Climate Change Impacts Studies for Rajasthan

(Areas of Inland Drainage and Mahi Basin)

under

National Water Mission

Proposal

Submitted to

Indian National Committee on Climate Change (INCCC)

NIH, Roorkee

Department of Civil Engineering

Malaviya National Institute of Technology Jaipur

Jaipur - 302017

May 2012

Appendix 1 Performa of Application for Research Grants

1 Research Station/ Institution

Malaviya National Institute of Technology Jaipur,
J.L.N.Marg, Jaipur-302017. (Raj)
Telephone: 0141 2529078 Fax: 0141 2529029 E-mail: director@mnit.ac.in
Nearest Rail head/Airport: Railway Station Jaipur/Sanganer Airport Jaipur

2 Principal Investigator

Dr. Mahender Choudhary, Associate Professor
Dept. of Civil Eng., Malaviya National Institute of Technology Jaipur,
J.L.N. Marg, Jaipur-302017. (Raj)
Telephone: 0141 2713377(O), 9413766111(M), 0141 2529029(Fax)
E-mail: mahender.choudhary@gmail.com

3 Co- Investigators

1.	Name of Co-PI	**Dr. Y.P.Mathur**
	Designation	Professor
	Department/ Institute	Department of Civil Engineering, MNIT Jaipur
	Address	J.L.N.Marg, Jaipur-302017. (Raj)
	Telephone	0141 2713267 (Office) 09413941350 (Mobile)
	Fax	0141 2529029
	Email	yogeshpmathur@gmail.com
2	Name of Co-PI	**Dr. M.K. Jat**
	Designation	Associate Professor
	Department/ Institute	Department of Civil Engineering, MNIT Jaipur
	Address	J.L.N.Marg, Jaipur-302017. (Raj)
	Telephone	0141 2713412 (Office) 09829053563 (Mobile)
	Fax	0141 2529029
	Email	mahesh.mnit@gmail.com
3	Name of Co-PI	**Dr. Rohit Goyal**
	Designation	Professor
	Department/ Institute	Department of Civil Engineering, MNIT Jaipur
	Address	J.L.N.Marg, Jaipur-302017. (Raj)
	Telephone	0141 2713263 (Office) 9414052971 (Mobile)
	Fax	0141 2529029
	Email	rgoyal_jp@yahoo.com
4	Name of Co-PI	**Dr. Sudhir Kumar**
	Designation	Professor

	Department/ Institute	Department of Civil Engineering, MNIT Jaipur
	Address	J.L.N.Marg, Jaipur-302017. (Raj)
	Telephone	0141 2713379 (Office) 9414241804 (Mobile)
	Fax	0141 2529029
	Email	sudhir.mnit@gmail.com
5	Name of Co-PI	**Dr. Gunwant Sharma**
	Designation	Professor
	Department/ Institute	Department of Civil Engineering, MNIT Jaipur
	Address	J.L.N.Marg, Jaipur-302017. (Raj)
	Telephone	0141 2713267 (Office) 9413941350 (Mobile)
	Fax	0141 2529029
	Email	yogeshpmathur@gmail.com
6	Name of Co-PI	**Dr. Urmila Brighu**
	Designation	Associate Professor
	Department/ Institute	Department of Civil Engineering, MNIT Jaipur
	Address	J.L.N.Marg, Jaipur-302017. (Raj)
	Telephone	+919314501211 (Mobile)
	Fax	
	Email	ubrighu11@yahoo.com
7	Name of Co-PI	**Dr. B.R.Chahar**
	Designation	Associate Professor
	Department/ Institute	Department of Civil Engineering
	Address	IIT Delhi, Hauz Khas, New Delhi110017
	Telephone	+919868266407 (Mobile)
	Fax	
	Email	br.chahar@gmail.com
8	Name of Co-PI	**Dr. Devesh Sharma**
	Designation	Assistant Professor
	Department/ Institute	Department of Environmental Science
	Address	Central University of Rajasthan, Kishangarh, Ajmer
	Telephone	0141 2713267 (Office) +919694667928 (Mobile)
	Fax	
	Email	deveshsharma@curaj.ac.in

