Nagri village of Jharkhand at an elevation of about 600 m and has length of about 800 km. In its tail reach, the river is known as Maipura. The Baitarni rises near Dumuria village in the hill ranges of Kendujhar district of Odisha at an elevation of about 900 m and has a length of about 355 km.

The river is known as Dhamra in its lower reaches. Brahmani and Baitarni form common delta area before falling into the Bay of Bengal. The lower reaches of the basin near the deltaic area are subject to floods. Moreover Mahanadi, Brahmani and Baitarani are interconnected near their delta, worst flood occur when there is simultaneous heavy rains in all the three catchments. Floods are also caused from cyclonic storms since the coastal areas of the basin are cyclone-prone. The industrial development potential of this basin is very high due to its rich mineral resources (iron ore, copper, bauxite etc.) and power potential (548 MW at 60% load factor). Rourkela is an important industrial centre located in this basin. There various other industries (Iron and steel, Thermal power plant, fertilizers etc) existing the basin and more than 50 small to large industries are planned to set up in the upper and middle reaches of the basin. Hence, in future there will be very high water demands from industrial sectors.

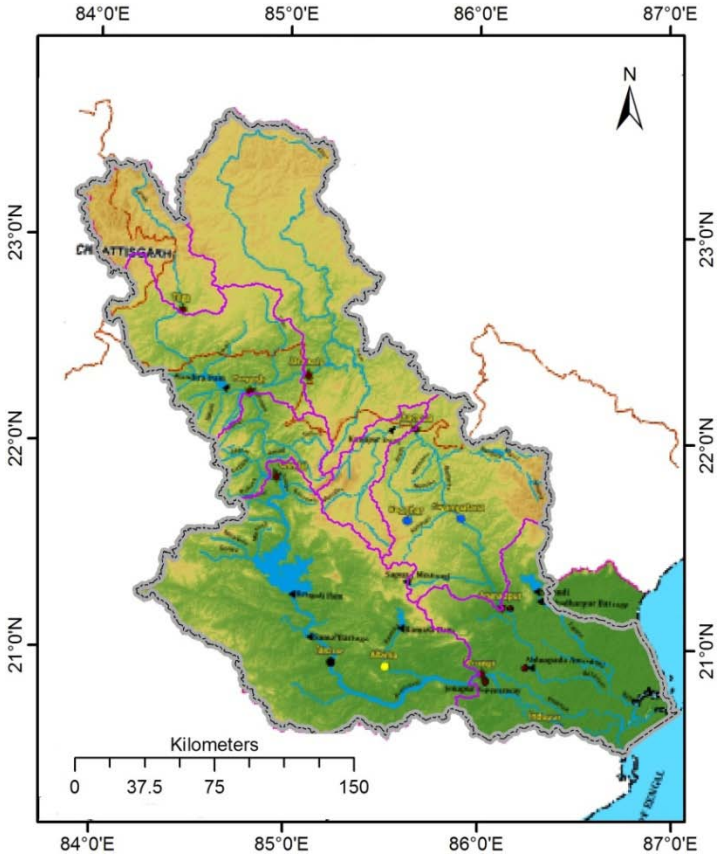


Fig. 1: Index map of study area

Historical rainfall and flow data of the Brahmani Baitarani river basin will be collected and time series of monthly, seasonal and annual values of rainfall and discharge will be analyzed using statistical methods. Trend analysis will be performed to determine whether or not there have been any significant changes in rainfall and discharge over this catchment. The analogue year's plots will be used to identify years with near normal, above normal and below normal conditions, using the long term mean of the variables.

Rainfall runoff models are used to derive runoff for a particular area from inputs of rainfall and potential evapotranspiration. All rainfall runoff models in source are conceptual models that represent catchment hydrological response to rainfall as a series of mathematical relationships. They provide runoff output from each functional unit as total discharge, which is split into quick flow (surface flow) and slow flow (baseflow) proportions. The rainfall-

runoff models presently available in source are: Sacramento (sixteen parameters), SIMHYD (7 parameter), SMARG, GR4J (modèle du Génie Rural à 4 paramètres Journalier) (four parameters), IHACRES (six parameters), AWBM (3 parameter), SURM. These models will be configured to run the rainfall-runoff models at the catchment scale.

Different methods are available to obtain the daily rainfall time series for conceptual rainfall–runoff models, depending on data availability, time constraints etc. The implications of different rainfall inputs on the calibration and simulation of rainfall–runoff models will be analysed. First, the simulated runoff resulting from single lumped daily rainfall series for each catchment obtained from three methods: single rainfall station, thiessen average, and average of interpolated rainfall surface will be compared. Secondly, runoff generated from catchment modelling using daily/monthly rainfall series and modelling with smaller functional units within a sub catchment will be compared. The source platform includes set of optimisation tools for calibration of various model parameters. These high-level optimisation features include: Shuffled Complex Evolution (SCE-UA), multi-objective complex evolution (MOCOM-UA), Rosenbrock and other optimisation algorithms; predefined and user defined custom objective functions; option for custom optimisation problems such as regional calibration. Some of these techniques will be applied to calibrate the model. Finally, the calibrated model will be used to simulate hydrological time series for various time periods and will be compared with observed time series to test the applicability of the eWater source modelling platform in Brahmani Baitarani river basin.

7. **Research outcome of the project**
    - Trends of rainfall and stream flow in the Brahmani Baitarani river basin.
    - Calibration and validation of various model parameters of eWater source modelling platform for Brahmani Baitarani river basin.
    - Water availability at various river reaches and sub catchments.
    - Quantify rainfall-driven runoff in the catchment under present conditions and alterations made to runoff by climate variability, different land uses etc.
    - eWater source hydrological model setup for Brahmani Baitarani river basin.
    - The rainfall runoff modelling setup will help in development of IWRM plan in Brahmani Baitarani river basin.
    - Research papers and reports.

8. **Cost estimates**
    a. Total cost of the project: □ 15,07,200
    b. Source of funding: Internal
    c. Sub Head wise abstract of the cost

SI. No.	Sub head	Amount (in Rupees)
1	Salary (JRF)	7,39,200
2	Travelling expenditure	3,18,000
3	Infrastructure/Equipment	1,50,000
4	Experimental charges/ Data	1,50,000
5	Misc. expenditure	1,50,000
	Grand Total:	15,07,200

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

Salary: Salary for one JRF @□18000 per month for 2 year and □20000 per month for 3rd year. The HRA of 10% has been added extra.

Travel Expenditure*:* Funds would be required towards TA/DA by PI and team members for visits to Brahmani Baitarani river basin and departments maintaining related datasets for discussions, information collection, verification and assessment of data and results. Part of the travel grants will be used to participate in conferences and workshops to disseminate preliminary results of the project, and to obtain critical feedback. Further, travel of the project investigators to CWC, MoWR meetings and relevant training/workshops would also be met from the travel head. Travel expenses for field visits, data collection etc. = □ 1,50,000 (6 trips, @ Rs. 25,000 per trip per person); Travel expenses to attend training, conferences/workshop = □1,20,000 (6 travels, @Rs 20000 per person per trip); Travel expenses for attending meetings at CWC/MoWR = □ 48,000 (6 travels, @Rs 8000 per trip).

Infrastructure/Equipment: The source platform requires high end systems to run effectively. Recommended system requirement for the source platform is Windows with 16 GB RAM (Minimum 4 GB) and minimum 10,000 rpm hard drive. One high end desktop is required for this study. External hard disk, UPS, laser printer etc. are also required. Further basic furniture like one computer table, chair and storage are required. 1 High end PC = □ 60,000; 1 Laser Printer = □ 40,000;
Hard disk, UPS etc. = □ 25,000, Furniture (computer table, chair, storage/book case) = □ 25,000.

Experimental charges/ Data: The project involves purchase of extensive data (hydro meteorological and satellite images, thematic maps), visits to several government agencies for collection these data. Services of assistants/helpers will be needed during field surveys for ground truth verification and data collection.

Misc. expenditure: Expenses would be incurred for purchase of stationery, cartridges of printer and other consumables, charges towards colour printing of large size maps, preparation of project reports and for meeting expenses of other unforeseen needs of the project.

9. **Work Schedule:**

a. Probable date of commencement of the project: April 2014

b. Duration of the project: 3 Years

c. Stages of work and milestone:

Sl. No.	**Work Element**	**First Year**	**Second Year**	**Third Year**
1	Literature Review and detailed formulation of research approach			
2	Collection of hydro meteorological data, satellite images, thematic maps etc.			
3	Compilation, statistical and trend analysis of rainfall and river discharge			
4	Rainfall runoff model set up in eWater Source platform			

5	Implications of different rainfall inputs and sub catchment size			
6	Calibration and parameter estimation			
7	Model performance evaluation with in various time periods			
8	Reporting	1st Interim report	2nd Interim report	Final report

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sharad Kr. Jain	Scientist G & Head
2	Dr. S K Singh	Scientist F
3	Mrs. Deepa Chalisgaonkar	Scientist F
4	Dr. Sanjay K Jain	Scientist F
5	Dr. M K Goel	Scientist F
6	Sri D S Rathore	Scientist F
7	Dr. P K Bhunya	Scientist D
8	Dr. Renoj Thayyen	Scientist D
9	Sri L N Thakural	Scientist B
10	Sri. Manish Nema	Scientist B
11	Sri P K Mishra	Scientist B
12	Sri Tanvear Ahmed	Scientist B
13	Sri P K Agarwal	Scientist B
14	Sri Yatvear Singh	PRA
15	Mrs. Anju Chowdhary	SRA

WORK PROGRAMME FOR THE YEAR 2014-2015

S. No	Title	Study Team	Duration	Funding (Rs.in Lakhs)
Completed Internal Studies				
1.	Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, ladakh Range	Renoj J. Theyyan S. P. Rai M. K. Goel	5 years (09/06-12/14)	NIH
Ongoing Internal Studies				
1.	Trend and variability analysis of rainfall and temperature in Himalayan region	L. N. Thakural Sanjay Kumar Sanjay K. Jain Sharad K. Jain Tanvear Ahmed	3 years (10/11-09/14)	NIH
2.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel Sharad K. Jain Deepa Chalisgaonkar Prabhash K. Mishra	2 Years (04/13-03/15)	NIH
3.	Web GIS based snow cover information system for the Indus Basin	D. S. Rathore Deepa Chalisgaonkar L. N. Thakural Tanvear Ahmed	2 Years (04/13-03/15)	NIH
4.	Assessment of Water Footprint of the National Capital Territory (NCT) of India	Deepa Chalisgaonkar Sharad K. Jain M. K. Nema P. K. Mishra	2 Years (04/13-03/15)	NIH
5.	Impact of Climate and Land Use Change on Floods of Various Return Periods	P. K. Bhunya Sanjay Kumar D S Rathore	2 Years (04/13-03/15)	NIH
6.	Assessing climate change impact across KBK region of Odisha	P. K. Mishra Sharad K. Jain Sanjay K. Jain P. K. Bhunya	2 Years (04/13-03/15)	NIH
7.	Glacier change and glacier runoff variation in the upper Satluj river basin	Sanjay K. Jain Sharad K. Jain Renoj J. Theyyan	2.5 Years (10/13-03/16)	NIH
8.	Variability of the Hydro-climatic variables in Punjab Plains of lower Satluj	M. K. Nema Sharad K. Jain	2 Years (11/13-10/15)	NIH (11.34)
Ongoing Sponsored Studies				
1.	Glaciological studies of Phuche Glacier, Ladakh Range, India	Renoj J. Theyyan M K Goel S P Rai	5 Years 1/10-12/14	DST (56)
2.	Ganga River Basin Environment Management Plan	Sharad K Jain N. C. Ghosh Sanjay K. Jain M. K. Goel	2 Years 07/12-06/14	IIT Kanpur (12)

3.	Assessment of Environmental flow for Himalayan River	Sharad K. Jain Pradeep Kumar P. K. Agarwal P. K. Mishra	1 Year 07/14-07/15	MOES (9.95)
Proposed New Internal Studies				
1.	Hydrologic Modelling of a part of Satluj Basin using SWAT Model	P. K. Agarwal Sanjay K. Jain M.K. Goel Sharad K. Jain Tanvear Ahmed	2 -3/4 Years (06/14-3/17)	NIH (23)
2.	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 (07/14-06/16)	NIH (34)
3.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Theyyan S P Rai	3 years (04/14-03/17)	NIH (20)

INTERNAL RESEARCH PROJECT: NIH/WRS/2009/01

a) Title of the Study **:*Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, Ladakh Range***

b) Study Group : Dr. R.J Thayyen, Dr.S.P Rai & Dr. M.K Goel

c) Date of Start : September 2009

d) Schedule date of completion: December 2014

e) Type of study : NIH

f) Location map / Study area : Same as above

Objectives of the study are:

1. To study climatological and runoff characteristics of a glacier catchment in Ladakh range and modeling of catchment runoff.
2. Study the composition of stable isotopes $\delta^{18}O/\delta D$ in the catchment runoff, winter snow, summer snow/rainfall. Separate glacier melt component from snow, rain, groundwater component of the river flow in the catchment runoff and study its temporal and seasonal variations.

h) Statement of the problem:

Understanding of the cryospheric system processes of cold-arid regions of Ladakh is very poor. Present study is initiated to bridge the knowledge gap of this very important and unique glacier system of the trans-Himalaya. One of the key question is how glacier melt is influencing the catchment runoff in the cold-arid systems?.Evaluating the hydrological characteristics of the cold-arid system is also a priority.

i) Approved action plan

- Procurement and installation of equipments
- Catchment runoff measurements
- Year round monitoring of meteorological parameters
- Catchment runoff modeling
- Stable isotope characterization of winter snow, summer rain/snow and stream flow
- Hydrograph separation by isotope method

j) Achievements

Year	Objectives (for the period April 2013 – September 2013)	Achievements
2013	i. Catchment runoff measurements	Achieved
	ii. Year round monitoring of meteorological parameters	Achieved
	iii. Catchment runoff modeling	Achieved
	iv. Stable isotope measurement of winter snow, summer rain/snow and stream flow	Achieved
	v. Hydrograph separation by isotope method	Achieved
	vi. Report Writing	Nearly Completed

k) Recommendation / suggestions in previous meetings of Working group / TAC / GB

There were no specific/major recommendations pertaining to the study.

l) Analysis and Results:

The project entitled "Cryospheric system studies of Ganglass catchment, Ladakh Range, India" is the first attempt made in the country to understand the high altitude cryospheric system hydrology of the cold-arid system of the Ladakh. The project executed at a high altitude catchment in the Ladakh range extending from 4700 m to 5745 m a.s.l. This experimental catchment is spread over 15.8km^2 and have a glacier cover of 0.62km^2. This headwater catchment feed to Leh town and the Ganglass catchment and remain as the sole water source for the entire city of Leh, which is a favorite tourist destination in the country. Tourism to Ladakh increased exponentially from 20000 in 2004 to 1.8 Lakh in 2012, putting huge pressure on the water resources- Habitat equilibrium.

To understand the cryospheric systems dynamics, a Benchmark glacier catchment strategy has implemented in the upper Ganglass catchment. This strategy has been formulated with a core philosophy of understanding the orographic forcing and feedback on the high altitude cryospheric systems and studying the role of various cryospheric and atmospheric components on the catchment discharge. Runoff modeling and isotopic studies of stream flow, precipitation and local water sources were employed for achieving these goals. Discharge measurements were carried out at 4700 m a.s.l. with the help of a Radar Water Level Recorder. Four years of runoff data, meteorological data, Electrical conductivity data, snow cover depletion data, isotopic data etc. were generated though this project; building the most comprehensive data base for this region.

The study has revealed the sharp vertical hydrological gradient in the cold-arid system. While mean annual precipitation remained 115 mm per year, the annual discharge from the upper Ganglass catchment is ranged between 10.7 x10^6 m^3 to 7.7 x10^6 m^3 (685 to 490 mm w.e.) showing the significantly wetter regime at the higher altitude regions. A tandem study on glacier mass balance exchange have shown that the 4% glacier cover in the catchment contributed only around 5% of the annual discharge. It is observed that the flow regime during prolonged snow cover and shorter snow cover were distinctly different and have corresponding change in the EC-Q variations. Supported by the field geomorphological evidences it is proposed that the steady discharge with higher EC values during the years with shorter snow cover is sourced from the permafrost melt. By employing the two component mixing model it is estimated that the permafrost contribution could be at least 25% during the years with shorter snow cover.

Temperature Lapse rate is the most critical parameter in the snow melt runoff model. Generally standard environmental lapse rate ranging from 6.5 to 8.9^{o}C is used for snow melt modeling. We have found that the Slope Environmental Lapse Rate (SELR) have significant seasonal variation liked with the moisture influx to the region. During summer months SELR between 3500 to 4700 m a.s.l was consistently ranged between 10 to 15 ^{o}C espousing the cold-arid conditions. Higher altitude section (4700-5600m a.s.l.) is found to have experiencing lower SELR. We have developed a model solution for SELR by generating monthly indices separately for the two distinct sections. The trials have demonstrated that the model have high efficiency for calculating the monthly SELR.

Runoff modeling was performed by using the WinSRM model. The model delivered very good result for 2010 and 2012, when the catchment experienced prolonged snow cover. But

during the shorter snow cover years (eg. 2011) model performed very poorly as model did not have the permafrost melt module.

Isotope data for stream flow, precipitation, snow etc. for generated for four years and final synthesis is in progress. The result will be presented during the working group meeting.
It is felt that the study required to be continued for better understanding of the permafrost melt processes and long-term climate forcing on the cryospheric system of the cold-arid system.

m) Adopters of the results of the study and their feedback

Ladakh Autonomous Hill Development Council (LHADC), Leh

n) Deliverables

Reports and research papers

o) Data generated in the study

Catchment runoff data at 4700 m asl.-04 Years. Snow cover depletion curve,Snow cover duration at 4700m asl. Electrical conductivity data of stream discharge, Isoptopic data of stream flow at 4700 m asl.

***

INTERNAL RESEARCH PROJECT: NIH/WRS/2011/01

Title of Study	-	**Trend and variability analysis of Rainfall and Temperature in Himalayan region**
Study Group	-	Mr. L. N. Thakural, Sc-B, PI Dr. Sanjay Kumar, Sc-E1, Co-PI Dr. Sanjay Kumar Jain, Sc-F, Co-PI Dr. Sharad Kumar Jain, Sc-F, Co-PI Mr. Tanveer Ahmed, PRA, Co-PI
Type of Study	-	Internal
Start Date	-	October 01, 2011
Scheduled date of completion	-	September 30, 2014

Location/Study area

The study is a case study and is a step to understand the behaviour of climate in Himalayan region covering western, central and eastern Himalayas. The Himalayas, which means the storehouse of snow and ice, is the world's youngest, highest, most rugged, sensitive and extensive mountain system having 14 peaks over 8000m and hundreds over 7000m and 530 peaks above 6000m.

Objectives of the study:

The objectives of the study are:

1. To create database for hydrological parameters (Rainfall and Temperature) for the Himalayan region.
2. To estimate temporal and spatial characteristics of the rainfall and temperature time series.
3. To carry out trend and variability analysis of rainfall and temperature.

Statement of the problem:

Interest in climate variations has experienced a significant increase in recent years due to the important economic and social consequences connected with extreme weather events. Most of the studies regarding climate change only seek to detect potential trends or fluctuations in the long term mean of climatic signals, but the study of variability changes and extreme event behaviour is also essential. In the present study statistical analysis, trend and climatic variability changes in climatic variables namely temperature and rainfall will be carried out in Himalayan region, India. The parametric and non-parametric approaches will be used to determine the trends in the time series data of these meteorological parameters

Methodology:

Statistical techniques/tools will be used to evaluate the temporal and spatial characteristics of the rainfall and temperature time series (statistical distribution, temporal correlation, spatial

correlations). As meteorological data in the Himalayan region is scarce the rainfall data from APHRODITE would also be used in the study. A comparison of rainfall from APHRODITE with the ground based stations will also be carried out. The trends and variability analysis of rainfall and temperature time series would be evaluated using the following statistical techniques for various time scales.

1. Parametric approach for trend and variability.
2. Mann-Kendall test and Sens's estimator of slope method (non-parametric) for trend and variability.