4 Brief Bio-data of the Investigators *(enclose at the end of the proposal)*

5 Project Title (*keep it as short as possible***)**

Climate Change Impacts Studies for Rajasthan (Areas of Inland Drainage and Mahi Basin)

6 Track Record and Workload Assessment of the PI

Dr. Mahender Choudhary, AssociateProfessor, Dept. of Civil Eng., MNIT Jaipur is working in the field of Water resources management and climate change impact on Water Resources. He has research interest and worked in the field of Arid Hydrology, hydrological modeling, water management; artificial ground water recharging and climate change impact studies. Dr. Choudhary has received training at UNESCO-IHE, Delft, The Netherlands on 'Climate change in Integrated Water resources management' and at Hadley Centre, Met Office, UK on 'Regional Climate Modelling using PRECIS'. Presently one Ph.D. on the impact of Climate Change on Urban Water management is under the supervision of Dr. Mahender Choudhary is in progress. The list of projects completed by Dr. Choudhary is as follows

Title of Project	Status	Duration	Grant (Rs.)	Sponsored by
Proper Management of Flood Water for Rural Development at JNV Paota, Jaipur	Completed	2008 2 Year	6.90 Lac	DST
Quantification survey of pollen proteins in allergen extracts	Completed	2008 2 Year	0.75 Lac	Institution of Engineers
Environmental Assessment & Monitoring of Project	Completed	4 years	40 Lac	DPIP, Govt. of Rajasthan
Checking of the DPR's of Pradhan-mantri Gramin Sadak Yojana (PMGSY)	Completed	Since 2003	3-5 Lac annually	MORD, Govt. of India
Third party quality inspection of water supply and drainage projects	Completed	2003-04	2 Lac	RUIDP, Govt. of Rajasthan
Design & Drawing of RWH structures in Jaipur	Completed	2010	6 Lac	JDA Jaipur

Drawing of RWH structures (for Storm Water) in Jaipur	Completed	2011	5 Lac	JDA Jaipur
Design of Storm Water Harvesting system	Completed	2010	1 Lac	TODAR

There are no foreclosed or ongoing projects with Dr. Mahender Choudhary

7 If the scheme is sanctioned, in whose name the cheque is to be issued. (write precise title of the account)

Registrar MNIT Jaipur

8 Category of R&D Activity (Tick those which are applicable)

a. Basic Research

b. Applied Research

c. Action Research

d. Education & Training

e. Mass Awareness Program

f. Infrastructure Development

g. Creation of Centers of Excellence

9 Description of the Proposal

The impact of Climate Change (CC) is being felt around the globe. In order to study the impact of CC on National Water Resources, Central Water Commission (CWC) has prepared a plan for basin level study under National Water Mission and NAPCC. The Department of Civil Engineering Malaviya National Institute of Technology (MNIT) Jaipur along with IIT Delhi and Central University of Rajasthan, Kishangarh, Ajmer proposes a comprehensive research on the Areas of Inland Drainage in Rajasthan in western part of the state and Mahi Basin in the South Eastern part of the State. The primary objective of the project is to study the impact of Climate Change on various Hydrological parameters of a river basin using high resolution GCM outputs from multi model downscaling experiments. This would include the analysis of extreme weather phenomenon, development of basin specific Hydrological model for quality and quantity of available water and identification of hotspots with respect to hydrological parameters. The outputs of these studies would then be used for planning of Adaptation to the climate change in the form of water distribution for Municipal and Irrigation uses, Reservoir operation, crop cycling and Mitigation strategies for extreme events like flood, drought, heat wave and cold wave etc.