Approved action plan and timeline:

Sr. No.	Major Activities	1st Year	2nd Year	3rd Year
1	Literature review			
2	Data collection & preparation for analysis			
3	Temporal and Spatial characteristics of the rainfall and temperature time series and their statistical distribution.			
4	Analysis using parametric approach			
5	Analysis using non-parametric approach			
6	Preparation of report**		Part-1 Part-2	Part-3

Achievements

Year	Objectives (November-May 2014)	Achievements
2014	Analysis for Western Himalayan region	• The hydro meteorological data in the eastern Himalayas has been analyzed for temporal and spatial characteristics. • The parametric approach has been used to find out the trend in temperature and rainfall time series. • The non-parametric approach has been used to detect trends in temperature and rainfall series.

Recommendations / suggestions in previous WG

Recommendations	Action Taken
Dr. S. N Rai, NGRI, Hyderabad suggested that it is very important to make field visits of some of the stations lying in the study area.	A field visit was made to some stations in Central Himalayas.

Analysis and Results:

WESTERN HIMALAYAN REGION

The western Himalayan region comprises mainly of two northern states Jammu & Kashmir and Himachal Pradesh.

Jammu and Kashmir

The Jammu-Kashmir state lying in the North-West Himalayas region an area of 2, 22,236sq. Km. It is the 6th largest state of the country located between 32.17 degree and 36.58 degree north latitude and 37.26 degree and 80.30 degree east longitude in northern most part of India. The state shares its boundary with Pakistan, Afghanistan and China from West to East and with Punjab and Himachal Pradesh in the south. The state has three divisions viz., Jammu, Vale of Kashmir and Ladakh.

The state of Kashmir has three distinct climatic regions viz., Arctic cold desert areas of Ladakh, temperate Kashmir valley and sub-tropical region of Jammu. Altitude varies widely between 1,000 ft. and 28,250 ft. above the sea-level in the state. The climate of Jammu and Kashmir varies greatly owing to its rugged topography. In the south parts of the state, the climate is typically monsoonal. The annual rainfall varies from region to region with 92.6 mm in Leh to 650.5 mm in Srinagar to 1,116 mm in Jammu. In summer, Jammu city is very hot and can reach up to 43°C whilst in July and August, very heavy and erratic rainfall occurs with monthly extremes of up to 650 mm. During October, conditions are hot and extremely dry, with minimal rainfall and temperatures around 29°C. Srinagar receives as much as 635 mm of rain with the wettest months being March to May with around 85 mm per month. The climate of Ladakh and Zanskar is extremely dry and cold. Annual precipitation is only around 100 mm (4 inches) per year and humidity is very low.

Himachal Pradesh

Himachal Pradesh lying in Western Himalaya has an area 21,495 sq km and is bordered by Jammu and Kashmir on the north, Punjab on the west and Haryana and Uttarakhand on the South-east. Himachal Pradesh is situated in the Western Himalayas, Covering an area of 55,673 kilometres (34,594 mm), Himachal Pradesh is a mountainous state with elevation ranging from about 350 metres (1,148 ft) to 7,000 level. There is great variation in the climatic conditions of Himachal Pradesh due to extreme variation in elevation. The climate varies from hot and sub-humid tropical in the southern tracts to cold, alpine and glacial in the northern and eastern mountain ranges with more elevation. The state has areas like Dharamsala that receive very heavy rainfall, as well as those like Lahaul and

Spiti that are cold and almost rainless. Himachal experiences three seasons; hot weather season, cold weather season and rainy season. Summer lasts from mid April till the end of June and most parts become very hot. Winter lasts from late November till mid March. Snowfall is common in alpine tracts (generally above 2,200 metres (7,218 ft) i.e. in the Higher and Trans-Himalayan region).

In the present study, 13 stations of Jammu and Kashmir and eight stations of Himachal Pradesh study were examined, to know trend and variability in temperature. The four rainfall stations of Jammu and Kashmir were taken for the trend and variability in rainfall. The parametric (Linear regression) and non-parametric (Mann-Kendall and Sen's Slope estimator) approaches were used for carrying out trend analysis using the meteorological data.

Trends in Temperature

The magnitude of the trends in the mean temperature time series on seasonal and annual time scale is determined using the Sen's slope estimator (Table 1). The Man-Kendall test was applied to this time series to ascertain the significance of trends (Table 1).

Table 1: Sen's slope (^{0}C/year) for seasonal and annual mean temperature

Station	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
Kupwara	**.046**	.014	-.006	.02	.017
Batote	**.075**	.009	.03	**.056**	.037
Badarwah	**.098**	.016	.034	.071	.048
Kukernag	**.062**	.001	-.013	**.059**	.029
Pehalgam	**.072**	.017	.043	**.072**	**.044**
Katra	**.107**	.005	.018	**.05**	.04
Gulmarg	.097	.012	**.068**	.073	**.049**
Srinagar	.023	.006	.001	.006	.016
Dras	.009	-.005	-.001	.003	0
Leh	-.011	.004	-.01	-.006	-.003
Quazigund	.012	-.012	.018	**.058**	**.02**
Banihal	.034	.005	**.022**	**.044**	.025
Jammu	-.03	-.021	-.008	-.014	-.016

Note: Bold indicates statistical significance at 95% confidence level as per with Mann-Kendall test (+ for increasing and – for decreasing)

The result of Mann-Kendall test to know the significant of trends in seasonal and annual temperature is given in Table 1. It is revealed from the table that except two stations Leh and Jammu, all other stations depict increasing trend in mean temperature at annual, pre monsoon and winter scale. The six stations Kupwara, Batote, Badarwah, Kukernag, Phelgam and Katra in pre monsoon season shows increasing statistically significant trends. Furthermore, six stations during winter seasons are showing increasing significant trend.

Trends in Rainfall

The magnitude of the trends in the annual mean rainfall time series on seasonal and annual time scale is determined using the Sen's slope estimator is given in Table 2. The Man-Kendall test was applied to this time series to ascertain the significance of trends (Table 2).

Table 2: Sen's estimator of slope (mm/year) for seasonal and annual rainfall

Station	Pre-monsoon	Monsoon	Post-monsoon	Winter	Annual
Srinagar	0.24	-0.12	0.24	-0.43	0.57
Dras	3.34	0.07	0.32	4.39	7.67
Leh	0.07	0.14	**0.05**	0.13	0.44
Banihal	3.59	-0.64	0.15	**-13.75**	-6.62

Note: Bold values indicate statistical significance at 95% confidence level as per the Mann-Kendall test (+ for increasing and – for decreasing)

From Table 2 it is clear that Srinagar, Dras and Leh have increasing trend in rainfall at annual scale while Banihal (-6.62 mm/year) is having decreasing trend and none of the station is showing significant trend either of increasing or decreasing. During the Post monsoon season all stations depict increasing trend. Leh was found statistically significant in post monsoon having increasing trend and Banihal in winter showing maximum significant decreasing trend (-13.75 mm/year).

Himachal Pradesh

In the present study, from the Himachal Pradesh Bhakra, Kaza, Rampur, Kalpa, Namigia, Sunni, Kasol, Nangal stations were examined for trends and variability.

Table 3: Sen's estimator of slope (mm/year) for seasonal and annual temperature

Station	Pre monsoon	Monsoon	Post Monsoon	Winter	ANNUAL

	Mean Max Temp				
Bhakra	0.065	0.007	-0.037	**-0.058**	0.003
Kalpa	**0.129**	-0.008	**0.058**	**0.118**	**0.07**
Kasol	**0.091**	-0.014	-0.02	0	0.008
Kaza	-0.096	0.094	0.061	0.041	0.072
Namgia	**0.148**	-0.005	0.024	0.141	0.08
Nangal	0.058	-0.047	-0.037	-0.012	-0.009
Rampur	**0.11**	0.029	0.032	0.029	0.056
Suni	0.009	-0.008	-0.041	-0.011	-0.01
	Mean Min Temp				
Bhakra	0.03	-0.0115	-0.03	-0.028	-0.011
Kalpa	0.083	0.009	0.039	0.066	**0.049**
Kasol	0.027	-0.049	-0.036	-0.065	-0.043
Kaza	-0.003	0.138	0.172	0.066	0.097
Namgia	0.105	0.076	0.049	0.052	0.075
Nangal	-0.02	**-0.035**	**-0.055**	-0.05	-0.035
Rampur	0.027	0.011	-0.024	-0.007	0.003
Suni	-0.073	-0.02	-0.049	0.097	0.029
Station	**Mean Temp**				
Bhakra	0.051	-0.008	-0.03	**-0.045**	-0.003
Kalpa	**0.115**	0.003	**0.048**	**0.092**	**0.063**
Kasol	0.027	**-0.049**	-0.036	-0.065	-0.043
Kaza	-0.036	0.136	0.156	0.04	0.068
Namgia	0.121	0.042	**0.057**	**0.101**	0.078
Nangal	0.051	-0.008	-0.03	**-0.045**	-0.003
Rampur	0.051	-0.008	-0.03	**-0.045**	-0.003
Suni	-0.018	-0.01	-0.038	0.029	0.008

Note: Bold indicate statistical significance at 95% confidence level as per the Mann-Kendall test (+ for increasing and – for decreasing)

It is revealed from Table 3 that at annual scale all stations except Nangal and Sunni are showing increasing trends in mean maximum temperature with kalpa station having significant at 95 % confidence interval. During pre monsoon season all stations except Kaza

are showing increasing trend in mean max temperature, of which Kalpa, Kasol, Namgia and Rampur stations are showing statistically significant. There is no statistically significant trend at any station in monsoon season. Most of the stations having decreasing trend in mean max temperature except Bhakra, Kaza and Rampur. While mean minimum temperature at all stations Bhakra, Kasol, Nangal have decreasing trend and rest stations Kalpa, Kaza, Namigia, Rampur and Sunni showing increasing trend at annual scale. The mean temperature analysis shows that during winter season except at three stations Kasol, Kaza and Sunni all other stations are having significant increasing or decreasing trends.

Rainfall trends

The magnitude of the trend in the time series as determined using the Sen's estimator is given in Table 4. The annual rainfall indicates increasing trend at one station namely Rampur (1.519 mm/year) and decreasing trend at all other four stations with maximum decrease (-3.386 mm/year) at Sunni. During monsoon season Kalpa showing the maximum increase in rainfall (2.463 mm/year) while Nangal depicts maximum decreasing trend (-2.761 mm/year). Only two stations, Kalpa and Namgia during pre monsoon showing decreasing statistically significant trends.

Table 4: Sen's estimator of slope (mm/year) for seasonal and annual rainfall in Western Himalayan region

Station	Pre monsoon	Monsoon	Post Monsoon	Winter	ANNUAL
	Rainfall				
Bhakra	0.743	-1.771	-0.573	-2.618	-2.905
Kalpa	**-4.008**	2.463	-0.413	0	-2.787
Kasol	-0.565	1.55	-0.276	-2.18	-3.2
Namgia	**-2.667**	-0.276	0	0	-3.36
Nangal	0.491	-2.761	-0.688	-2.593	-3.162
Rampur	-0.524	2	-1.05	0.762	1.519
Sunni	-0.121	1.575	-0.064	-1.5	-3.386

Note: Bold indicates statistical significance at 95% confidence level as per with Mann-Kendall test (+ for increasing and – for decreasing)

Adopters of the results of the study

Mountainous basin is highly sensitive to climate change, any change in temperature and rainfall highly influences stream flow downstream. The trend describes the long smooth movement of the variable lasting over the span of observations, ignoring the short term fluctuations. The study is a step to understand the behavior of climate in Himalayan terrain of India which can be utilized for proper planning and management.

Deliverables:

Research papers and reports

Major items of equipments procured: Nil.

Lab facilities used during the study

GIS software, ERDAS Imagine and ARCGIS and Microsoft office.

Data procured and generated during the study:

Rainfall and Temperature data collected from various sources.

- Rainfall data from APHRODITE downloaded (0.5 deg. 1957-2007)
- Ground based observations of temperature and rainfall (North-East, Western Himalayan regions).
- GIS map prepared for the study area.

Study benefits/impacts

The study will evaluate the temporal and spatial characteristics and trends in temperature and rainfall time series in the Himalayan region essential for the assessment of impacts of climate variability and change on the water resources of a region.

INTERNAL RESEARCH PROJECT: NIH/WRS/2013/01

Thrust area under XII five year plan: Integrated Water Resources Development & Management

Title of Study - *NIH_Basin* – A WINDOWS based model for water resources assessment in a river basin

Study Group - M. K. Goel
Sharad K. Jain
Deepa Chalisgaonkar
Prabhash K. Mishra

Type of Study - Internal

Start Date - April 01, 2013

Scheduled date of completion - 31st March, 2015

Objective of the study

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 developed in earlier study for comprehensive analysis of water resources at basin scale.

Proposed Methodology

A detailed spatially distributed model has been developed at NIH to assess various components of hydrological cycle in a river basin. Various spatial, temporal, and attribute information are utilized by the model to estimate the water availability in the basin; water demands for different uses; and water storage in different hydraulic structures, in soil water zone, and in groundwater aquifer in a river basin. The model can be used to: a) visualize the effect of changes in land use, cropping pattern, climate 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 has large requirements for database development and its applications. Therefore, it is planned to prepare input data files in graphical user-interactive forms for its easier application by other user agency. In addition, some limitations of the current model are planned to be addressed which include: i) specification of EAC tables or corresponding relationships for various storage structures, ii) rule-curve based operation of reservoirs so that different operation policies of the system can be simulated, iii) option of hydropower simulation in the basin, iv) routing of overland and channel flow, and v) simplified representation of groundwater resources.

Progress Achieved

The model is under continuous stage of development. Since the last working group, efforts have been made to make some modifications in the model methodology.

For approximating the EAC relationships for a reservoir, the approach developed by J. Mohammadzadeh-Habili et. al (2009) has been adopted. This method approximates Elevation-Area and Elevation-Capacity curves within full range of reservoir depth (from river bed to FRL). Data requirement of model includes river bed level at dam site, MDDL (m) of reservoir, and FRL (m) of reservoir. The method has been programmed in FORTRAN language. This method avoids the necessity of obtaining EAC tables for various reservoirs in the river basin.

In previous river basin model, operation of a storage reservoir was simulated using standard linear operation policy (SLOP). In the present report, the model has been modified to include rule curve based operation for storage reservoirs so that control on basin water resources utilization can be analyzed and various water management issues can be addressed. The option of hydropower simulation of a reservoir has also been added.

In the previous model, prevailing groundwater surface in the basin for each month was an important input and a groundwater model (Visual MODFLOW) was linked to generate groundwater surfaces corresponding to monthly pumping and recharge patterns in the river basin. This approach required to run the groundwater model for each month which was a tedious task. In simplified approach, the computations for groundwater conditions are performed at the sub-basin scale. 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). The grid-wise pumping and recharge estimations are accumulated over each sub-basin and then divided by the 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 at the end of each month.

In subsequent report, the WINDOWS interface of the model would be developed and described and some further modifications in modeling methodology would be made.

Adopters of study and study benefits/impacts

The study can help water resources departments and river basin authorities in the analysis for river basin planning and management. It can also help in assessing the impact of various natural and anthropogenic activities on various components of the hydrological cycle at basin scale.

Deliverable

A WINDOWS based model developed at NIH for integrated river basin planning and management.

* * *

INTERNAL RESEARCH PROJECT: NIH/WRS/2013/02

Title of study	-	**Web GIS based snow cover information system for Indus basin**
Study group	-	D. S. Rathore, Sc F, PI Deepa Chalisgaonkar, Sc F, Co-PI L.N. Thakural, Sc B, Co-PI Tanvear Ahmad, Sc B, Co-PI
Type of study	-	Internal
Natural of study	-	Hydrological information
Date of start	-	April 01, 2013
Scheduled date of completion		31st March 2015
Duration of the study	-	2 year

Objective:

To develop methodology for snow cover mapping

The objective of the study is to publish snow cover information on web as an OGC web service for Indus basin.

Statement of the problem

Satellite remotely sensed data for surface reflectance are available free of cost over internet. The information may be processed to prepare thematic maps of snow cover and make it available to researchers through web services.

Location map/study area

Indus basin is selected for the study.

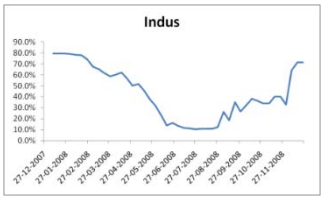
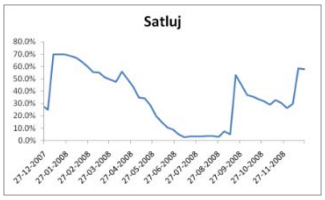
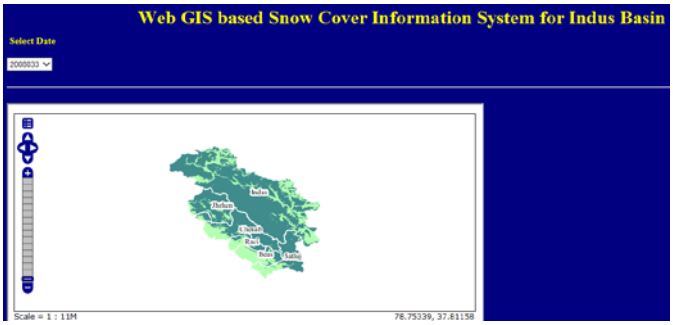
Approved action plan and timeline: 2013-14/14-15

1st quarter	2nd quarter	3rd quarter	4th quarter
Download of data	Processing of the data	Preparation of Web GIS application	Writing of report

Recommendations / suggestions in previous WG

None

Achievements

Year	Objectives	Achievements
2013-14	To develop methodology for snow cover mapping To publish snow cover information on web as an OGC web service for Indus basin	NDSI, Reflectance NIR were used to delineate snow. FCC were used to identify cloud hindrance and modify the snow depletion statistics by interpolation/ duplication in cloud hindrance scenes. MOD09A1 data (Terra 8- day composite) were downloaded for 2008. Reflectance data were processed using bands 2, 4 and 6 for snow delineation. Significant   snow area change and cloud were visually interpreted. Snow statistics were modified in case of cloud cover by interpolating or duplicating area (Fig. 1a, 1b). The Web GIS application was developed (Fig. 2). Fig. 1a, 1b Snow cover area for Indus and Satluj in 2008  Fig. 2 Web GIS for snow cover in Indus basin for year 2008
2014-15	1st Quarter	MOD09A1 data were downloaded for years 2009- 2012, MYD09A1 data were downloaded for years 2007-2009

Data procured and generated during the study:

Satellite data downloaded/ available

- MOD09A1 (2008-12), MYD09A1 (2007-2009)
- Indus basin map

Data generated

Snow maps, depletion curve for Indus basin/ sub basins (2008).

INTERNAL RESEARCH PROJECT: NIH/WRS/2013/03

Title of Study	-	**Assessment of Water Footprint of the National Capital Territory (NCT) of India**
Study Group	-	D. Chalisgaonkar, Sc-F S. K. Jain, Sc-F M. K. Nema, Sc-B Prabhash K. Mishra, Sc-B
Type of Study	-	Internal
Start Date	-	April 01, 2013
Target date of completion	-	31st March, 2015

Background

India has more than 17% of the world's population, but has only 4% of world's renewable water resources with 2.6% of world's land area. Country witnesses extreme variability of both temporal and spatial nature in the water availability, distribution and utilization. Water footprint (WF) is a useful indicator to deal with water scarcity. Information about water footprint can help in understanding of how a more sustainable and equitable use of fresh water can be achieved.

An inadequate piped water supply from the public utility, characterized by intermittence and unreliability, and supplemented by private uncontrolled groundwater abstraction, is a common feature of National Capital Territory (NCT) Delhi. This study is an attempt to assess the Water Footprint of NCT Delhi which will assist in increasing awareness on the water consumption and will help in finding how to save/conserve water. It also focuses on local water management in urban areas in order to improve currently used technologies and to integrate innovative tools for monitoring and managing citizens' water use, water networks and wastewater treatment systems.

Objectives

The objective of this study is to estimate the water footprints of NCT Delhi from both a supply and consumption perspective by quantifying green, blue and grey water footprints within NCT Delhi associated with water consumption. Additionally, the aim is to understand how the water resources of NCT Delhi are being utilized for water consumption.

Approach

The investigation for water footprint assessment has been done for the domestic water use as a first step. The domestic water footprint of NCT Delhi can be assessed by computing the environmental pressure exerted by the population of NCT Delhi in terms of the water it uses directly and indirectly. As the WF is the volume of freshwater used to produce the product, measured over the full supply chain, the three types of water footprints considered are:

Blue Water Footprint:

It is the volume of surface water and groundwater consumed (i.e. evaporated or incorporated into the product) during production processes.

Green Water Footprint

It is the volume of rainwater consumed (i.e. evaporated or incorporated into the product) by the product; and

Grey Water Footprint

It is the amount of freshwater required to mix pollutants and maintain water quality according to agreed water quality standards.

Methodology

The methodology used in this study is largely based on earlier studies supported by Water Footprint Network (www.waterfootprint.org). In the present study, the previous methodologies are integrated and upgraded where possible. The main upgrades are the incorporation and assessment of blue and grey water resources.

The study of existing water management schemes of water supply and sewage treatment of NCT Delhi reveals the following activities influence the domestic water use within the city boundary:

- Sources of Water in NCT Delhi
- Consumption of water for domestic purposes
- Processing at a sewage treatment plant

The water footprints thus consist of two components: consumptive water use and wastewater pollution. The current study has focused on the quantification of consumptive water use. The impact of water pollution has been assessed by quantifying the dilution water volumes required to dilute waste flows to such extent that the quality of the water remains below agreed water quality standards.

The WF of the NCT Delhi has been computed based on this data for the period 2006-2010. The related data has been collected from various sources, published reports from various departments of government of NCT Delhi and from some other important websites and other reports. The virtual water content related data is available at country level not at NCT Delhi level, so it was used for NCT Delhi as well. The data which was not available has been assumed.

The domestic WF has been computed based on the available data of direct (real) and indirect (virtual) water consumption of NCT Delhi. The livestock and vehicle have been considered while computing domestic WF by the human population. As the live stock census carried out once in five years so the latest available livestock data of 2007 has been used.

As the study area is an urban area, so the green component of the domestic component is almost negligible. The blue component of domestic WF has been calculated by first calculating the total volume of water available for human consumption out of the total

volume of water supplied by DJB. This has been done by subtracting the water requirements of all the animals in NCT Delhi and water required for vehicles in NCT Delhi from the total volume of water supplied by DJB. The blue water footprint was then computed by dividing this figure by the human population in NCT Delhi. As the computation of grey water footprint includes the amount of freshwater required for mixing pollutants and maintaining water quality according to agreed water quality standards, the water quality data of the outlets of sewage treatment plants (STP) for the year 2010 of NCT Delhi has been used. The water quality criterion of Central Pollution Control Board ('C' Class water), given in table 15, has been taken as the water quality standards for the computation of dilution water requirement. The 'Dissolved Oxygen' (DO) parameter for the STPs is not available so it has been ignored. The grey water footprint has been taken as the highest of the dilution water requirement of each of the component.

WORK PLAN FOR 2014-15: INDUSTRIAL & AGRICULTURE WATER FOOTPRINT

TASK	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Literature review and concepulisation				
Data collection and boundary delineation				
Data analysis				
Final report writing				

Benefits of the Study:

- Economic benefits: better water management and better water use have positive impacts on water costs;
- Environmental benefits: better water quality and more efficient water consumption have lower impacts on ecosystem;
- Social benefits: better quality of water means better quality of life;
- An Indian approach on water use: definition of common strategies on water footprint will contribute to promote transnational awareness on domestic water management, saving and innovations.

Deliverables:

Research paper and Reports covering Water Footprint for NCT Delhi (Blue, Green and Gray components.

INTERNAL RESEARCH PROJECT: NIH/WRS/2013/04

Title: Impact of Climate and Land use Change on Floods of Various Return Periods

Study Group:

(i) **P. K Bhunya, Scientist D**
(ii) **Dr. Sanjay Kumar, Scientist D**
(iii)**D. S Rathore, Scientist F**

Objectives

(i) Compute the climate scenarios using General Circulation Model (GCM) by downscaling it to fit the region.
(ii) Impact of weighted climate change scenarios on the return period of flood for one catchment in Mahandi basin.
(iii) To examine the statistical trend in 50-y and 500-y return period flood affected by factors such as land use.
(iv) Future scenario and uncertainty introduced by increasing the upper and lower bound floods by a certain percent, and check its effect on a in-situ diversion weirs (on a main stream in referred (i) catchment).

Progress

Since I have submitted my resignation to be relieved by June 6th, 2014, I shall be submitting an interim report before I leave.

Deliverables

Climate is a statistical description of weather conditions and their variations, including both averages and extremes. Although climate forecasts are uncertain and will remain so, partly because of scientific uncertainty but also because many aspects of decisions about action. This study is to assess the uncertainty in impacts of climate change on floods in the Mahanadi region.

INTERNAL RESEARCH PROJECT: NIH/WRS/2013/05

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

Project Team:

a. **Project Investigator:** Prabhash Kumar Mishra, Scientist 'B'
b. **Project Co-Investigators:** Dr. S. K. Jain, Scientist 'G'/ Head, WRSD
Dr. Sanjay Kumar Jain, Scientist 'F'
Dr. P.K. Bhunya, Scientist 'D'

Title of the Project: Assessing climate change impact across KBK region of Odisha

Objectives:

a. To analyze long term historical climate data to determine trend in rainfall, temperature PET etc.
b. To analyze the future climate in the region based on downscaled GCM data.
c. To assess the current potential and gap in utilization of water resource in the region to develop management plan

Type of Study - Internal

Start Date - April, 2013

Scheduled date of completion - March, 2015

Progress Made:

In the present study, trends in long-term climatic data, i.e., rainfall (110 years), temperature (102years), and potential evapotranspiration (102 years) have been investigated on monthly, seasonal and annual series in eight districts spread over in the KBK region in the western part of Odisha, India. The trends are generated using both parametric (linear regression method) and non-parametric (Mann-Kendall test and Sen's Slope estimates). Before analyzing for trend, outliers test and autocorrelation test were carried out to remove any unexpected high values and make the series correlation free. However, it is not always advisable when the data length exceeds 70 years with low coet1icient of variation.

Rainfall trend

The statistical analysis of the rainfall data indicates an annual average rainfall of 1297 mm with a standard deviation of 205 mm and coefficient of variation of 16%. The majority of the rainfall is received during June, July, August, and September due to monsoon front. Winter rainfall is insignificant in the KBK region. The region often witness pre-monsoon rainfall amounting to about 97 mm in the month of April and May. Often, cyclonic rainfall occurs during October and November due to low pressure created in the Bay of Bengal. The rainfall trend analysis indicates two districts with significant trend (Malkangiri with increasing and Nuapada with decreasing) in the annual rainfall at 95% significant level. The magnitude of the decreasing trends in the annual rainfall varies from 0.204 mm/ year (Kalahandi) to 1.419 mm year (Nuapada). The analysis also indicates a non-significant increasing trends in the annual rainfall in the districts of Koraput (+0.935 mm year) and Rayagada (+0.382 mm/ year). The annual rainfall series for the districts of Bolangir, Nabarangpur and Soncpur indicates non-

significant decreasing trend. The winter seriesin the entire region showed a decreasing trend. Monsoon trend in the northern districts is showing decreasing trend in comparison to districts situated towards south of KBK region. The probable change years were mainly found prior to 196 J for annual rainfall series during the period 1901 to2010 as per Pettitt's test, whereas SNHT indicates last decade (2005) when significant shift in rainfall pattern has occurred.

Temperature trend

Temperature is one of the important variables affecting the climate in a region. In the study monthly, annual and seasonal trend of mean, maximum and minimum temperature of KBK districts and entire KBK region has been investigated for the period 1901 to 2002 (102 years). Seasonal analysis has also been carried out for the annual mean temperature. The annual mean temperature in the region is 25.43°C. Summer mean temperature reaches up to 30.65°e, whereas it plunges less than 20°C during winter. Similarly, the statistical analysis of the maximum temperature series indicates an average maximum temperature of 31°C, reaches maximum of 35.80oC during summer. The mean maximum temperature in the region during winter hovers around 28°C. Annual minimum temperature series indicates a mean temperature of 19.91°C 'ranging from 20.91°C to 18.88°C. Winter minimum temperature reaches up to 12°C. In total the temperature variability across KBK region is significant. Both regression method and MK test indicate a significant increasing temperature trend in the mean annual series. The districts like

Kalahandi, Koraput, Malkangiri, Nabarangpur, and Nuapada, the increasing temperature trend issignificant at alpha = 0.001 level of significance. The seasonal mean temperature is also showing an increasing trend in the region. The northern part of the KBK region covering districts of Sonepur and Bolangir, showing increasing trend at alpha = 0.01 level of significance. The trend detection test for the maximum and minimum temperature series also indicate a significant increasing temperature trend. The Southern and Western part of the KBK region (Nabarangpur, Malkangiri) in particular, are experiencing significant increasing temperature trend at alpha = 0.001 level of significance in comparison to the Northern and Eastern part (Bolangir and Sonepur).

Potential evapotranspiration trend

On investigation of the potential evapotranspiration of the eight districts and whole KBK region, it has been found that the trend is upward in nature i.e. increasing. This indicates a higher crop water requirement in the region in the future.

Overall, the study concludes based on the trend analysis that the region is witnessing significant decreasing trends in annual rainfall in the northern parts covering the districts of Kalahandi,Nuapada and Sonepur which are already facing water scarcity. Southern districts like Koraput and Malkangiri with considerable forest coverage in comparison to other districts in the KBK region are showing increasing rainfall trend. The study also concludes a significant increasing trend in the temperature, both minimum and maximum, in future. This will result in higher crop water requirement by the crops to meet the high evaporation and transpiration losses. How far these trends sustain in long-run requires further investigations using data simulated from different global climate models before finalizing water resources availability, distribution and utilization to meet current and future need.

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INTERNAL RESEARCH PROJECT: NIH/WRS/2013/06

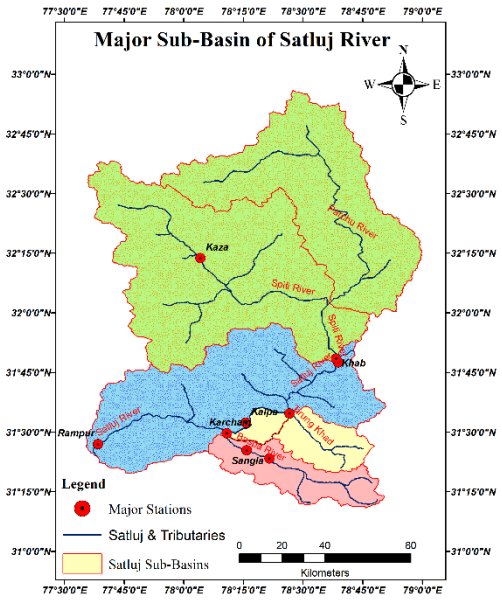
1. **Title** - Glacier change and glacier runoff variation in the upper Satluj river basin

2. **Study Group** - Dr. Sanjay K. Jain, Sc "F"
   Dr. Sharad K. Jain, Sc "F"
   Dr. Renoj Theyyan, Sc "D"

3. **Date of Start** - October 2013
4. **Schedule date of completion** - March 2016
5. **Type of study** - Internal
6. **Location map/study area**

7. **Objectives:**

A major goal of the proposed study is to obtain broader understanding of glacier change (spatial and temporal), reasons and their impact on glacier melt runoff. 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.
- Assessment of changes in glacier cover area using satellite data
- Modelling of glacier melt runoff.
- Glacier mass balance
- Changes in glacier mass balance will be used to investigate glacier melt contributions.

8. **Statement of the problem:**

Glacier runoff contributions to streamflow provide critical water supply in many mountainous regions. These glacier runoff contributions are highly sensitive to changes in temperature. The change in glacier cover area results in significant changes to both total annual and summer streamflow downstream. Warmer temperatures cause increased glacial melt but as glaciers recede; their potential contributions to water supplies are also affected. In Western Himalayan basins, several water resources projects are under operation and many more are coming up in near future to harness the available potential. These projects are of paramount importance in terms of drinking water, irrigation, hydropower generation, flood control and subsequent socio-economic development of the region. The availability of stream flow for glacier melt for these projects through out the year is very important.

9. Approved Action Plan

S.No.	Work element	First	Second	Third
	Deliverable			
		1st. Interim report	**2nd. Interim report**	**Final report**
		April 2014	April 2015	March 2016

10. Methodology:

- Creation of data base of the study area(s)
- Glacier inventory and glacier change occurring in the study area.
- Trend analysis of past and future metrological data
- Glacier mass balance study
- Modeling of glacier melt runoff
- Projection of temperature change
- Assessment of changes in glacier melt runoff vis-à-vis glacier change/change in meteorological inputs

11. Achievements:

In the present study three sub basins of Satluj basin has been taken and they are Baspa, Tirunglhad and Spiti. These three sub basin maps have been prepared. In two basins viz. Baspa and Tirunghkhad, glacier change has been computed using glacier map obtained from Topograhical maps (1966) and satellite data (2000, 2006 and 2011). It was observed that the glacier area in these two basins has been receding. An interim report has been prepared. The satellite data of Spiti basin has been procured from NRSC, Hyderabad and processing of this data is in progress. Discharge data of three sites (Sangla, Thangi and Khab) and temperature data (Raksham, Kaza, Kalpa) have been collected. The processing of this data is in progress. The progress of the study will be presented in the meeting.

12. Adopters of the results of the study and their feedback

Hydropower Companies and state departments

13. Deliverables

The glacier inventory and change in the glacier of the study area. Expected runoff in future and changes in hydropower potential.

14. Data generated in the study

Glacier maps from satellite data.

INTERNAL RESEARCH PROJECT: **NIH/WRS/2013/07**

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

Project Team:

a. **Project Investigator:** Manish Kumar Nema, Scientist 'B'
b. **Project Co-Investigators:** Dr. S. K. Jain, Scientist 'F'/ Head, WRSD

Title of the Project: Variability of the Hydro-climatic variables in Punjab Plains of lower Satluj

Objectives:

a. To collect/procure/computerize long-term hydrological and climatic data of study area
b. To create an integrated hydrological database of lower Satluj
c. To analyze recorded hydro-climatic data for trends or changes in Punjab Plains of lower Satluj
d. To evaluate monthly/seasonal/annual hydrology of the region

Type of Study - Internal

Start Date - November, 2013

Scheduled date of completion - October, 2015

Methodology

Data Acquisition: All possible hydro-climatic data and other related information shall be acquired, purchased, collected from various state and central agencies mainly includes Indian Meteorology Department (IMD); Central Water Commission (CWC); Bhakra Beas Management Board (BBMB); Ground Water Department, Govt. of Punjab; etc

Processing of Acquired Hydrological data: Integrated hydrological data base will be created in GIS environment after data pre-processing like identification and removal the data gaps, outliers etc.

Linear Regression and Mann–Kendall Test for Trend Analysis: Prior to perfume linear regression test data series shall be standardized by subtracting the mean and diving by their standard deviations. To test for randomness against trend in hydrology and climatology the widely used Kendall's τ statistic will be applied

Magnitude of the Trends: The magnitude of the trend in a time series will be determined using a non-parametric method known as Sen's Slope Estimator.

Progress Made:

As the various meteorological data set from IMD are under process the freely available monthly data of rainfall for the districts (from 1901-2010) which fall under the study area is taken from the India water portal website. Meanwhile a visit to state irrigation department was also made in order to get the flow data of Satluj River, some of the discharge data has already been procured and processing is underway. For this interim report only rainfall trend analysis is performed. The time series of rainfall data were analyzed using the Mann-Kendall non-parametric test for trend. The magnitude of the

trend in a time series was determined using a non-parametric method known as Sen's slope estimator method. Overall annual rainfall showed increasing trend at almost all the districts with certain significance level. Average rainfall of the study area was 546mm. the highest average annual rainfall is estimated at Gurdaspur district (661mm) and lowest at Moga district (379mm). While looking at the trend analysis part the maximum increase was 1.95 mm/year and the maximum decrease was -0.08 mm/year. Over the complete study area, the annual rainfall showed an increasing trend and the rate of rise was estimated 1.42 mm/year.

Seasonal analysis showed that monsoonal rainfall increased statistically significant over all districts except Hoshiarpur district. Spring rainfall increased over 6 districts with statistically significance levels. Winter rainfall at five districts showed falling trend but these are not at significance levels. The annual rainfall trends fully indorsing to the monsoon trend, which implicit the dominance of the monsoon for rainwater arability in the region. The study indicated a clear pattern of rainfall trends in the study area with less variability, this could be due to homogeneous geographic and climatic conditions of the districts falling the study area. This report is submitted as an interim report for year 2013-14 and remaining work and objectives shall be accomplished in the coming year.

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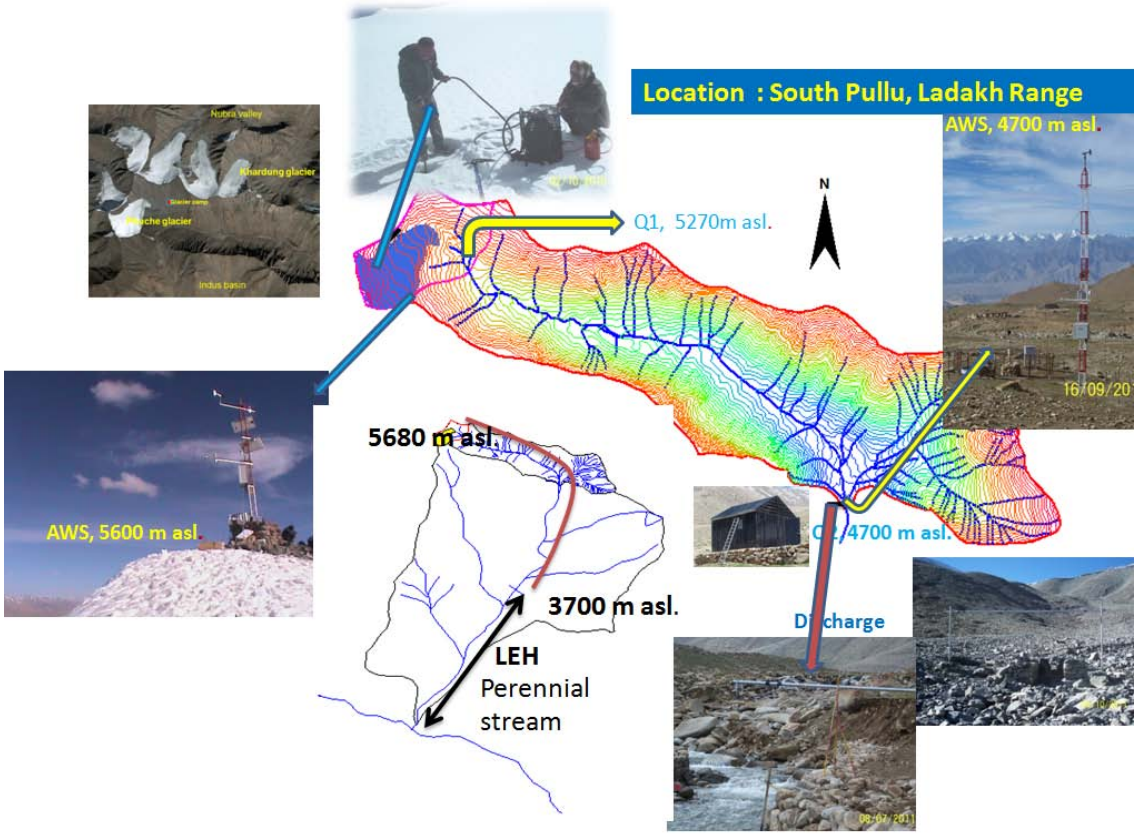
EXTERNAL RESEARCH PROJECT: NIH/WRS/2010/01

a) Title of the Study : ***Glaciological studies of Phuche Glacier, Ladakh Range***.
b) Study Group : Dr. R.J Thayyen, Dr.S.P Rai & Dr. M.K Goel
c) Date of Start : 1st January 2010
d) Schedule date of completion: December 2014
e) Type of study : Sponsored Project (DST)
f) Location map / Study area



g) Objectives :