Water resources development is largely seen as a medium for social and economic development. Exploitation of this resource through a formal and a rigorous management paradigm has often put it in direct, and often bruising, competition with society's desire to preserve the integrity of our natural eco-system and its various services that the latter has come to depend upon. Accordingly, therefore, perturbations, both in short as well as in long term, have the potential of causing damage all across the entire spectrum. Presently, global climate change is being attributed to global warming which has been triggered by release of 'greenhouse gases' into the atmosphere at an alarmingly increasing rate. It is widely recognised that climate change is affecting the weather parameters such as rainfall, temperature, evaporation and transpiration. These large scale changes in the Earth's environment are a result of the 'Greenhouse effect', acid rain and the impact of the use of certain industrial and commercial chemicals on the protective ozone layer. It is widely believed that the predicted changes, during the next few decades, could far exceed natural climate variations in historical times and in the context of the foregoing discussion, water supply across the entire spectrum of uses and the quality of derived eco-system services is ultimately linked to climate and, in turn, to the various factors, including greenhouse gases, that determine its character.

Recent experiences do portend towards the intensity and scale of morbidity and the consequent derangements that are likely in river basins across the country. These derangements are not all that rare; nor are the damages likely to be superficial. Such disturbances can be quite cataclysmic in their consequences and this invariably results in a dramatic metamorphosis of the watershed landscape including the associated ecology. This is in line with the widely accepted Principle of Disproportionate Percentages which suggests that even the most trivia affect beyond apparent means. The "Butterfly Effect" in Meteorology is a well-known example of the principle of disproportionate percentages and there is a fair degree of unanimity amongst scientists that increasing carbon dioxide level in the atmosphere will result in changes not just in global and regional climate but also in watershed dynamics and land surface processes. A diagnosis of the past performance of a river basin is essential in case future prognosis of its hydrologic cycle is desired with a degree of objectivity and assurance. The prognosis that is being sought, must consider the influence of climatic as well as anthropogenic factors on the hydrologic cycle. A rational evaluation of the impact of climatic changes on a river basin's water cycle requires that the impact of anthropogenic influences of the branch cycle and those due to climatic factors be amenable to differentiation from each other.

Climate change impact assessment is carried out using General Circulation Models (GCMs), which are the most credible tools for future climate projections. However, since GCMs work at coarse spatial resolutions, impact assessment of hydrologic variables at regional scales demands either dynamic or statistical downscaling. In the present case downscaling of GCM would be done using Statistical and Dynamic downscaling methods. Multiple GCMs will be used for downscaling and confirming to CMIP5 radiation forcing to quantify model uncertainties in the predictions. The output from these multi-model downscaling experiments will be used in basin level hydrological model.

For hydrological modelling of the basin it is proposed to use SWAT (Soil and Water Assessment Tool) model (Arnold et al., 1998). SWAT is a river basin, or watershed, scale model 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 and it operates on daily time scale. The model is physically based, semi-distributed and computationally efficient, uses readily available inputs, and enables users to study long-term impacts. In SWAT, basins are divided into multiple sub-watersheds which are further subdivided into hydrologic response units, which consist of homogeneous land use, management, and soil characteristics. The overall hydrological balance is simulated for each hydrologic response units (HRU) including precipitation, infiltration, soil water redistribution, evapotranspiration, lateral subsurface flow, and return flow.

Region 1: Area of Inland Drainage in Rajasthan

The proposed project consists of the area of Inland Drainage in Rajasthan and has unique hydrological characteristics. The area has no drainage and mostly occupied by the Thar Desert (Figure 1). It has an Arid Climate and slopes gently towards West – Southwest towards Indus River system. Rainfall varies between 100-400 mm annually and is received mainly during monsoon season. In addition to the monsoon rain which is very erratic and often fails the region receives water from Indira Gandhi canal system from which water is mainly used for drinking purpose and irrigation of Rabi crops. The soil formation consists of a thin veneer of Dune Sand of zero to few meters in thickness underlain by an impervious clay layer. The area is not investigated properly and at a few places subsurface palaeochannel containing fresh water or perched aquifers have been reported. Monsoon often fails in the region and Droughts are a common phenomenon followed by heat wave. In the recent past there have been few instances of flooding due to high rainfall intensity and low percolation rate. In such an environment, climate-change can have a serious impact on the effectiveness of policies as it doesn't only affect the availability of new resources, but also the efficient utilization of the existing resources. Judicious and well-thought adaptation measures will be needed. The outcomes from the studies carried out shall be disseminated through the digital platform that will enable more effective formulation, implementation and evaluation of policies in a dynamic manner.