The objectives of the study are as follows:

i. Winter & Summer Mass Balance studies by glaciological method
ii. Runoff measurements
iii. Collection and standardisation of meteorological parameters by AWS
iv. Mass Balance & Runoff modeling

v. To study the composition of stable isotopes $\delta^{18}O/\delta D$ in the winter snow, summer snow/rainfall and separate snow, rain and glacier melt components in the glacier discharge and its temporal and seasonal variations.

h) Statement of the problem:

Response of small glaciers in the Cold-Arid climate system of the Trans-Himalaya to the prevailing climate is not yet known, leading to a huge knowledge gap in our understanding of factors influencing glacier response to the climate change and its consequences. As people fully depend on glacier streams of the region for their sustenance, as the glacier melt feeds into a dry regime, study of these glaciers have greater societal importance.

ii) Approved action plan

- Procurement and installation of equipments
- Yearly winter and summer mass balance measurement
- Glacier runoff measurements
- Year round monitoring of meteorological parameters and standardization
- Mass balance & runoff modeling
- Stable isotope characterization of winter snow pack, summer rain/snow and stream flow
- Hydrograph separation by isotope method

j) Achievements

Year	Objectives (for the period April 2013 – September 2013)	Achievements
2013	a) Yearly winter and summer mass balance measurement	Achieved/Under progress
	b) Glacier runoff measurements	Achieved/under progress
	c) Year round monitoring of meteorological parameters and standardization	Achieved/under progress
	d) Mass balance & runoff modeling	Under progress
	e) Stable isotope characterization of winter snow pack, summer rain/snow and stream flow	Achieved/under progress
	f) Hydrograph separation by isotope method	Under progress
	g) vi) Interim-Report writing	Under progress

k) Recommendation / suggestions in previous meetings of Working group / TAC / GB

There were no specific/major recommendations pertaining to the study.

l) Analysis and Results:

Glacier response to prevailing weather is influenced by many factors like regional/local climate, aspect, altitude, Debris cover, dust/soot deposits etc. How to achieve a region specific understanding of glacier response – climate relationship by resolving these various forcing factors is a challenging question. Glacier melt contribution to the catchment runoff across the Himalaya under various glacio-hydrological regimes are also not well understood. This knowledge gap is primarily because of the standard practice in India to estimate only the annual glacier mass balance leaving aside the melting snow accumulated in winter and summer precipitation contributions. Under this project, winter and summer mass balance of Phuche and Khardung glaciers were studied. These wo glaciers are part of Khardung glacier complex in the cold-arid climate and situated just 2.5 Km apart on the Ladakh Range near Leh. These glaciers are being monitored for winter and summer mass balance since 2010 by glaciological method. Both these glaciers have same NE aspect but have different wind regime as the Khardung glacier is situated on the northern slopes of the Ladakh range feeding to the Nubra valley and the Phuche glacier is in the Ganglass valley feeding to the River Indus. During the four years of study (2010-2013), Phuche glacier experienced two slightly positive mass balance years interspersed with two significant negative mass balance years. While Khadung glacier experienced consistent mass loss with a remarkable cumulative mass loss of (-)2690 mm w.e. during these four years. Cumulative mass loss of Phuche glacier was significantly less at (-)670 mm w.e. during the same period. Winter mass balance of Phuche glacier ranged between 660 to 590mm w.e and annual mass exchange from the glacier range between 630 to 835mm w.e. Winter mass balance of Khardung glacier range between 690 to 567mm w.e and annual mass exchange from Khardung glacier ranged between 1140 to 770mm w.e. These values gives the first information on mass exchange on a Himalayan glacier and suggest that the winter snow accumulation on the glacier is many fold than the precipitation monitored at the valley bottom at Leh at 3500m a.s.l. Lack of precipitation data from glacier accumulation area is proved to be one of the key factors restraining our understanding on the glacier contribution to the stream flow and catchment/basin water balance. This study provide a firm basis for a reliable water balance estimate of the headwater catchments of the cold-arid system. This study also provided the first unequivocal evidence of mass loss of Ladakh glaciers in response to prevailing weather and suggests that the southern extent of the 'Karakorum anomaly' did not reach the Ladakh range.

m) Adopters of the results of the study and their feedback

Ladakh Autonomous Hill Development Council (LHADC), Leh

n) Deliverables

Reports and research papers

o) Data generated in the study

Winter & Summer mass balance data, Pro-glacial stream runoff data, Data on various meteorological parameters from 4700m asl. & 5600m asl. Electrical conductivity data of stream discharge, Isoptopic data of stream flow & Snowpack.

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EXTERNAL RESEARCH PROJECT: NIH-E/WRS/2012/01

Project Team:

a. **Project Investigator:** Dr. S. K. Jain, Scientist 'F'/ Head, WRSD
b. **Project Co-Investigators:** Dr**.** N. C. Ghosh, Scientist 'F'/ Head, GWD
Dr**.**Sanjay K. Jain, Scientist 'F'
Dr**.**M. K. Goel, Scientist 'F'

Title of the Project: Ganga River Basin Environment Management Plan

Type of Study	-	IIT Kanpur Sponsored
Amount	-	12 Lakhs
Start Date	-	July, 2012
Scheduled date of completion	-	June, 2015

Status:

The task for preparing Ganga River Basin Management Plan was entrusted by MOEF to a consortium led by IIT Kanpur. For this task several groups were constituted and NIH is contributing to the Water Resources Management and Environmental Flows group. NIH carried out hydrologic modeling of the Upper Ganga basin by using the SWAT model. NIH has completed modeling of the basin up to Devprayag and the model set up and a report has been forwarded to the WRM group and IIT Delhi who are carrying out modeling for the entire basin.

The project was to be over by September 2013 but an extension was sought and now the schedule data of completion is June 2014.

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EXTERNAL RESEARCH PROJECT: NIH-E/WRS/2014/02

Project Team:

a. **Project Investigator:** Dr. S. K. Jain, Scientist 'F'/ Head, WRSD

b. **Project Co-Investigators:** Dr. Pradeep Kumar, Scientist 'B'

Shri P. K. Agarwal, Scientist 'B'
Shri P. K. Mishra, Scientist 'B'

Title of the Project: Assessment of Environmental flow for Himalayan River

Type of Study	-	MOES Sponsored
Amount	-	9.95 Lakhs
Start Date	-	July, 2014
Scheduled date of completion	-	July, 2015

Status:

A project proposal for carrying out work to create baseline database and estimate environmental flows for a few Himalayan rivers was submitted to the Ministry of Earth Sciences and the same has been approved. Formal orders are being issued and funds are expected to be released soon. In the meantime work has started to collect the data and create the database.

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INTERNAL RESEARCH PROJECT: NIH/WRS/2014/01

1. **Thrust Area under XII five year Plan:** Integrated water resources management/ watershed hydrology
2. **Project Team:**
3.
   a. **Project Investigator:** P. K. Agarwal, Scientist B

   b. **Project Co-Investigators**: Dr Sanjay K. Jain, Scientist 'F"
   Dr. M. K. Goel, Scientist "F"
   Dr. Sharad K. Jain, Sientist "G"
   Shri Tanvear Ahmed, Scientist"B"

4. **Title of The Project** Hydrological modeling of a part of Satluj basin using SWAT Model
5. **Objectives**

   i. To develop the data base 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 evapor-transpiration etc.

6. **Present State of Art**

   The Soil and Water Assessment Tool (SWAT) model is a river basin or watershed scale model developed by the USDA Agricultural Research Service. SWAT is a spatially distributed, continuous time model that operates on a daily time step. SWAT was developed 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. It can incorporate the effects of tanks and the reservoirs/check dams off-stream as well as on-stream. SWAT requires specific input about weather, soil properties, topography, vegetation, and land management practices to model hydrology and water quality in a watershed. The model allows a basin to be subdivided into sub-basins or watersheds which is particularly beneficial when different areas of the macro-watershed are dominated by land uses or soils different enough in properties to have different impacts on the hydrological response. Within SWAT the input information for each watershed is grouped and is called hydrologic response units or HRUs. The major advantage of the model is that unlike the other conventional conceptual simulation models it does not require much calibration and therefore can be used on ungauged watersheds. Model outputs include all water balance components (surface runoff, evaporation, lateral flow, recharge, percolation, sediment yield, etc.) at the level of each watershed and are available at daily, monthly or annual time steps.

7. **Methodology**

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

   - Data base preparation in ArcGIS (DEM, Land use, soil map)

- Collection of metrological data (rainfall, temperature, wind, solar radiation, humidity)
- Setup of SWAT model using Acr-GIS.
- Calibration and validation of SWAT model
- To carry out the effect of land use & other changes on stream flow.

8. Research Outcome from the Project

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

9. **Cost Estimate**:

a. Total cost of the Project Rs. 23.00 Lacs

b. Sources of Funding Internal Funding from 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

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

Salary may be taken for 15 man months @ 1.00 lacs/man month average

Travelling expenditure for Field visit and collection of data as per requirement

Infrastructure/Equipment/Data charges are required for collection of data/satellite data

Misc. Expenditure: For miscellaneous expenditures lik stationary, printing, etc.

10. Work Schedule

a. Probable 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**										

INTERNAL RESEARCH PROJECT: NIH/WRS/2014/02

Thrust area under XII five year plan: Integrated Water Resources Development & Management

Project team:

a) **Project Investigator:** D. S. Rathore, Sc. "F"
b) **Project Co- investigators:** M. K. Goel, Sc. "F",
R.P. Pandey, Sc. "F",
Sanjay Kumar, Sc. "D",
Surjeet Singh, Sc. "D"

Collaboration: State Water Resources Department, Maharashtra,
Ground water Development Agency, Pune, Maharshtra

Title of Project - Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra

Objectives:

Following are the envisaged objectives of study:

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

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. The modelling systems may be run stand alone and also in the platform using appropriate adapters. The platform has GIS, spreadsheet, scenario, script, time series and dashboard (for web applications) managers. Operations are performed with tools specific to the managers. Using script and spreadsheet, various interfaces can be developed to support decision makers. Data are stored in PostgreSQL and data input/output tools are also provided. In the project, Mike Basin and subsequently Mike Hydro modelling system has been provided. The DSS supports rainfall-runoff modelling, river basin simulation (through modelling system) and presentation of spatial and temporal data and modelling results in platform using available or specifically developed interfaces in web environment and dissemination of the information over web using specifically developed dashboard. Data for downscaled regional climate scenario are available for download.

Initially, the platform worked with the Mike BASIN system which has been recently modified as Mike HYDRO. It is planned to carry out the basin analysis in new system.

Methodology

Mike HYDRO modeling system will be used and all database for the Upper Bhima basin up to Ujjani dam developed in HP-II project (for the Mike BASIN modeling system) will be transformed to the new system. Rainfall- runoff modelling will be done using NAM for finding different hydrological components for various sub-basins. Rule curves would be developed for various project complexes and multi reservoir operation analysis at the basin scale 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 in DSS (Planning) platform. Conjunctive use scenario in canal command areas will be run and overall water resources management for the whole basin would be analyzed. River water quality modelling will be carried out in Mike Hydro with the available data. Web-interfaces through Dashboards would be developed for dissemination of input and results of simulation in DSS (Planning). For climatic scenario, available downscaled climate data will be utilized and model runs would be taken to find their impact on the water availability and allocation analysis in the basin.

Research outcome from the project

Following are the envisaged outcome of the study:

a) Water availability in various sub-basins in present and changed future climate.
b) Reservoir operation rules for existing and future climatic scenarios.
c) Meteorological and hydrological drought indices.
d) Conjunctive use in canal command areas.
e) River water quality modeling in river reaches and impact of climate change.
f) Interfaces for decision support.

Cost estimate

a) ***Total cost of the project:*** 34 lakh
b) ***Source of funding:*** Internal
c) Sub-headwise abstract of the cost

S. No.	Sub-head	Amount in Rs. (in Lakhs)
1	Salary (Regular - Scientist, SRA/RA Rs. 20 + 9 lakh)	29.00
2	Travelling expenditure	3.00
3	Infrastructure/ equipment	-
4	Experimental charges	-
5	Misc expenditure	2.00
	Grand Total	**34.00**

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

Nearly 50 person- months will be utilized to carry out computer simulations, data entry, model set up and script development etc. Visit to the study area will be required for data collection, discussions etc.

Work schedule

a) Probable date of commencement of project: July, 2014

b) Duration of the project: 2 years

c) Stages of work and milestone:

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							

* * *

INTERNAL/EXTERNAL RESEARCH PROJECT: NIH/WRS/2014/

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
   c. **Project Investigator:** Dr. R.J Thayyen, Sci-D
3. **Project Co-Investigators:** Dr. S.P Rai, Sci-E
4. Title of the Project: **Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh**
5. **Objectives:**
   1. To improve the understanding of the climate forcing on cold-arid cryospheric system.
   2. To improve the understanding of the melt water generation process and the role of permafrost.
   3. To improve the understanding of various runoff components under different surface snow conditions.
   4. To study the temporal variations in isotopic characteristics of winter base flow and summer flow of the perennial reach.
5. **Present state-of-art**

The proposed project is the second phase of the project entitled "Cryospheric system studies and runoff modeling of Ganglass catchment, Leh, Ladakh Range.". Summary of the report is presented below:

The project entitled "Cryospheric system studies of Ganglass catchment, Ladakh Range, India" is the first attempt made in the country to understand the high altitude cryospheric system hydrology of the cold-arid system of the Ladakh. The project executed at a high altitude catchment in the Ladakh range extending from 4700 m to 5745 m a.s.l. This experimental catchment is spread over 15.8km^2 and have a glacier cover of 0.62km^2. This headwater catchment feed to Leh town and the Ganglass catchment and remain as the sole water source for the entire city of Leh, which is a favorite tourist destination in the country. Tourism to Ladakh increased exponentially from 20000 in 2004 to 1.8 Lakh in 2012, putting huge pressure on the water resources- Habitat equilibrium.

To understand the cryospheric systems dynamics, a Benchmark glacier catchment strategy has implemented in the upper Ganglass catchment. This strategy has been formulated with a core philosophy of understanding the orographic forcing and feedback on the high altitude cryospheric systems and studying the role of various cryospheric and atmospheric components on the catchment discharge. Runoff modeling and isotopic studies of stream flow, precipitation and local water sources were employed for achieving these goals. Discharge measurements were carried out at 4700 m a.s.l. with the help of a Radar Water Level Recorder. Four years of runoff data, meteorological data, Electrical conductivity data, snow cover depletion data, isotopic data etc. were generated though this project; building the most comprehensive data base for this region.

The study has revealed the sharp vertical hydrological gradient in the cold-arid system. While mean annual precipitation remained 115 mm per year, the annual discharge from the upper Ganglass catchment is ranged between 10.7 x10^6 m^3 to 7.7 x10^6 m^3 (685 to 490 mm w.e.) showing the

significantly wetter regime at the higher altitude regions. A tandem study on glacier mass balance exchange have shown that the 4% glacier cover in the catchment contributed only around 5% of the annual discharge. It is observed that the flow regime during prolonged snow cover and shorter snow cover were distinctly different and have corresponding change in the EC-Q variations. Supported by the field geomorphological evidences it is proposed that the steady discharge with higher EC values during the years with shorter snow cover is sourced from the permafrost melt. By employing the two component mixing model it is estimated that the permafrost contribution could be at least 25% during the years with shorter snow cover.

Temperature Lapse rate is the most critical parameter in the snow melt runoff model. Generally standard environmental lapse rate ranging from 6.5 to 8.9^{o}C is used for snow melt modeling. We have found that the Slope Environmental Lapse Rate (SELR) have significant seasonal variation liked with the moisture influx to the region. During summer months SELR between 3500 to 4700 m a.s.l was consistently ranged between 10 to 15 ^{o}C espousing the cold-arid conditions. Higher altitude section (4700-5600m a.s.l.) is found to have experiencing lower SELR. We have developed a model solution for SELR by generating monthly indices separately for the two distinct sections. The trials have demonstrated that the model have high efficiency for calculating the monthly SELR.

Runoff modeling was performed by using the WinSRM model. The model delivered very good result for 2010 and 2012, when the catchment experienced prolonged snow cover. But during the shorter snow cover years (eg. 2011) model performed very poorly as model did not have the permafrost melt module.

Isotope data for stream flow, precipitation, snow etc. for generated for four years and final synthesis is in progress. The result will be presented during the working group meeting.

It is felt that the study required to be continued for better understanding of the permafrost melt processes and long-term climate forcing on the cryospheric system of the cold-arid system.

6. Methodology

1. Monitoring of weather parameters by AWS at 3500 m a.s.l., 4700 m a.s.l. and 5600 m a.s.l.
2. Monitoring discharge and Electrical conductivity at 4700 m a.s.l
3. Measuring ground temperature for permafrost studies
4. Geophysical investigation of potential permafrost zones
5. Isotope studies of stream discharge at 4700m a.s.l. and 3600 m a.s.l

7. Research Outcome from the project: Research papers and project reports

8. Cost estimates:

a. Total cost of the project: Rs.

b. Source of funding :

c. Sub-head wise abstract of the cost :

S. No.	Sub-head		Amount (in Rupees)
1.	Salary	160 man-days of Sci. – D @ /day	

		Sci-E @	
		67 man-days of Sci. – G @ /day	
		Project Officer	
2.	Travelling Expenditure		500000
3.	Infrastructure / Equipment / Data		1500000
4.	Experimental charges		0
5.	Misc. expenditure		500000
	Grand Total:		2000000+

9. Justification for sub-head wise abstract of the cost: Work Schedule:

a. Probable date of commencement of the project: 01.04.2014

b. Duration of the project: 3 years

c. Stages of work and milestones:

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**												
3.	**Permafrost temp.**												
4.	Geophysics-permafrost												
5.	Isotope studies												

RESEARCH MANAGEMENT AND OUTREACH DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr V C Goyal	Scientist F & Head
2	Sri Omkar Singh	Scientist E
3	Dr R V Kale	Scientist B
4	Sri Subhash Kichlu	PRA
5	Sri Rajesh Agarwal	SRA

WORK PROGRAM FOR YEAR 2013-2014

S. No.	Study	Team	Duration
	Internal Studies		
1	Recession Flow Analysis for Evaluation of Spring Flow in Indian Catchments **(Completed Study)**	Ravindra V Kale (PI) V C Goyal	DOS: Apr 2011 DOC: March 2014
2	Pilot Basin Studies (PBS) at six identified sites, jointly with the RCs and CFMSs	**Joint study** **NIH HQs:** V C Goyal (Team Leader) Omkar Singh Ravindra V. Kale **NIH RCs/CFMSs:** RC-Belgaum, RC-Jammu RC-Kakinada, RC-Bhopal CFMS-Guwahati, CFMS-Patna	DOS: Apr 2012 DOC: Mar 2015
3.	Water Conservation and Management in Ibrahimpur Masahi Village of Haridwar District (Uttarakhand)	Omkar Singh, V.C. Goyal and C.K. Jain **Scientific/Technical Staff** Subhash Kichlu, Yatvir Singh, Rajesh Agarwal, Rakesh Goyal, N.K. Lakhera and C.S. Chowhan	DOS: Apr 2013 DOC: Mar 2015
	Sponsored Project		
4.	Integrating hydrology, climate change and IWRM with livelihood issues: Development of methodology and a DSS for water-scarce Bundelkhand region in India (**Continuing Study**)	**Funded by TIFAC, Government of India under INDIA-IIASA Programme of TIFAC** **NIH** Dr. V. C. Goyal (PI) Dr T Thomas (Co-PI) Dr. R. V. Kale (Co-PI) **Nodal Coordinator :** Dr (Mrs) K Vijaya Lakshmi, DA, New Delhi Dr Sandeep Goyal, MAPCOST, Govt. of MP (India) **International Collaborators:** IIASA, Austria	DOS: Aug 2013-DOC: Jan 2016

PROPOSED WORK PROGRAMME FOR THE YEAR 2014-2015

S.No.	Study	Team	Duration
	Internal Studies		
1.	Participatory development of structure for IWRM Framework in identified sub-basins under Pilot Basin Studies (PBS) program **(New Study)**	V C Goyal (PI) Omkar Singh R V Kale	DOS: July 2014 DOC: June 2015
2.	Water Conservation and Management in Ibrahimpur Masahi Village of Haridwar District (Uttarakhand) **(Ongoing Study)**	Omkar Singh (PI), V.C. Goyal, C.K. Jain, J.V. Tyagi and Sanjay Kr. Jain **Scientific/Technical Staff** Subhash Kichlu, Yatvir Singh, Rajesh Agarwal, Rakesh Goyal, N.K. Lakhera and C.S. Chowhan	DOS: Apr 2013 DOC: Mar 2015
	Sponsored Studies		
3.	Customization of WEAP model for application in Ur river watershed in Tikamgarh district of Bundelkhand region. **(Under TIFAC Project) (New Study)**	R V Kale (PI) T Thomas- RC Bhopal Jyoti Patil Rajesh Agarwal	DOS: Apr 2014 DOC: Sep 2015

Sponsored Projects

1. Integrating hydrology, climate change and IWRM with livelihood issues: Development of methodology and a DSS for water-scarce Bundelkhand region in India, **Funded by TIFAC, Government of India under INDIA-IIASA Programme of TIFAC**
   Period: Aug 2013-Dec 2016 (30 months) Budget: Rs 56.64 lakh
   Team from NIH:
   V C Goyal (PI), T Thomas (Co-PI), R V Kale (Co-PI)

   Nodal Coordinators from other partners:
   Dr (Mrs) K Vijaya Lakshmi, DA, New Delhi
   Dr Sandeep Goyal, MAPCOST, Govt. of MP (India)
   International Collaborators: IIASA, Austria

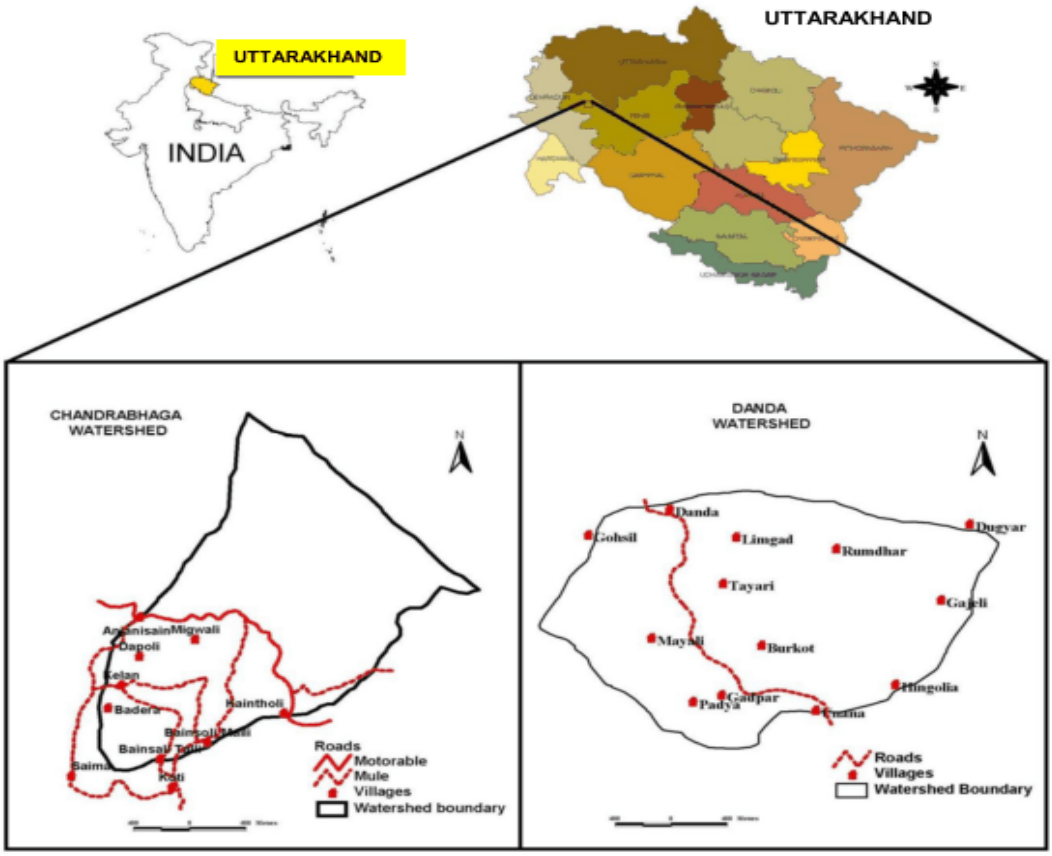
2. Development of a DSS for Hydrology and Watershed Management in Neeranchal Project, **To be funded by Dept. of Land Resources (GoI) under a World Bank supported project**
   Period: Jun/Jul 2014-May 2019 Budget: Rs 50 Crore approx.
   Partners: NIH; IIT Delhi; WTC Delhi; NRSC Hyderabad

Study - 1

1. **Title of the study**: Recession Flow Analysis for Evaluation of Spring Flow in Himalayan Region, India (**Completed Study**)
2. **Name of PI, Co-PI, & their affiliations**
   PI : Dr. R. V. Kale, Sc B, RMOD
   **Co-PI : ** Dr. V. C. Goyal, Sc F and Head, RMOD
3. **Type of study**
   Internal (NIH funded)
4. **Date of start:** April 2011

5. **Scheduled date of completion:** March 2013

6. **Location map:** The study is being carried out for two small watersheds in the State of Uttarakhand, India. In these Himalayan watersheds number of springs found which are reliable sources of, clean water supply for drinking and domestic use. The geographical location of these watersheds is shown in following map:



7. **Study objectives**
   I. To develop a technique to assess the reliability of the spring flow as a sustainable source of drinking and domestic water by analyzing the flow characteristics
   II. To assess the potential for springs development as a water source

8. **Statement of the problem**

Springs in the Himalayas, in the Western Ghats and other places in India are the main source of drinking water due to logistical difficulty in creating storage for water. In such areas, majority of spring are of small orders which become dry during summer months. Flow/discharges in such springs vary considerably depending on the catchment characteristics (e.g. area, hydrogeology) and recharge in the catchment. The knowledge about the number of springs as well as their flow characteristics is important in the sustainable development of the water resources of these areas. The study of spring flow analysis has relevance to the water supply to rural areas, specifically hilly areas. As in many locations, rural development agencies would like to develop water resources of the catchment but lack the necessary hydraulic information. Further, the measurement and prediction of spring flows in aquifers are critical to water resources managers to maintain preferred flows based on the effect that current and projected ground water withdrawals have on water levels. Subsequently, the assessment of spring flow using physically based model requires the knowledge of fundamental input parameters such as hydraulic conductivity, specific yield and effective hydraulic conductivity describing the subsurface hydrology which are most problematic to obtain. Since well-drilling to estimate hydraulic parameters is often prohibitively expensive in developing countries, recession flow analysis is a very cost-effective and accurate alternative.

9. **Approved action plan**

Action plan: The collected spring flow and rainfall data will be analyzed for continuity and consistency of the record. In next step, a model will be formulated and will be tested for its accuracy. Then, formulated model will be used for the recession spring flow analysis. The results of the analysis will be produced in the form of research publication, technical report and user manual for field organisations.

Time-line and justification for time over runs:

Period	Task to be completed
April, 2011 – Sep. 2011	Review of literature and collection and preprocessing of data
15th Sep, 2011 – 14th March, 2012	Model formulation
15th March, 2012 – 15th March, 2013	Data analysis, results preparation and report preparation
April, 2013- April, 2014	Incorporation of topographic module to estimate morphological parameters of the spring watersheds using RS and GIS with hydrological module to arrive at aquifer hydraulic parameters and study report completion. During 37th WG meeting, this objective is undertaken as an extended part of originally decided study. But due to non-availability of the measured average aquifer thickness value, this particular task would be taken in the future as a separate study. Further, it was also not a part of objective originally decided. Further, study on the estimation of Base Flow Index

	(BFI) for each spring using various methods was undertaken. A new methodology has been developed to estimate BFI for each spring and the results are compared with various available methods. This task is completed.

10. **Objectives vis-à-vis achievements (clearly separate achievements reported in the previous meetings)**

Objectives	**Acheivements**
To develop a technique to assess the reliability of the spring flow as a sustainable source of drinking and domestic water by analyzing the flow characteristics	**<u>Upto March, 2012</u>** • Review of literature was in progress. • Collection and preprocessing of required spring flow data was under progress. • A fully automated objective-based method (adapted matching strip method) for master recession curve separation is tested for it accuracy and required modifications are carried out • Recession flow analysis of springs in the Chandrabhaga watershed using above mentioned method was in progress. • Major work on the mentioned objective was in progress
	<u>March, 2012 – Oct., 2012</u> • Preprocessing of the spring flow data for Danda Watershed was completed. • Recession flow analysis of springs in the Danda watershed using above mentioned method was in progress.
	<u>Oct, 2012 – March, 2013</u> • Recession flow analysis of the springs in the Chandrabhaga and Danda watershed using fully automated objective-based method (adapted matching strip method) for master recession curve separation, especially estimation of average recession constants of the spring is completed.
	<u>March, 2013 – Sept., 2013</u> • Estimation of seasonal recession constants (for Rainy, winter and summer season) for all the 30 springs in the Danda watershed and 20 springs in the Chandrabhaga watershed is completed. • Recession constants from all these springs are used to cross verify the optimally

	separated recession constants for all these springs using fully automated objective-based method (adapted matching strip method) for master recession curve separation. • Statistical analysis of the observed time series datasets of all the springs has been carried out to verify the difference in the behavior of the springs flow. • The work on this objective is completed.
To assess the potential for springs development as a water source	**<u>Oct, 2013 – April, 2014</u>** • In order to know the base flow contribution as compared to the direct runoff in response to rainfall, Base Flow Index (BFI) for each spring has been developed using Eckhardt recursive digital filter and results are compared with those obtained by using modified recession constant (K) (using adaptive matching strip method for recession curve separation) and $BFI_{\max}$ value (using inverse recursive digital filter) in the Eckhardt recursive digital filter. Further, the results obtained with Eckhardt recursive digital filter and modified Eckhardt recursive digital filter are compared with those obtained using Web based WHAT model, $BFI_{\max}$ optimization available in WHAT model and $BFI_{\max}$ value optimized with Genetical Algorithm (GA). • Following the suggestions given by the Director, NIH Roorkee, the attempt has been made to verify that how accurately the recession constants obtained using MRC of particular watershed can be applied to estimate the recession flow and volume of the ungauged springs. This task is completed.

11. Recommendations/suggestions in previous meetings of Working Group/TAC/GB should be mentioned along with the action taken

Recommendations/suggestions	**Action taken**
<u>36th WGM</u> Dr. S. K. Bartarya suggested that it would be interesting if recession flow analysis may be made according to control/classification of springs such as Fracture joint or Fluvial related spring etc. (as given in Valdiya & Bartarya,	• We are attempting to accomplish recession flow analysis according to control/classification of springs such as fracture joint or fluvial related spring etc. (as given in Valdiya & Bartarya, 1991) or on types of

1991) or on types of aquifer. Further, he also suggested that tracers and isotopes may be incorporated as another tool.	aquifer. • Regarding, suggestion on use of "tracers and isotopes as another tool", it is not possible to consider this suggestion in this study. However, this suggestion could be well taken in a separate study.
37th WGM No any specific suggestion/comment	NA
38th WGM No any specific suggestion/comment	NA
39th WGM No any specific suggestion/comment	NA

12. Analysis and Results

- Spring flow data for 20 springs in Chandrbhaga Watershed and 30 springs in Danda watershed has been obtained from previous studies. These time-series data sets have been checked for consistency and accuracy of the records.
- Various statistical parameters such as maximum flow discharge, minimum flow discharge, average flow discharge, mode, median, standard deviation, lower 95% confidence interval of average discharge, upper 95% confidence interval of average discharge, variance, skewness, kurtosis, coefficient of variation, mean absolute deviation and probability of flow at 90%, 95% and 99% (i.e. P90, P95 and P99). The detail will be given in the WG meeting.
- A fully automated objective-based method (adapted matching strip method) was chosen for Master recession curve separation. This program extensively checked for the accuracy and necessary debugging is carried out. Using this program, preparation of master recession curves for all the springs in the Chandrabhaga and Danda Watersheds has been completed. The FDC plotted for entire time series has been used to select two probable ranges of percent of flow rate in order to facilitate optimal separation of MRC into three recession segments. Consequently, the Recession constants estimated for the springs in Chandrabhaga and Danda Watershed are given in following Tables 1 and 2, respectively.

Table 1. Calculated Recession constants (k) and correlations coefficients (R^2) for springs in Chandrabhaga Watershed using MRC.

Spring ID No.	MRC by Exponential equation		Optimal separation model Q%	Recession constant when MRC separated into three segments				R^2 values for each separated segment of MRC and optimal MRC			
	k	R2		k_1	k_2	k_3	k	Seg 1	Seg 2	Seg 3	Optimal
1	0.978	0.93	14% and 56%	0.981	0.985	0.975	0.980	0.76	0.71	0.91	0.93
2	0.980	0.93	16% and 53%	0.980	0.987	0.979	0.980	0.75	0.85	0.90	0.94
3	0.966	0.90	1% and 27%		0.984	0.968	0.980		0.69	0.89	0.92
4a	0.959	0.84	2% and 46%		0.961	0.961	0.957		0.70	0.81	0.92
4b	0.960	0.84	4% and 76%		0.957	0.968	0.970		0.75	0.82	0.90
5	0.976	0.80	6% and 75%	0.946	0.972	0.977	0.970	0.86	0.62	0.84	0.88
6	0.985	0.89	4% and 75%	0.974	0.984	0.984	0.990	0.90	0.76	0.70	0.87
7	0.970	0.93	19% and 90%	0.959	0.973	0.971	0.970	0.51	0.90	0.85	0.95
8	0.978	0.93	42% and 83%	0.974	0.980	0.979	0.977	0.80	0.85	0.72	0.96
9	0.970	0.84	2% and 76%	0.957	0.976	0.958	0.970	0.87	0.70	0.55	0.81
10	0.973	0.93	3% and 31%	0.963	0.978	0.968	0.980	0.75	0.87	0.84	0.90
11	0.966	0.89	3% and 32%	0.944	0.964	0.949	0.961	0.94	0.81	0.78	0.90
13	0.966	0.88	7% and 45%	0.967	0.977	0.953	0.960	0.73	0.84	0.62	0.80
14	0.977	0.79	13% and 47%	0.976	0.966	0.983	0.973	0.86	0.85	0.43	0.80
15	0.984	0.85	16% and 47%	0.969	0.994	0.977	0.984	0.87	0.59	0.82	0.87

16	0.981	0.88	20% and 96%	0.981	0.977	0.976	0.977	0.78	0.88	0.99	0.95
17	0.972	0.91	26% and 64%	0.967	0.983	0.980	0.975	0.92	0.71	0.82	0.96
18	0.980	0.90	32% and 58%	0.962	0.971	0.966	0.968	0.81	0.83	0.63	0.93
19	0.979	0.63	70% and 82%	0.969	0.988	0.964	0.967	0.89	0.64	0.91	0.95
20	0.970	0.96	31% and 94%	0.972	0.973	0.993	0.972	0.68	0.96	0.86	0.98

Table 2. Calculated Recession constants (k) and correlations coefficients (R^2) for springs in Danda Watershed using MRC.

Spring ID No.	MRC by Exponential equation		Optimal separation model Q%	Recession constant when MRC separated into three segments				R^2 values for each separated segment of MRC and optimal MRC			
	k	R2		k_1	k_2	k_3	k	Seg 1	Seg 2	Seg 3	Optimal
1	0.964	0.91	9% and 45%	0.967	0.978	0.961	0.957	0.94	0.69	0.73	0.94
2	0.980	0.73	10% and 47%	0.973	0.985	0.991	0.971	0.95	0.51	0.26	0.87
3	0.951	0.85	5% and 45%	0.957	0.953	0.965	0.953	0.98	0.75	0.86	0.93
4	0.972	0.75	34% and 59%	0.981	0.989	0.962	0.970	0.67	0.65	0.83	0.84
5	0.989	0.59	5% and 53%	0.976	0.967	0.996	0.989	0.92	0.69	0.68	0.65
6	0.949	0.96	3% and 15%	0.893	0.936	0.949	0.947	0.96	0.79	0.96	0.97
7	0.934	0.93	5% and 30%		0.903	0.953	0.938		0.90	0.90	0.95
8	0.958	0.90	25% and 49%	0.939	0.983	0.948	0.955	0.80	0.68	0.81	0.94
9	0.955	0.93	16% and 67%	0.951	0.948	0.960	0.951	0.63	0.89	0.87	0.97
10	0.975	0.86	22% and 44%	0.930	0.977	0.978	0.971	0.78	0.76	0.80	0.91
11	0.988	0.81	5% and 35%	0.944	0.990	0.984	0.984	0.95	0.73	0.81	0.88
13	0.982	0.73	1% and 39%		0.950	0.983	0.974		0.74	0.67	0.90
15	0.984	0.73	6% and 98%	0.899	0.963	0.996	0.984	0.90	0.88	0.96	0.64
16	0.974	0.85	3% and 22%		0.986	0.976	0.969		0.91	0.86	0.92
17	0.974	0.77	18% and 99%	0.952	0.965	0.996	0.971	0.77	0.96	0.99	0.91
18	0.976	0.70	2% and 37%		0.986	0.973	0.973		0.37	0.86	0.92
20	0.984	0.81	2% and 28%		0.960	0.984	0.981		0.72	0.82	0.86
21	0.980	0.72	3% and 26%		0.885	0.983	0.979		0.76	0.68	0.73
25	0.977	0.87	3% and 28%		0.952	0.979	0.974		0.82	0.78	0.86
27	0.973	0.80	30% and 90%	0.971	0.977	0.990	0.972	0.93	0.75	0.97	0.94
28	0.974	0.89	19% and 74%	0.974	0.973	0.950	0.968	0.98	0.83	0.44	0.86
29	0.945	0.95	7% and 28%		0.946	0.951	0.949		0.86	0.98	0.98
30	0.944	0.97	4% and 77%		0.951	0.954	0.950		0.92	0.98	0.98

Estimation of Recession Constants Using Seasonal Spring Flow Records

In order to check the reliability as well accuracy of the separation of MRC in two/three segements(see Tables 1 and 2), estimation of recession constants has been carried out using seasonal spring flow records. In case of separated MRC in three segments, it is assumed that out of these three segements, first segement represents MRC of rainy season, second segement epresents MRC of winter season and third segement represents MRC of summer season. To understand the annual and season variability and availability of spring discharge through time, the flow duration curves (FDC) have been plotted for all the spring. Duration curve for month grouped into three seasons (1) Summer or pre-monsoon season (March to 15th June) (2) Monsoon or rainy season (June (2nd half to September), and (3) winter season (October to February) for seasonal analysis of the daily discharge data. The estimated seasonal recession constants and respective coefficient of determination (R^2) for the springs in the chndrabhaga and Danda watershed are shown in Figure 1.

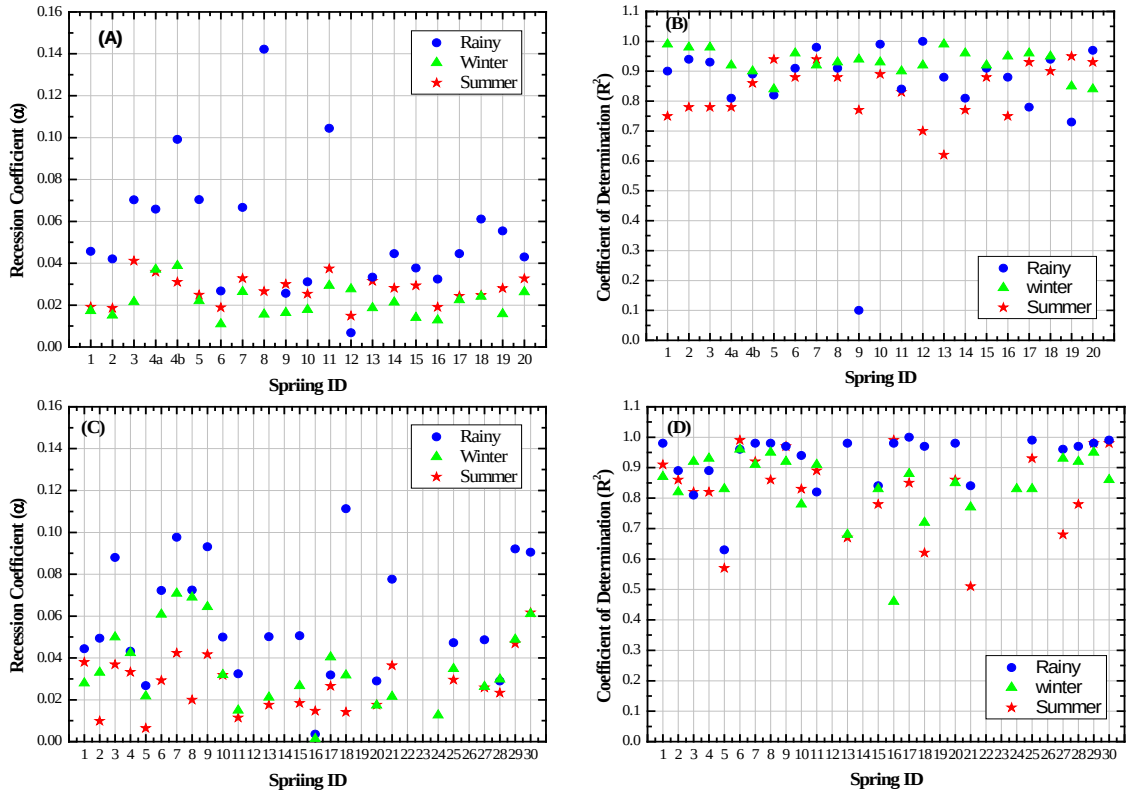


Figure 1. Seasonal recession constants and coefficient of determinations for the springs in the Chandrabhaga (A & B) and Danda Watersheds (C & D), respectively.