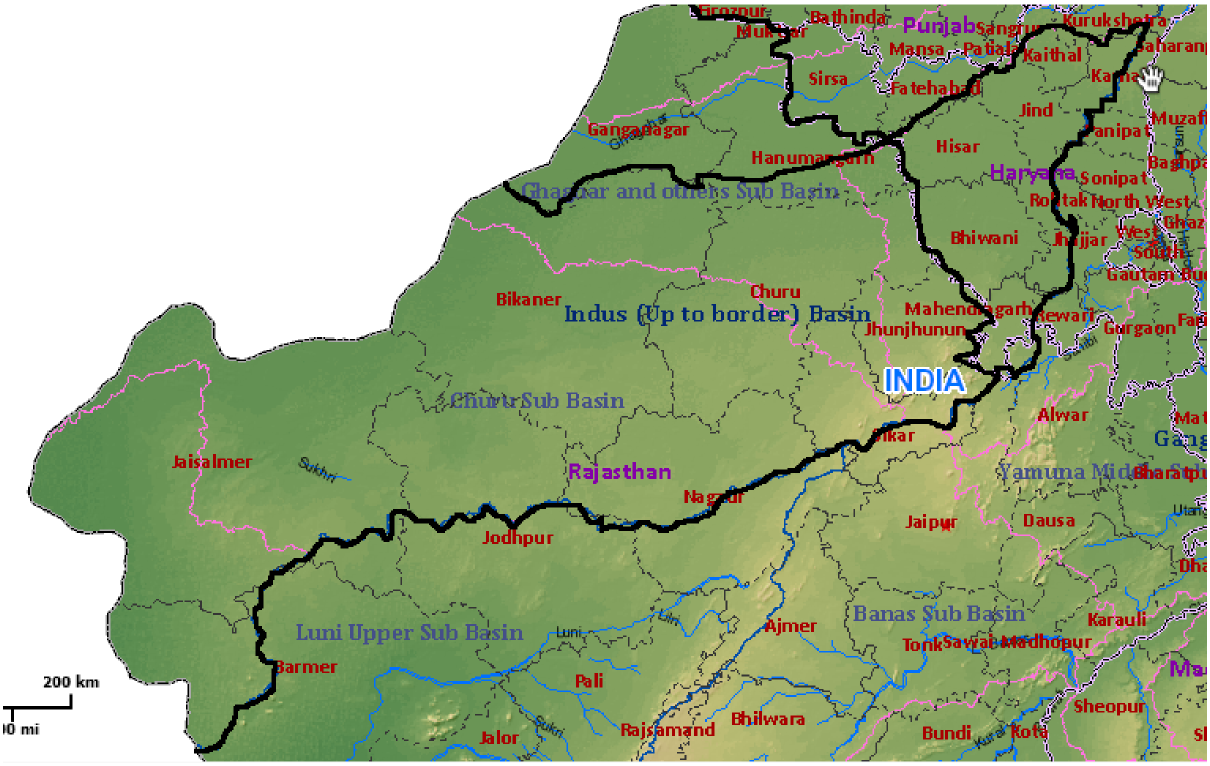

Figure 1: Area of Inland Drainage in Rajasthan Desert

Region 2: Mahi Basin

The proposed project consists of the area Mahi River Basin. River Mahi originates in Dhar District and joins Gulf of Khambat. The Mahi basin extends over an area of 34,842 km^2 which is nearly 1.1 percent of the total geographical area of the country. It lies between east longitudes 72º 15' to 78º 15' and north latitudes 22º 0' to 22º 40' N respectively (Figure 2). The Mahi River originates in the Mahi Kanta hills in the Vindhyachal range, in the western part of Madhya Pradesh. It is bounded on the north and north-west by the Aravalli hills, on the east by the ridge separating it from the Chambal basin, on the south by the Vindhayas and on the west by the Gulf of Cambay. The basin lies in the States of Rajasthan, Gujarat and Madhya Pradesh. The upper part of the basin in Rajasthan and Madhya Pradesh comprises mostly hills and forests except the lower half in M.P., which is fairly plain. The central part lying in Gujarat consists of developed lands. The lower part of the basin lying in Gujarat is flat and fertile and well developed alluvial tract. Important soil types in the basin are red and black soils. The culturable area of the basin is about 2.21 Mha which is 1.1% of the total culturable area of the country. The principal tributaries of the Mahi River are Som, Jakham, Moran, Anas, and the Bhadar. Major projects on the River Mahi are Jakham Reservoir, Panam Dam, Mahi Bajaj Sagar Project and Kadana Project. As per a previous study by Gosain et al. (2003) the two river basins Sabarmati and Mahi show drastic decreases in precipitation and consequent decrease in total runoff to the tune of two thirds of prevailing runoff. This may lead to severe drought conditions in future in these basins. Therefore, it becomes necessary to undertake a comprehensive study of the Mahi basin for climate change impacts on hydrology of the Basin. The reservoir operation strategy under changed climate would require improved water use efficiency and conjunctive use of ground water under and Integrated water resources management approach. The outcomes from the studies carried out shall be disseminated through the digital platform that will enable more effective formulation, implementation and evaluation of policies in a dynamic manner.

Figure 2: Area of Mahi Basin

10 Objectives. Classify the objectives of proposed research under one or more of following and explain the objectives briefly.

The objective of the proposed project is to study the impact of Climate change on the hydrology of the study area and suggest strategic adaptation and mitigation options. There are four main activities to be performed viz. Surface water modelling (using SWAT), groundwater modelling (using mudflow), crop productivity modelling and reservoir/canal operation modelling. The specific objectives are as follows:

- Literature review : analysis of past studies and literature available to ascertain the present state of the art.