- Characterization of springs in study area was done through spring flow variability and low flow variability index using FDC. The brief results for Rupado spring (Spring ID # 6, Danda Watershed) are demonstrated here and results for all the spring will be presented in WG meeting. The minimum, maximum and average value of discharges with their date of observation of the Rupado spring for entire period from August 1999 to December 2004 and seasonal time series for this period is given in Table 3.

Table 3. The Observed Minimum, Maximum and Average Discharge Values and Date of Observations for Different Period of Time-Series.

Time-series observation period	Min. discharge (lps)	Date	Max. discharge (lps)	Date	Average discharge (lps)
Entire	0.0027	28-Apr-04	0.7937	11-Aug-00	0.0998
rainy season	0.0066	21-Jun-01	0.7937	11-Aug-00	0.1856
Winter season	0.0040	28-Feb-04	0.5000	15-Oct-04	0.0824
				19-Oct-04	
				23-Oct-04	
Summer season	0.0027	28-Apr-04	0.5000	2-Mar-01	0.0350

The flow duration curve of the spring for entire period and selected separation criteria ranges when separation is performed on three MRC's is shown in Fig. 2. Similarly, the seasonal FDC's namely for rainy season, winter season and summer season for the period from August 1999 to December 2004 are shown in Fig. 3. Fig. 4 represents the separated MRC's for the rupado spring having optimal separation criteria, calculated as 3% and 15% of the flow rate duration, respectively. Similarly, the plot of MRC's using exponential decay function is shown in Fig. 5. On the plot of MRC's (Figs. 4

and 5), the exponetial decay equation for each separated segment and for each seasonal MRC and respective goodness of fit is given. Subseqently, the average values of recession coefficient (α_i), recession constant (k_i) , flow half life period in days ($t_{1/2}$) and spring flow at the start and end of MRC recession segement/ seasonal MRC for Rupado spring are shown in Table 4. Similar analysis has been cariied out for all the springs in both the watersheds.

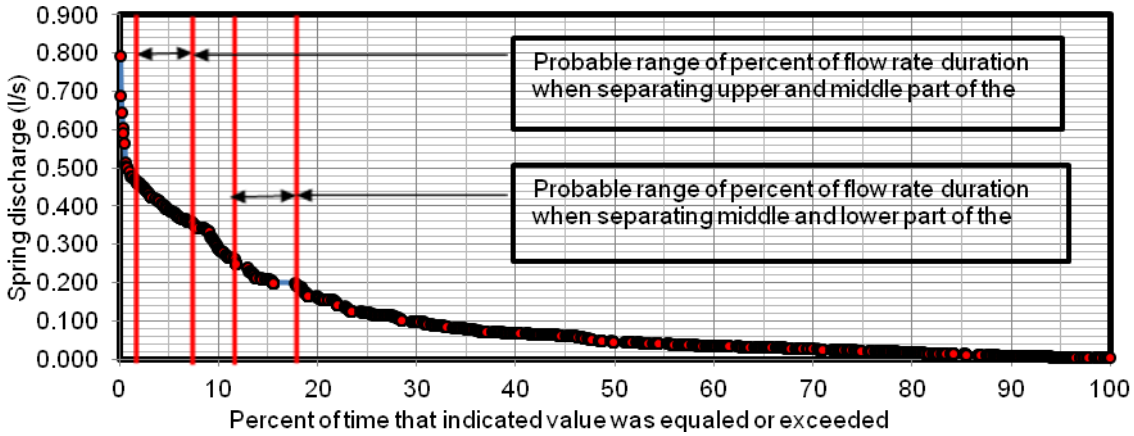


Figure 2. Flow duration curve of the Rupado Spring (ID No.6) for period 1999-2004 and selected separation criteria ranges when separation is performed on three MRC's.

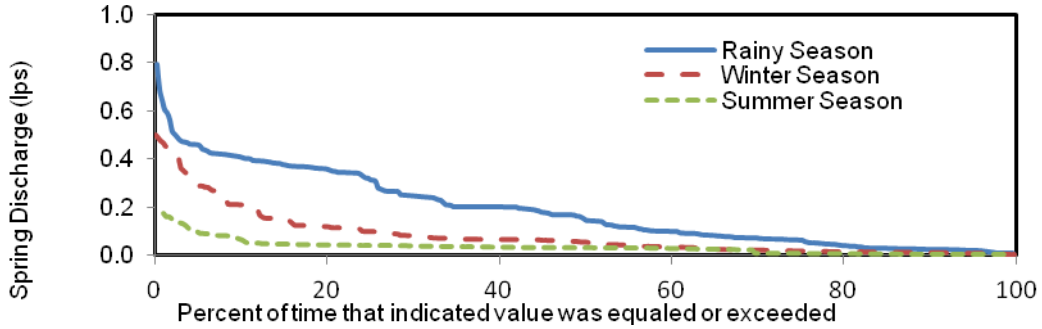


Figure 3. Seasonal flow duration curve of the Rupado spring for the period 1999-2004.

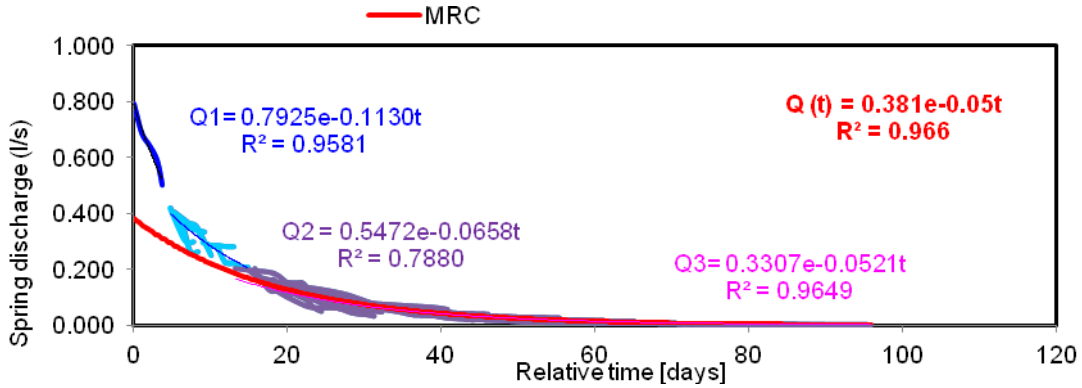


Figure 4. The separated MRC of the Rupado spring for the period 1999-2004 when separation is performed on three MRC's.

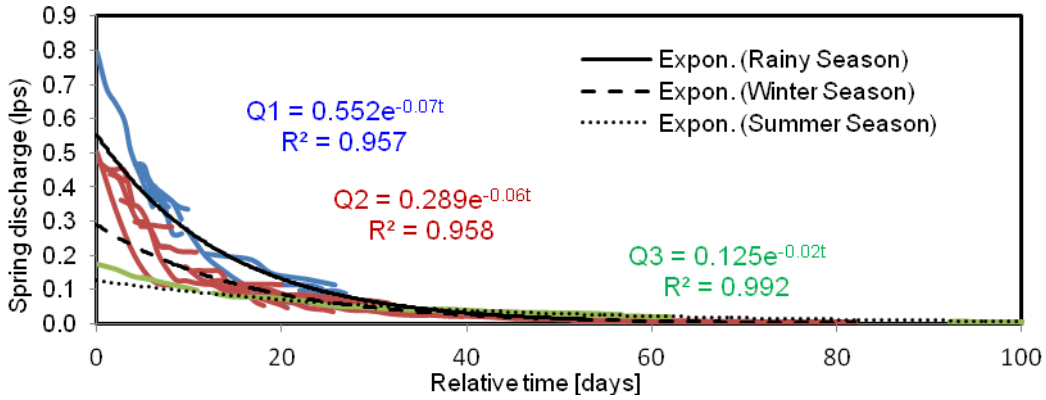


Figure 5. Seasonal MRC of the Rupado spring for the period 1999-2004.

Table 4. The Average Values of Different Recession Parameters and Spring Flow at the Start and End of MRC Recession Segement/ Seasonal MRC For Rupado Spring.

MRC		Recession coefficient (α_i)	Recession constant (k_i)	Coefficient of determination (R^2)	Flow half life, (days) ($t_{1/2}$)	Spring flow discharge values (lps)	
						Start of recession period	End of recession period
Entire time-series	Segment 1	0.113	0.893	0.9581	6	0.794	0.502
	Segment 2	0.066	0.936	0.7880	10	0.422	0.209
	Segment 3	0.052	0.949	0.9649	13	0.206	0.003
	Average	0.055	0.946	0.966	13		
Rainy season		0.072	0.930	0.96	10	0.794	0.500
Winter season		0.061	0.941	0.96	11	0.500	0.172
Summer season		0.029	0.971	0.99	24	0.172	0.003

- To measure the variability of spring flow, the ratio of (Q_{10}/Q_{90}) proposed by Netopil (1971) is being used. The (Q_{10}/Q_{90}) value for Rupado spring is 37.4. which indicates high flow variability. The low flow variability measured by (Q_{50}/Q_{90}) ratio is also 5.88 which indicates relatively low variability of Rupado spring. Similarly, the analysis of the variability of all the springs have been carried out.

Estimation of Base Flow Index (BFI)

Digital filters are useful tools for assessing the contribution of groundwater to total river/spring flow. Several of those filters have been proposed in the last decades. One of the last contributions on this subject was given by Ekchardt (2005) who proposed a more general form of a digital baseflow filter and showed that some of the most used filters are special cases of this general form. Eckhardt (2005) proposed a general form of the digital filtering method with representative $BFI_{\max}$ (maximum value of long term ratio of baseflow to total stream flow) parameter values for various hydrogeological situations to minimize the subjective influence of using $BFI_{\max}$ on baseflow separation. Eckdhardt (2005; 2012) estimated representative $BFI_{\max}$ values for different hydrological and hydro-geological situations. He proposed the use of $BFI_{\max}$ values of 0.80 for perennial streams with porous aquifers, 0.50 for ephemeral streams with porous aquifers and 0.25 for perennial streams with hard rock aquifers. To our knowledge no any study has been carried out which uses spring flow records to test these values of parameters.

Ekchardt (2005 and 2012) recommended the use of recursive filter parameters such as α (recession constant) and $BFI_{\max}$ value which are specific to local condition. Therefore, the $BFI_{\max}$ and recession constant (filtering parameter) values are estimated using inverse recursive filter and fully automatic adaptive matching strip methods, respectively. In this study in order select proper recession constant, the recession constant of optimal MRC (denoted as optimal recession constant) and recession constant

of third segement has been used. Similarly, the BFI values using Eckdhardt suggestion has been carried out. Further, the results obtained with Eckhardt recursive digital filter and modified Eckhardt recursive digital filter are compared with those obtained using Web based WHAT model, BFI_{max} optimization available in WHAT model and BFI_{max} value optimized with Genetical Algorithm (GA). Typical results are shown here for spring ID#6 in Danda watershed and Spring ID#4a in the chandrabhaga watershed in Figs. 6 and 7, respectively. Similarly, the analysis for all the spring has been carried out which will be presented in detail during WG meeting.

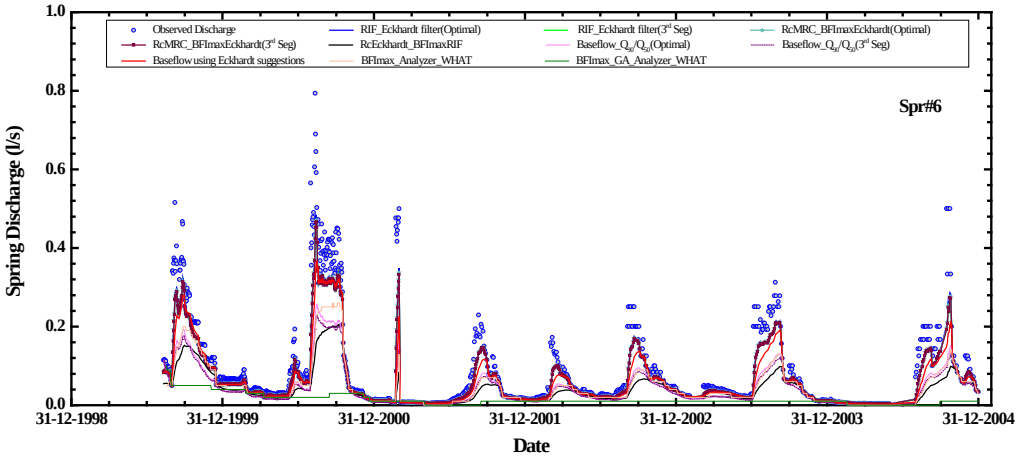


Figure 6. Baseflow separation digital filtering methods using various methods (Spring ID#6, Rupado spring in the Danda Watershed).

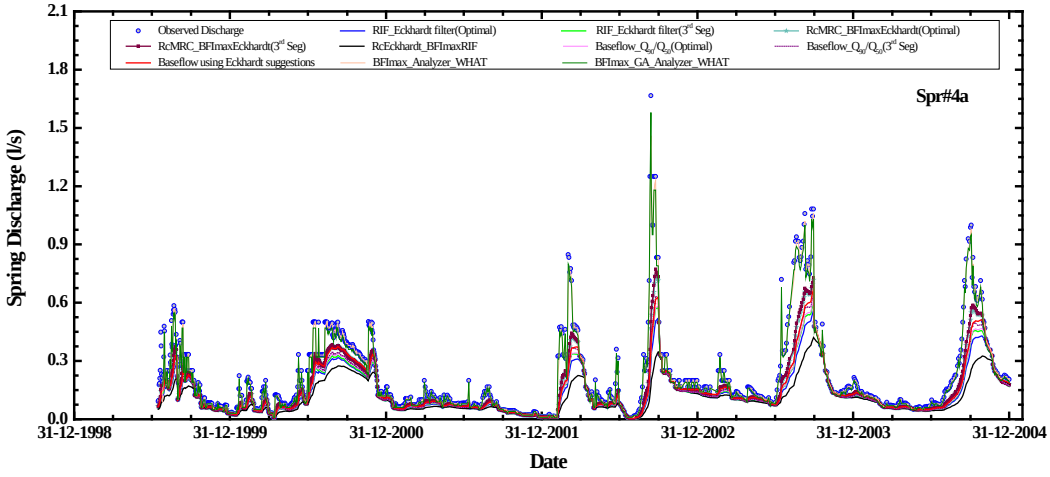


Figure 6. Baseflow separation digital filtering methods using various methods (Spring ID#4a, Bainsoli Malli spring in the Chandrabhaga Watershed).

Verification of the applicability of estimated recession constants of the watershed in estimation of recession flow and volume of ungauged spring

In order to verify the accuracy as well as the applicability of the estimated recession constants in the prediction of recession flow and volume of the ungauged spring, the MRC for the watershed has been developed using the average discharge time-series of some of the springs (approx. 60-70% spring). The recession constants were estimated using the different flow characteristics of the springs and then it were applied to the remaining springs (assuming that these springs are ungauged). Based on this study it was found that there is very good agreement has been achieved between the estimated discharge and volume of the ungauged springs and their observed discharge and volume. The results will be presented in more detail during the WG meeting.

13. **Adopters of the results of the study and their feedback:** N.A. at present

14. **List of deliverables** (e.g. equipment, papers, reports, softwares, manuals, brochures, flyers, training programmes, users interaction workshops)
    a) Papers
    b) Report: Interim report is prepared during April/May 2013.
    c) Final Report

Research Paper published or accepted out of this research project are as follow:

1. **Kale R. V.** and Goyal, V. C. (2013), Recession Flow Analysis for Assessment of Springs, In Proceeding "Efficient Water Management: Challenges and Opportunities", India Water Week – 2013, held at Vigyan Bhawan, New Delhi on 8-12th April 2013 (Full length paper is published in soft copy format).
2. **Kale R. V.** and Goyal, V. C. (2013),Estimation of recession constants for the springs in a Himalayan Watershed, 8th International Conference of European Water Resources Association (EWRA) on " Water Resources Management in an Interdisciplinary & Changing Context" Porto Portugal, 26-29th June, 2013.
3. **R. V. Kale** and V. C. Goyal (2013) Estimation of recession constants for springs in danda watershed (uttrakhand), International Conference: AWRDM-2013 "Advances in Water Resources Development and Management" Chandigarh, India, October 23-27, 2013.
4. **R. V. Kale** and V. C. Goyal (2014) Estimation of recession constants for springs in danda watershed (uttrakhand), *Int. J. of Earth Sci. and Engg*., 7(1), *271-277.*

15. Major items of equipment procured : NIL

16. Lab facilities used during the study: NIL

17. Data procured and/or generated during the study

The following are the data requirement for the analysis of spring flow data using recession flow model

a) Daily precipitation and spring flow data
b) Information on catchment characteristics

These information's have been collected from previous study reports by NIH

18. Study Benefits/Impact (2-column table showing achievements against measurable indicators as mentioned in the approved study document)

Measurable indicators	Expected achievements
New technologies/processes	This study will provide improved methodology for analysis of spring flow data series in order to analyze the water resources availability in the study region.
Improvement in skill	It is expected

15. **Specific linkages with Institutions and/or end-users/beneficiaries:** NIL

16. **Shortcomings/difficulties, if any**

There is some difficulty encountered during the estimation of aquifer parameters and hence, there is delay in the completion of this task within the stipulated period.

17. **Future plan:** To be evolved at later stages of the study.

Study – 2

1. **Title of the study**:

   Pilot Basin Studies in Identified Sites at Six RCs/CFMSs (**Continuing Study**)

2. **Name of PI, Co-PI, & their affiliations**

   Leader: Dr. V. C. Goyal, Sc F and Head, RMOD
   PI: One each from Divisions at the HQs and RCs/CFMSs

3. **Type of study**
   Internal (Jointly undertaken by NIH HQs and RCs/CFMSs)

4. **Date of start:** April 2012

5. **Scheduled date of completion:** March 2015

6. **Study Area:** Total six pilot basins (one at each RCs and CFMSs) have been selected in consultation with the respective state government in which selected pilot basin is falling to address the existing water-related problems. The details about these pilot basins have been given in the Table 1.

7. **Study objectives**
   NIH proposed to undertake six Pilot IWRM Basin studies in different locations covering various agro-ecological regions in India (See Figure 1). The study aims to:

   - To study in detail various hydrologic processes
   - To provide useful insight into propagation of IWRM concept for sustainable development of water resources with community participation
   - To evolve models of IWRM study for different hydrologic regions, for forward integration with Govt. schemes
   - To provide solution of local water problems, and build capacity of local community & institutions
   - To establish demo sites for researchers, students, managers and stakeholders

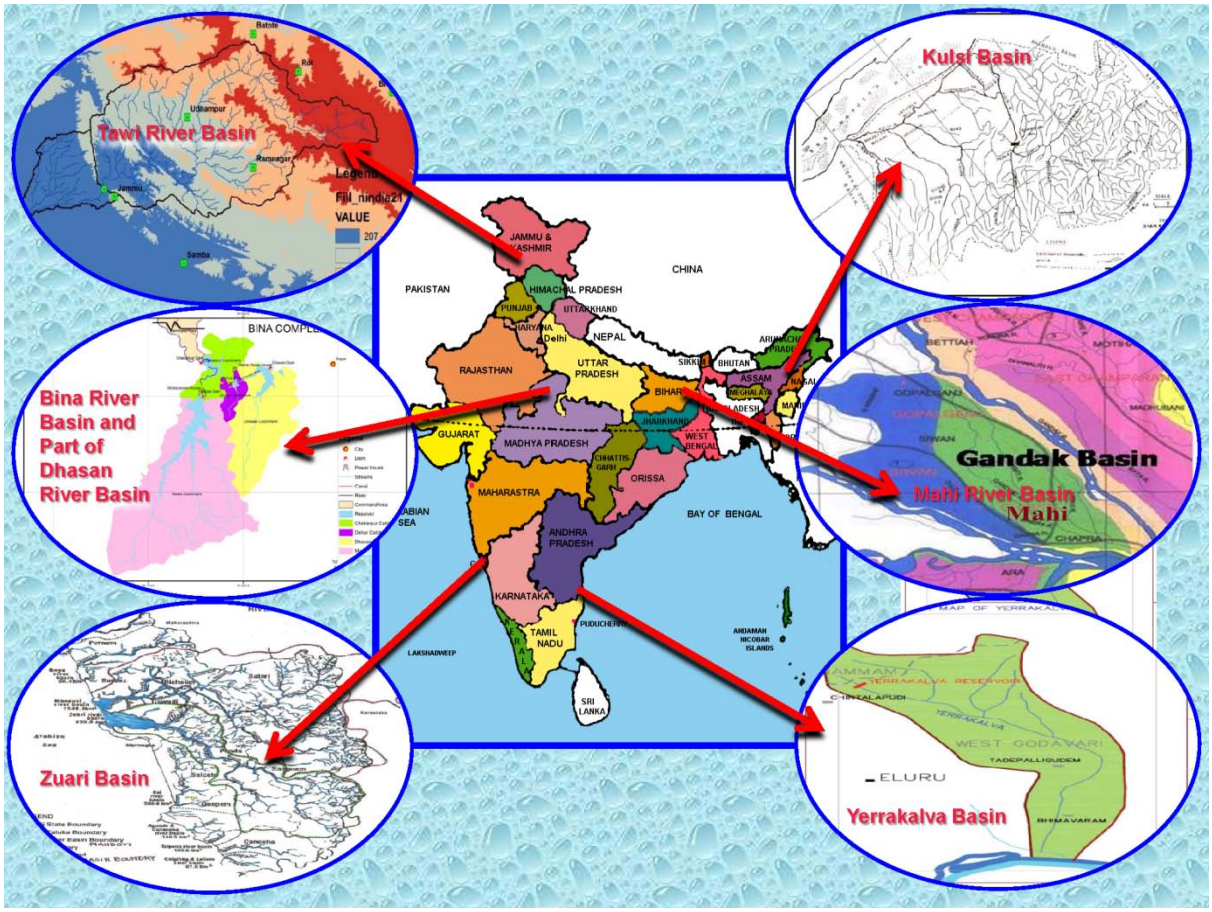


Figure 1. Pilot basins selected under IWRM-PBS program of NIH by its different RC/CFMS.

Achievements:

I. Stakeholders consultations in the respective study areas were conducted by the following RC/CFMS:

a) Deltaic Regional Centre, Kakinada
b) Hard Rock Regional Centre, Belgaum
c) Centre for Flood Management Studies (CFMS), Patna
d) Ganga Plains South Regional Centre, Bhopal
e) Western Himalayan Regional Centre, Jammu

II. Detailed Status Report on the PBS as part of work program at each RC and CFMS were prepared covering the following points:

- Statement of the problem
- Review of studies carried out (by RC/CFMS (NIH) and other agencies)
- Identification of gaps
- Proposed study components to address the gaps

- Data requirement for the study components and proposed instrumentation
- Work plan and time line

Status reports were submitted by the following RC/CFMS

a) Deltaic Regional Centre, Kakinada
b) Hard Rock Regional Centre, Belgaum
c) Centre for Flood Management Studies (CFMS), Patna
d) Ganga Plains South Regional Centre, Bhopal
e) Western Himalayan Regional Centre, Jammu
f) Status report by RC Guwahati is under progress.

III. An inception report on “IWRM-PILOT BASIN STUDIES (PBS) PROGRAM AT NIH” has been submitted to Director, NIH in April 2014. Study Team: Dr. V. C. Goyal (PI), Er. Omkar Singh and Dr. R. V. Kale

Study - 3

1. Title of the Study: WATER CONSERVATION AND MANAGEMENT IN IBRAHIMPUR MASAHI VILLAGE OF HARIDWAR DISTRICT (UTTARAKHAND)

2. Study Group:

Principal Investigators
Omkar Singh, V.C. Goyal, C.K. Jain, J.V. Tyagi and Sanjay K. Jain
Scientific/Technical Staff
Subhash Kichlu, Yatvir Singh, Rajesh Agarwal, Rakesh Goyal, N.K. Lakhera and C.S. Chowhan

3. Type of Study: Internal

4. Date of Start: April, 2013

5. Scheduled Date of Completion March, 2015

6. Duration of the Study: 2 years

7. Study Objectives:

- Assessment of water demand in Ibrahimpur Masahi Revenue Village of the Haridwar District
- Assessment of water availability in Ibrahimpur Masahi Revenue Village of the Haridwar District
- Assessment of water quality status/Eutrophication of Ponds in Ibrahimpur Masahi Revenue Village of the Haridwar District
- Preparation of water conservation plan for the identified village (s)
- Mass awareness activity for participatory water conservation & management

8. Statement of the Problem:

In our country, most of the traditional sources of water in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and witnessing severe eutrophication. 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 people by reducing the uncertainty of human life.

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 Shipla Nadi-Halzora Nadi watershed lies from 29^0 55' to 30^0 05' North latitude and 77^0 50' 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 55 km^2 upto their junction near Daryapur Dayalpur village. The area of Ibrahimpur Masahi revenue village is 14.26 km^2 which represents about $1/4^{th}$ of the watershed area. The Ibrahimpur Masahi revenue village consists of 5 five sub-villages under its jurisdiction, namely- Ibrahimpur, Masahi, Belki, Inayatpur and Halzora (Fig. 1).

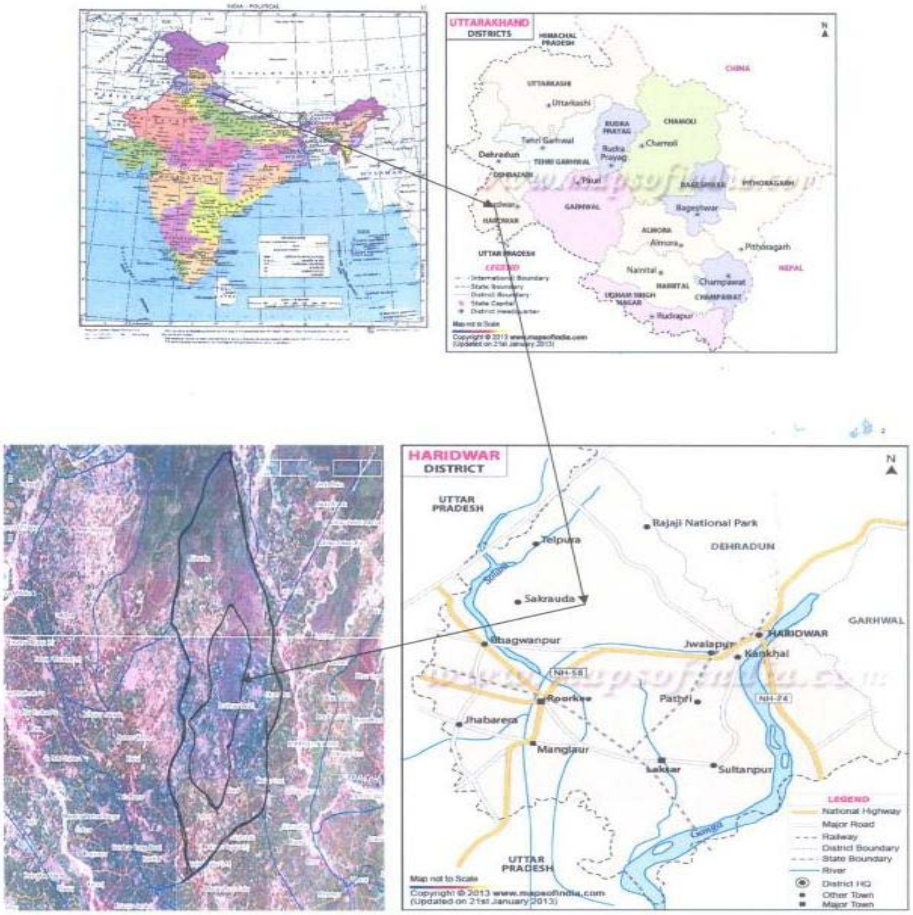


Fig. 1: Location Map of the Study Area

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. 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). Eutrophication of ponds will be 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. Accordingly, a water conservation plan for the

identified village (s) will be prepared. The mass awareness activities will also be carried out for creating awareness among the local people/school students for water conservation and management of local water sources. 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:

$$DWR_d\ (m^3/day) = (P_{rural} \times 40 + P_{urban} \times 135) \times 10^{-3}$$
$$DWR_m(m^3/month) = (P_{rural} \times 40 + P_{urban} \times 135) \times 10^{-3} \times 30$$
$$DWR_a(m^3/annum) = (P_{rural} \times 40 + P_{urban} \times 135) \times 10^{-3} \times 365$$

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):

$$LWR_d\ (m^3/day) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \times 10^{-3}$$
$$LWR_m\ (m^3/month) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \times 10^{-3} \times 30$$
$$LWR_a\ (m^3/yr) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \times 10^{-3} \times 365$$

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 number 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:

$$CWR\ (m^3) = CA\ (m^2) \times \Delta\ (m)$$

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.

Estimation of surface runoff

Estimation of surface runoff is essential for the assessment of water yield potential of a watershed, planning of soil and water conservation measures, reducing the sedimentation and flooding hazards downstream. The Soil Conservation Service Curve Number (SCS-N) method, developed by the USDA-Soil Conservation Service (SCS, 1972), is widely used for the estimation of direct runoff for a given rainfall event from small agricultural watersheds. The mathematical form of SCS-N method is given below:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

Where, Q= direct surface runoff in depth (mm)
P= Storm rainfall (mm)
S= maximum potential difference between rainfall and runoff (mm)

For convenience in evaluating antecedent moisture, soil condition, land use, and conservation practices, the U.S. Soil Conservation Service (1972) defines:

$$S = \frac{25400}{N} - 254$$

Where, N= an arbitrary curve number varying from 0 to 100. The curve number (N) can be obtained for various hydrologic soil group (A, B, C, D) on the basis of landuse/land cover, treatment/practice and hydrologic condition (good/poor/fair) as depicted under USDA-Soil Conservation Service (SCS, 1972).

10. Timeline:

S.No.	Major Activities	2013-14				2014-15			
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1.	Review of literature								
2.	Reconnaissance survey of study area								
3.	Procurement/Collection of necessary data for the study								
4.	Field investigations (WQ, WL Monitoring, survey of ponds etc.) and inventory of village water resources								
5.	Analysis of data for assessment of water demand, availability at village level, water quality & eutrophication status of ponds, etc.								
6.	Mass awareness activities								
7.	Report (s) preparation								

11. Objectives and achievement during last six months:

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.
ii) Assessment of water availability in Ibrahimpur Masahi Revenue Village of the Haridwar District.	The field investigations were carried out to study soil characteristics (infiltration, texture, soil moisture) in the study area. 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.
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.
Interim Report (2013-14)	An interim report has been submitted.

12. Recommendation / Suggestion:

Recommendation / Suggestion/Queries	**Action Taken**
• Dr. Prasad appreciated the study and informed that some studies of ponds have also been carried out by CWRDM. • Dr. S.N. Rai was keen to know about next steps in this study, and Dr. V.C. Goyal responded to his query. • Er. R.K. Khanna, informed about RRR program of MOWR relevant to this study for possible funding. • Dr. Arya apprised about the collection of village ponds photographs, which may be usefull for water histroy of the Nation.	Noted for compliance.

13. Analysis & Results: The water demand for domestic, livestock and agricultural uses was estimated for the Ibrahimpur Masahi Revenue Village. The Key results are given below:

Table 1: Estimated Total Water Requirement for Ibrahimpur Masahi Revenue Village

S.No.	Sector	Water Requirement (MCM/Year)
1.	Domestic (As per Projected Human Population of the village, 2021)	0.104
2.	Domestic (Livestock)	0.247
3.	Agriculture	8.569
	Total	8.920

Table 2: Monthly Dependable Rainfall (F= 50% ; F=75%) of Roorkee (1987-2013)

Month	Statistics					
	n	min	max	mean	F= 50%	F=75%
January	27	0	89.8	24.7	14.6	3.9
February	27	0	213.6	47	37.2	37
March	27	0	117.4	22.3	10.8	2.7
April	27	0	80	14.9	5.4	0.8
May	27	0	125.4	36.9	32.0	11.3
June	27	10.8	312.2	101.7	66.9	40.2
July	27	43.4	660	295.8	271.7	204.6
August	27	74.3	512.8	306	300.1	193.2
September	27	0	476.3	170.5	123.9	42.8
October	27	0	104.2	16.1	0.10	0
November	27	0	16	2.6	0.16	0
December	27	0	85	14.6	3.40	0.16
			Total (mm)	1053.1	866.3	536.7

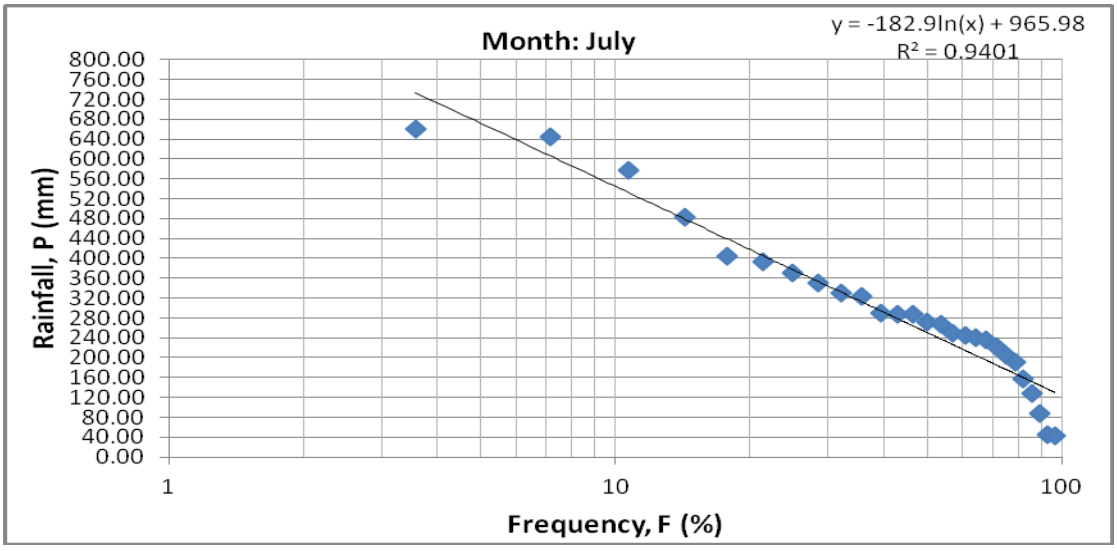


Fig. 2: Monthly Rainfall frequency curve for rainfall data of Roorkee (1987-2013)

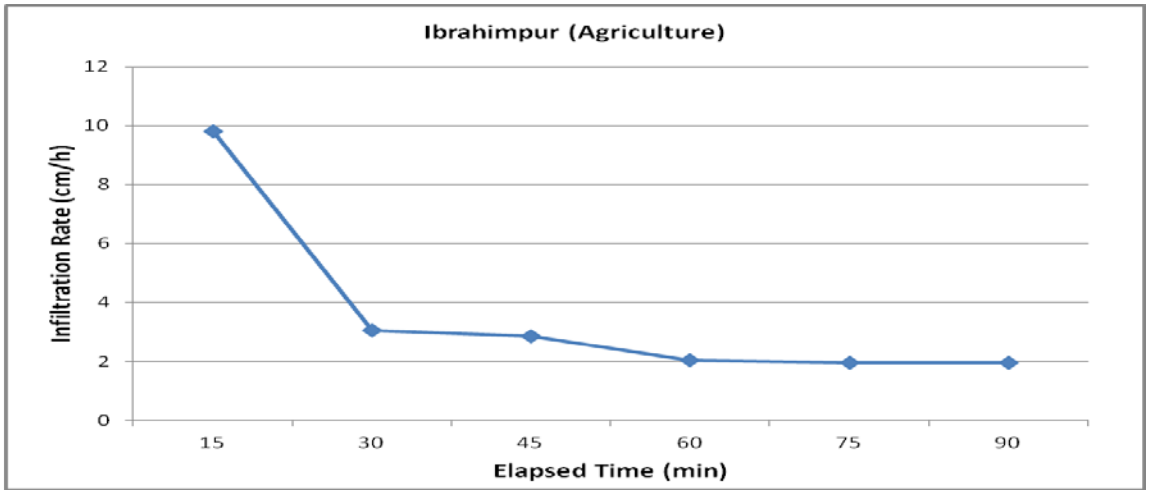


Fig.3: Infiltration Characteristics under Agricultural Landuse in the Study area

Table 3: Monthly Rain Water Availability (MCM) at Ibrahimpur Masahi Revenue Village Level and Watershed Level on the basis of 50% dependable Rainfall

Month	Rainfall (mm) at F= 50%	Rain Water Availability (MCM)	
		Watershed Scale	Ibrahimpur Masahi Revenue Village Scale
January	14.6	0.8	0.01
February	37.2	2	0.03
March	10.8	0.6	0.01
April	5.4	0.3	0
May	32.0	1.8	0.03
June	66.9	3.7	0.05
July	271.7	15	0.21
August	300.1	17	0.24
September	123.9	6.8	0.1
October	0.10	0	0
November	0.16	0	0
December	3.40	0.2	0
Total	866.3	48	12.35

14. **End Users / Beneficiaries of the Study:** Village Panchayats and Dist. Administration
15. **Deliverables:** Technical report and papers
16. **Major items of equipment procured:** -
17. **Lab facilities used during the study:** Soil & GW Lab, WQ Lab
18. **Data procured or generated during the study:** Soil Characteristics, Water Quality
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 Panchayats
22. **Shortcoming/Difficulties:** -
23. **Future Plan:** The future Plan of the study is given below:
    - Survey of Existing Ponds in the Study Area their Capacity Estimation
    - Preparation of Village Inventory Water Resources
    - Arrangement for Water Level Measurement in Shipla-Halzora River (Tributary of Solani River)
    - Monitoring Water Quality of Ponds and Estimation of Eutrophication Status
    - Preparation of DEM/Landuse/Land Cover Map of the Watershed
    - Estimation of Surface Runoff of the Watershed
    - Preparation of water conservation plan of the village
    - Mass awareness activity on water water conservation and management in the study area

Study– 4 (New Study)

Title of the study:

Participatory development of structure for IWRM Framework in identified sub-basins under Pilot Basin Studies (PBS) program **(New Study)**

Name of PI, Co-PI, & their affiliations

Dr V C Goyal, Sc F (**PI)**, Er Omkar Singh, Sc E and Dr R V Kale, Sc B
(Inputs contemplated from relevant professional organizations, such as SaciWaters, Hyderabad)

Type of study

Internal

Date of start: July 2014

Scheduled date of completion: June 2015

Study Area: Six pilot basins have been selected [Yerrakalva basin (A.P.), Zuari basin (Goa), Bina basin (M.P.), Mahi basin (Bihar), Tawi basin (J&K), Kulsi basin (Assam)] in consultation with the respective state governments in which selected pilot basin is falling to address the existing water-related problems.