- Data Collection: base line data collection of the study area and analysis.
- Trend analysis of hydrological and meteorological parameters like precipitation, temperature, stream flow, groundwater levels, sediment no. and size of water bodies, evapo-transpiration, land use land cover and extreme climate events like floods and droughts.
- Hydrological modelling of the basin in a GIS environment :
    - Conceptualisation of hydrological model of basin
    - Calibration and validation of hydrological model
- Hydrological responses corresponding to different climate change scenarios obtained from downscaling using different GCM models.
- Development of crop production functions, their calibration and validation.
- Hydrological impact analysis of climate change:
    - Generation of surface water responses i.e., stream flow under climate change scenarios and assessment of water availability
    - Impact of hydro-meteorological changes on crop production under different climate change scenarios
    - Groundwater responses under different climate change scenarios and water availability
    - Soil erosion responses under different climate change scenarios
- Adaptation strategy under Climate Change:
    - Optimal water allocations/use involving different sources and users under different climate change scenarios
    - Optimal reservoir/canal operations under different climate change scenarios

    - Optimum agricultural practices under different climate change scenarios
    - Various water demand management options for different sectors
- Identification of possible mitigation strategies for extreme hydrological events like floods and droughts

11. Contribution to Water Resources Development

The project would be helpful in understanding the impact of CC on the hydrology of Region one and two in the state of Rajasthan. That would mean that it will estimate the possible increase/decrease in availability of water, intensity of drought/floods, extremes of temperature and other parameters related to climate change so that strategic planning for Adaptation and Mitigation may be done. The study would also suggest canal/reservoir operation strategy for optimum water utilisation under CC.

12 Putting the Research to Use

a. The output of the research will be useful for Ministry of Water Resources and CWC for planning National Water Resources and increasing the understanding about impact of CC on regional water resources. It will also be useful to State Govt. Agriculture Dept., Water resources Dept., Forest Dept. etc. who are stake holder in water use.

b. The results will be available in GIS format and can be used by the entire stake holder from web based interface on a National Portal.

c. All the data from different users may not be available in the same format for which uniform reporting guidelines may be prepared in the initial stage itself.

d. The present end user is CWC which has initiated this project.