Statement of the problem

It is widely accepted that basin planning must seek to obtain a balance between water resources development and water resources protection from social and cultural points of view as well as economic and environmental aspects.

Various hydrology-related studies and activities are undergoing since 2012 in the six sub-basins identified under PBS Program of NIH. The ultimate outcome of the PBS Program is to bring out IWRM Framework for each of the sub-basins based on the hydrological studies, which would provide useful insight for sustainable development of water resources in the respective study areas. Therefore, an IWRM-based basin development strategy document is required outlining the availability of water and related natural resources, and the strategy to share, use, manage and protect the basin's resources in an equitable and acceptable way.

Study objectives

The objective of the study is to prepare an IWRM Framework document outlining the availability of water and related natural resources, and the strategy to share, use, manage and protect the basin's resources in an equitable and acceptable way.

Methodology

Through the proposed study, a document will be prepared which will provide the structure of IWRM Framework to be used for each of the six sub-basins of the PBS Program. This

document will have sections and reporting formats on the status of the basin, development trends, capacity development needs, and basin development strategy. Consultations will be held with the local stakeholders and the six sites. Professional organizations having specialized knowledge of IWRM issues (e.g. SaciWaters, Hyderabad) will be consulted/involved in preparation of the structure of the IWRM Framework document.

Timeline

S.N.	Activity	2014-15				2015-16
		Q1	Q2	Q3	Q4	Q1
1.	Compilation of IWRM Framework strategies					
2.	Preparation of draft IWRM Framework document for the PBS Program					
3.	Consultation with stakeholders on the draft document					
4.	Finalization of the IWRM Framework document					

Study – 5 (New Study)

1. **Thrust Area under XII five year Plan**: Integrated Water Resources Management (Hydrology for sustainability of water resources/DSS (Planning) activities)
2. **Project team**:
   a. **Project Investigator :** Dr. Ravindra V. Kale, Scientist 'B'
   b. **Project Co-Investigator:** T Thomas (RC Bhopal), Dr Jyoti Patil
   Staff: Mr. Rajesh Agarwal, RA

3. **Title of the Project:** Customization of WEAP model for application in Ur river watershed in Tikamgarh district of Bundelkhand region.

4. **Objectives:**
   The main object of the study is the customization of **W**ater **E**valuation **A**nd **P**lanning (WEAP) model for linking the Integrated Water Resource Management (IWRM) and hydrological inputs with livelihood issues in Ur River catchment in Tikamgarh district of Madhya Pradesh (India). This main objective of the study can be accomplished with following sub-objectives:
   1. To prepare the input data structure for WEAP model.
   2. To connect supply sources to demand sites using transmission links.
   3. To test the ability of WEAP model to be used as a simulation tool to perform different types of scenario analysis studies

5. **Present State-of-Art:**

   A *Decision Support System* (DSS) is a means of collecting data from many sources to inform a decision. Information can include experimental or survey data, output from models and expert or local knowledge. Modelling and Decision Support Systems (DSS) are complementary tools. A *model* is a simplified description of a system to assist calculations and predictions. *Modelling* at the sub-catchment or river basin level can integrate the hydrological, technical, ecological, environmental, economic, social, institutional and legal aspects of water problems into a coherent framework. Presently hydrological models simulating water balance elements (such as river run-off, groundwater and evapo-transpiration) are quite well developed. So are water quality models for rivers, groundwater and lakes. However, models for most other water aspects (ecological, environmental, economic, social, institutional and legal) need significant improvement.

   There are various hydrologic modelling tools which are designed to simulate water development and management policies in river basins. These models are applicable to wide variety of specific watershed or river basin conditions, water resource system configurations, institutional conditions, and management issues are briefly discussed. Each of these modelling softwares are based on a node-link network representation of the water resource system being simulated. Some of the models include optimization that replaces a more detailed representation of operating policies. All contain menu-driven

graphics-based interfaces that facilitate user interaction. Some of the important modelling tools used as a DSS in the IWRM are:

- River Basin Simulation Model RIBASIM
- Integrated River Basin Management (IRBM)
- MIKE Basin
- Water Balance Model (WBalMo)
- MULti-sectoral, Integrated and Operational Decision Support System (MULINO-DSS)
- e-Water toolkits
- Water Evaluation and Planning System (WEAP)

These modelling tools are applied for the various watersheds worldwide having complex hydrological and socio-economic conditions. In the number of research studies, the capabilities and limitations of these DSS tools have been discussed based on data requirements, modelling capabilities and integration of the various aspects involved in the IWRM.

The models described above can be used to perform various tasks such as catchment project planning, optimal water allocation, river flow routing, reservoir routing, demand and supply analysis, hydrological analysis, catchment water balance, water quality and sedimentation analysis, socio-economic alternative identifications and general catchment management support applications. However, some models are better in the spatial water quality analysis, supply and demand management in the catchment like MIKE BASIN and MULINO, whereas others are good for the analysis of projects where river and reservoir routing is done like the RIBASIM. WaBalMo works well for specific types of resources management, to implement a flood control, or when addressing water-quality issues. It also has the advantage of modelling the natural processes of rainfall-runoff, which is not possible with most of the models described that use hydrological data inputs at various locations.

The models described above with the exception of WEAP21 and WaBalMo, work as integrated water resources management tools when coupled or linked to an extra management model or hydrological model. WalBalMo is a model used mainly for the design projects in a catchment and requires detailed data for the design purposes. The Water Evaluation and Planning Model (WEAP), developed by the Stockholm Environment Institute has been used worldwide in order to perform scenario analyses for water resources management. WEAP21 seamlessly integrate both the hydrological and management model to provide a better platform for IWRM analysis. However, ‘specialized’ models; that simulate water resource management and those simulating hydrological process are able to perform detailed simulation if sufficient data of good quality are available and such models can be coupled with the WEAP model. WEAP model provides a dynamic links to other models and software, such as QUAL2K, MODFLOW, MODPATH, PEST, Excel and GAMS. Specifically, WEAP model provides unique approach for conducting integrated water resources planning assessments. Its transparent structure facilitates engagement of diverse stakeholders in an open process. Using this modelling tool, it is able to calculates water demand, supply, runoff, infiltration, crop requirements, flows, and storage, and pollution generation, treatment, discharge and instream water quality under varying hydrologic and policy scenarios. The most important characteristics of this model is that it can

evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems.

About WEAP model:

WEAP is a robust tool for assessment, management and planning of water resources where it 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 base 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. Basically, WEAP has two main functions:

1. Simulation of natural hydrological processes (e.g. evapotranspiration, runoff and infiltration) to enable assessment of the availability of water resources within a catchment; and
2. Simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (e.g. consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use.

In the WEAP model, in order to allow simulation of water allocation, the elements that comprise the water demand-supply system and their spatial and temporal relationships are characterized for the catchment under consideration. The system is represented in terms of its various water sources (for instance surface water, ground water, desalination, water reuse elements) withdrawal, transmission, reservoirs, waste water treatment facilities and water demands (user defined sectors but typically comprising irrigation, mines, industry, domestic water supply).

Study Area

The climate of Tikamgarh district is characterized by a hot and dry summer. The normal annual rainfall is 1057mm. About 90% of the annual rainfall is received during southwest monsoon period, i.e. June to September. The normal maximum temperature received during the month of May is 41.8° C and minimum during the month of January is 7.0°C. The normal annual mean maximum and minimum temperatures of Tikamgarh district are 32.4°C & 17.5°C respectively. The entire Tikamgarh district falls under Betwa sub-basin of Ganga basin. Dhasan, Jamni and Sadhni are perennial rivers whereas Ur, Bargi, Gorar and Supihar are ephemeral streams in the area. The overall drainage pattern in the area is dendritic.

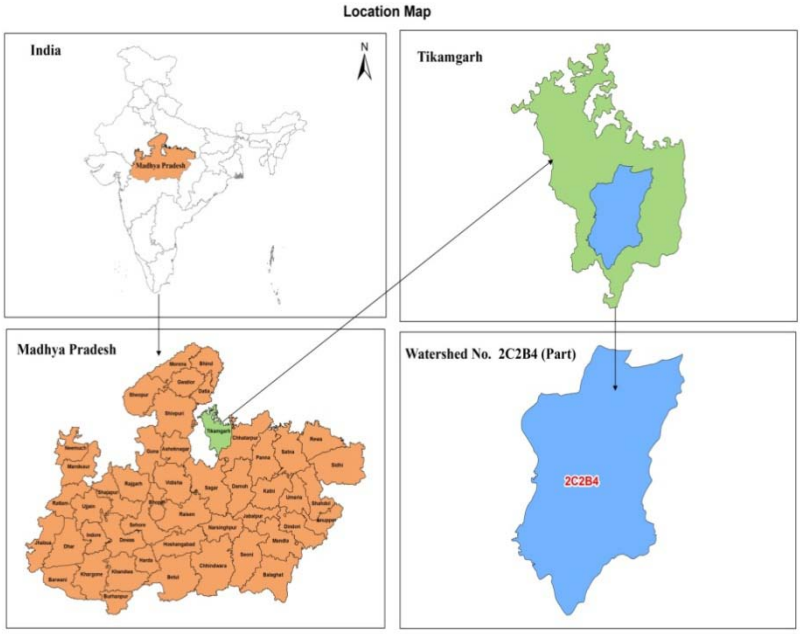


Figure 1. Location map of the Ur River catchment in Tikamgarh District (M.P.).

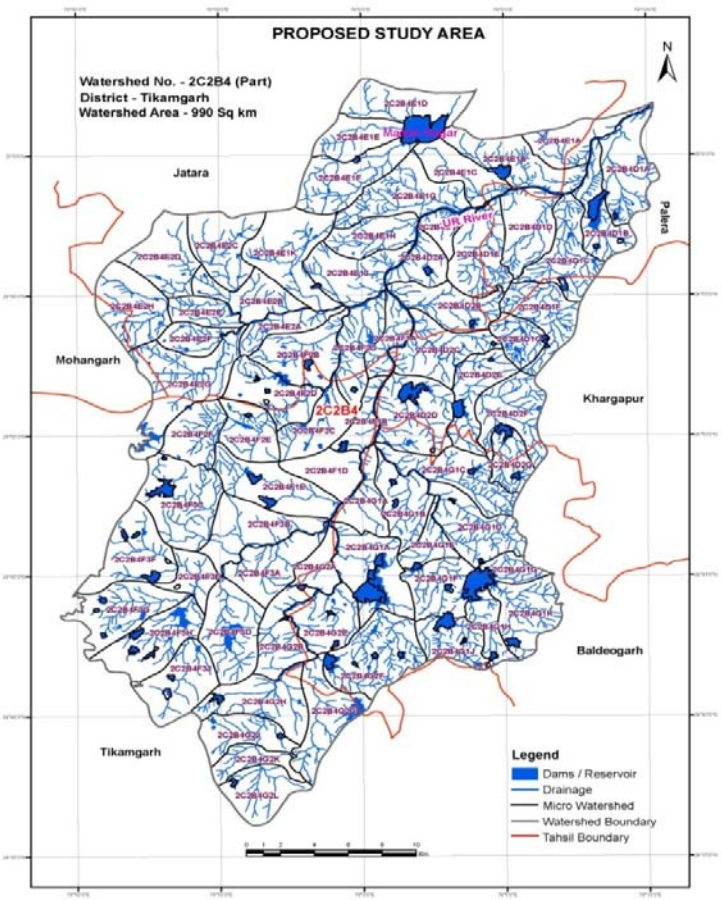


Figure 2. Map of proposed study area showing the details of existing streams, reservoirs/dams, micro watersheds and tahsil boundaries.

In this study Ur River watershed having area of 990.37 km^2 is selected for the studydevelopment of DSS for the IWRM. The watershed ID and watershed code of the Ur watershed is 4050104 and 2C2B4E1D, respectively as per the watershed classification system adopted by the M. P. Government. The Ur River watershed falls in the Betwa-Dhasan Lower Dhasan subcatchment. The location map of this watershed is shown in Figure 1. Further, Figure 2 shows the details of existing streams, reservoirs/dams, micro-watersheds and tehsil areas covered by the proposed study area. It covers around inhabited 200 villages in the Jatara, Tikamgarh, Baldeogarh, Kharagpur and Palera tehsils of the Tikamgarh District. Out of total area of 990.37 km^2, 11.18, 19.98, 45.58, 230.54, 69.79, 105.07, 99.68, 246.93, 34.50 and 131.28 km^2 areas are barren rocky, builtup, dense forest, double crop, fallow land, kharif crop, land with or without scrub, rabi crop, rivers & water bodies, scrub forest area, respectively.

The 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. The geological formations in the area mainly consist of Granite/Gneiss/ Schist/Amphibolite/Gabbro and Quartz Reefs type rock formation. Therefore, the underground granite layer limits groundwater recharge. Therefore, this watershed area is having large numbers of surface water harvesting structures or shallow dug wells. But, gradually the predominantly agrarian region started depending on groundwater for irrigation.

This area has witnessed fluctuations between extremes in weather conditions– long drought spell and intense monsoon rainfall. The recent long drought followed by extreme rainfalls in the monsoon season of 2008-09 is an example. In the last eight to nine years there have been significant changes in weather patterns which have adversely affected farmers and farming. Comparing with the situation 25 to 30 years earlier, people say that rainfall has decreased, the number of rainy days has decreased, rain tends to be concentrated in a smaller number of days, and cases of untimely rain are more common (frequently harming farmers instead of helping them). The damage caused by hailstorms, frost and storms has increased.

To improve the water situation in the region, it is felt that an integrated approach to water and waste 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 institutional systems at various levels (village, block, district levels) for community based management of water challenges. Prior to designing any interventions, it is important that the current status and its driving forces are well understood. This project is an effort to conduct a rapid assessment of the current status of water in the Ur River catchment of Bundelkhand region, and to develop a methodologies and a Decision Support System for introducing an integrated approach of water management with livelihood issues using WEAP system. A Decision Support System shall be developed considering hydrological, technological, economic, and social factors to recommend community-based water management policies for holistic development of the region.

6. Methodology

This study intended to customize the Water evaluation and Planning (WEAP) model by linking the Integrated Water Resource Management (IWRM) and hydrological inputs with livelihood issues in Ur River catchment in Tikamgarh District (M.P.).

The DSS structure that would be accomplished with customization of WEAP model to correspond to fulfill the objectives of the study with constraint imposed by limited data is presented in Figure 3. Note that, at the later stage some modeling tools can be added or removed based on the study needs and the constraint imposed due to limited data availability.

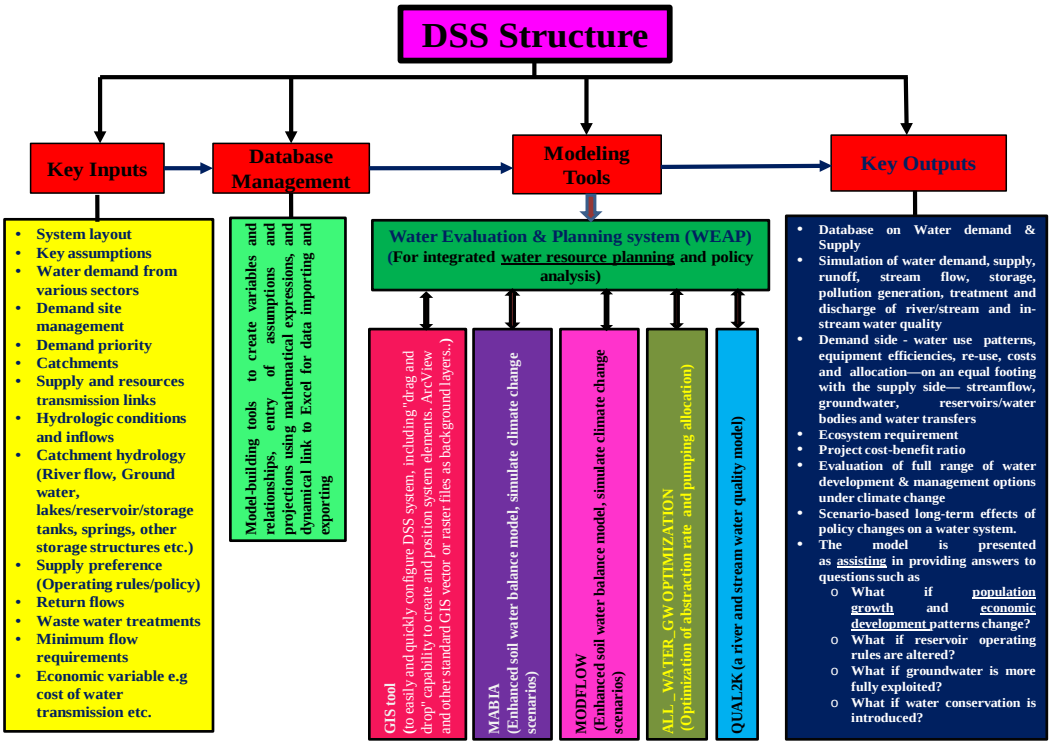


Figure 3. The proposed DSS structure using WEAP model to customize it for the Ur River catchment.

- The important task in this study is to collect the input data as given in Figure 3 required to customize this model. The climatic input data such as rainfall, temperature, relative humidity, wind speed could be obtained by the IMD.
- Agriculture areas and hydrological, morphological inputs can be obtained by using high resolution spatial data (e.g High resolution LISS-III & LISS IV data)
- In this watershed, discharge data of the Ur River is not available and thus, the G&D sites could be established to measure daily /hourly flow discharge data at the appropriate G&D sites.
- In this catchment, there are number of tanks/and ponds. However, there is no any information about the capacity of these structures available with the state

water resources department, and hence, it is proposed to undertake the bathymetric surveys for all these important tanks/reservoirs.

- Other important input data such as cropping pattern, kharif area, rabi area, ground water data, soil texture data, population data, livestock data available with different government/non-government organizations will be collected.
- The data on soil infiltration characteristics could be obtained by conducting the number of field experiments.
- In order to incorporate the livelihood issues in the proposed DSS, the number baseline surveys will be undertaken with the help of NGO to collect the necessary data.
- Finally, the WEAP model will be customized at sub-catchment scale in order to fulfill the requirements of the proposed DSS and output will be obtained on a daily/monthly scale. Prior to this, the hydrological processes occurring in the Ur River catchment will be modeled and 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 following step will be followed to generate typical scenarios:
- *Current Account* year will be chosen to serve as a base year of the proposed model.
- *Reference scenario* is established from the current Accounts to simulate likely evaluation of system without inerventation; and

7. **Research outcome from the project**

    - WEAP model will be customized for its application in Ur River watershed in Tikamgarh District (M.P.). Such model will be beneficial for the proper management of water resources in Ur River catchment and economic and social up-liftment of the area.

8. **Cost estimate**:
    a. **Total cost of the project:** Approx. 26,61,000/- (Twenty six lakh sixty one thousand rupees only)
    b. Source of funding: TIFAC sponsored project under INDIA-IIASA program **Sub Headwise abstract of the cost**

Si. No.	Sub-head	Amount (in Rupees)
1.	Salary (for research personnel recruited for the project)	3,36,000 (Senior Project officer) + 2,10,000 (Technical expert – IT/communication) = 5,46,000
2.	Travelling expenditure (Local travel + Air fare, International travel + living expenses at the IIASA)	5,15,000
3.	Infrastructure/Equipment Procurement and collection of data (satellite,	

	weather, soil, etc.) for landuse/land cover mapping and hydrologic analyses + Instruments	**(4,00,000 + 10,00, 000) = 14,00,000**
4.	**Experimental charges**	**1,50,000**
5.	**Misc. Expenditure**	**50,000**
	Grand Total	**26,61,000**

9. **Work Schedule**:
   - **a. Probable date of commencement of the project:** 1st April 2014
   - **b. Duration of the project:** Two Years (30th September 2015)
   - **c. Stages of work and milestone**

SI. No.	**Work Element**	**First Year**				**Second Year**	
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**
1	Identification of site and Instrumentation at the identified site						
2	Collection of hydro meteorological data, satellite images, thematic maps etc.						
3	Compilation and verification of hydro-mertological data, baseline survey data, census data and other qualitative data						
4	Preparation of input data for WEAP model						
5	Customization of WEAP based DSS for Ur River catchment and validation of model with observed data						
6	Scenario generation based on the Current Account						
7	Report writing						
	Deliverable	**1st Interim Report**				**Final Report**	