13 Present State of Art

Climate change is already happening and represents one of the greatest environmental, social and economic threats facing the planet. Environment and ecosystem components are sensitive to climate variability and change. Human health, agriculture, natural ecosystems, coastal areas, and heating and cooling requirements are examples of climate-sensitive systems. Some observed changes include change in regional circulation and monsoon pattern (i.e. hydrological cycle), shrinking of glaciers, later freezing and earlier break-up of ice on rivers and lakes, lengthening of growing seasons, shifts in plant and animal ranges and earlier flowering of trees (IPCC, 2007). The atmospheric temperature are expected to continue to rise as human activities continue to add carbon dioxide, methane, nitrous oxide, and other greenhouse (or heat-trapping) gases and particles to the atmosphere. The extent of climate change effects, and whether these effects prove harmful or beneficial, will vary by region, over time, and with the ability of different societal and environmental systems to adapt to or cope with the change. A brief review on international and national status of these areas is as follows:

International status

Any climate change impact assessment on water resources study requires the down-scaling of the precipitation and other variables such as temperature, relative humidity, solar radiation, wind direction and wind speed from the global scale to the regional scale. Such down-scaling is done by using either analogue or statistical down-scaling procedures.

The future predictions are described in terms of SRES (Special Report on Emissions Scenarios) storyline scenarios (IPCC, 2007). Each scenario has made assumptions that are dependent on demographic, social, economic, technological, and environmental developments. Around the same time there has been a study wherein general projection of the water resource demand for 2050 has been worked out by the Central Water Commission without considering any climate change impact (Thatte, 2000). He has shown that even without considering climate change impact, the total water demand shall surpass the availability by 2050 even under a low consumption scenario.

Sea-level rise could raise a wide range of issues in coastal areas. Studies in the New York City metropolitan area have projected that climate-change impacts associated with expectations that sea level will rise, could reduce the return period of the flood associated with the 100-year storm to 19 to 68 years on average, by the 2050s, and to 4 to 60 years by the 2080s, jeopardizing low-lying buildings and transportation systems. Similar impacts are expected in the eastern Caribbean, Mumbai (India), Rio de Janeiro and Shanghai, where coastal infrastructure, population and economic activities could be vulnerable to sea-level rise.

The causative factors leading to climate change can be due to natural variability within the system, natural external forcings or man-made forcings. Detection and attribution (D&A) studies differentiate the natural variability and trends in the climate system from those induced by anthropogenic activities and assign these variability to specific causative factors.

Differentiating between natural and anthropogenic influences in a quantitative manner is challenging task.

IPCC WGI/WGII expert meeting on detection and attribution related to anthropogenic climate change (Hegerl et al, 2010) has suggested some guidance while conducting any D&A studies. Much of the D&A studies have been conducted on assessing the human influence on possible temperature changes at continental, subcontinental, and even regional scales (Barnett et al, 2001; Christidis et al., 2005; Hasselmann, 1997; Hegerl et al, 1997; Hegerl et al., 2004; Karoly et al. 2003; Karoly and Stott 2006; Stott 2003; Stott et al. 2010; Zwiers and Zhang 2003). A review of techniques being used in climate change detection studies can be found in Zwiers (1999). Most of these studies have either adopted an optimal fingerprinting or extreme values distributions to assess the anthropogenic influence on the variable of interest. Although, evidence of man-made influence are being highlighted, the results are subjected to uncertainties associated with the model-derived climate change signals, model sensitivity, incorrect aerosol forcing and uncertainties in statistics used.

The impact assessment of climate change on hydrology necessitates the quantification of uncertainties originating from several sources. Uncertainties arise from various sources such as (i) GCM uncertainty, (ii) scenario uncertainty, (iii) internal variability and (iv) uncertainty due to various downscaling approaches. These uncertainties accumulate and cascade down with an increase in resolution or regional levels (Wilby, 2005). Quantification of these uncertainties is basically done by determining the spread of the outputs from various GCMs, scenarios and downscaling approaches. Studies have been employing probabilistic, Bayesian and Monte-Carlo approaches to evaluate the uncertainty (New and Hulme, 2000; Raisanen and Palmer,2001; Tebaldi et al., 2004; Wilby and Harris,2006). An ensemble of projections from different GCMs, scenarios, statistical/dynamical downscaling methods is generated to evaluate the effects of climate change on hydrological variables (Prudhomme and Davies, 2009; Kay et al., 2009; Wilby, 2005). Some recent studies have analysed the suitability or skill of GCMs using an index measured with respect to the observed climate (Murphy et al. 2004; Dessai et al., 2007; Wilby and Harris, 2006).

The above mentioned studies have considered different sources of uncertainty such as future greenhouse gas emissions; structure of GCM; downscaling from GCMs; hydrological model structure; hydrological model parameters and the internal variability due to sensitivity of initial conditions. Among these different sources of uncertainty, the largest contribution from the choice of a GCM. Scenario uncertainty and downscaling uncertainty are much smaller than GCM uncertainty and are almost of similar magnitude.

Regional projections can be obtained either by statistical downscaling in which specific relationships are derived between the GCM and the regional variable of interest or by dynamical downscaling with regional climate models. Another approach of most recent origin through which the downscaling uncertainty can be omitted is macroscale modeling. The outputs from GCMs in coarse resolution are utilized by hydrologic model. The areal heterogeneity in topography, land use, land cover, soil, vegetation and hydrological characteristics should be taken into account in macroscale hydrological modelling.

Vicuna (2008) investigated the effect of climate change on the generation of energy from high-elevation hydropower systems by generating scenarios from a macroscale hydrologic model and coupling it with two general circulation models under two greenhouse-gas emissions scenarios. Wenger et al. (2010) studied the effect of stream hydrology on the structure of aquatic communities. The macroscale hydrologic model was found efficient in simulating the hydrologic changes in smaller streams also.

Nijssen et al. (1997) predicted stream flow for continental river basins using a two layer Variable Infiltration Capacity (VIC-2L) model. Global river sensitivity to climate change was attempted by Nijssen et al (2001) by studying nine large river basins to analyze the regional hydrological consequences of climate predictions using Variable Infiltration Capacity (VIC) model.

Adaptation is the process through which adequate measures are taken to reduce or cope with the negative effects of climate change (IPCC, 2007). Adaptation can be done in a reactive or anticipatory way. Last few years have seen a significant increase in the literature on adaptation to climate change. The role of adaptation in impact assessment (Schneider et al., 2000) and also in reducing vulnerability (Yohe, 2000; Mimura an Yakoki, 2004) have been taken up by many studies. However, very few studies have been conducted on decision-making accounting hydrological impacts.

National status

The predictions made on the future scenarios through the region level downscaling are used by researchers to quantify the impacts on water resources. At the national level the NATCOM (NATional COMmunication) project has been the first one in this direction. Gupta and Deshpande (2004) has predicted that the gross per capita water availability in India will decline from about 1,820 m3/yr in 2001 to as low as about 1,140 in 2050. The reduction in per capita availability of water is entirely due to population growth and cannot be attributed to climate change or any other factor. A case study by Roy et al (2003) deals with the impact assessment of climate change on water availability in the DamodarRiver basin. Hydrologic modelling for evaluation of the effect of climate change on the water scenario has been performed. The water availability in the basin under changed climate scenario was evaluated using the projected daily precipitation and mean monthly temperature data for 2041-2060. It was concluded that decreased peak flows would hinder natural flushing of stream channels leading to loss of carrying capacity and production of non-monsoonal crops will be severely affected.

There has been one comprehensive study that has been carried out to quantify the climate change impact on majority of Indian River systems (Gosain et al, 2003). In this study, the SWAT model (Arnold et al, 1990), a distributed, continuous, daily hydrological model with a GIS interface has been used with daily weather generated by the HadRM2 control climate scenario (1981- 2000) and GHG (Green House Gas) climate scenarios (2041 – 2060). They concluded that although there is an increase in precipitation in some of the river systems for the GHG scenario, the corresponding runoff for these basins has not necessarily increased due to increases in evapo-transpiration on account of corresponding increased temperatures. Two river systems which are predicted to be worst affected from floods are Mahanadi and Brahmani. The frequency as well as the magnitude of the floods is predicted to be enhanced under the GHG scenario. They further concluded that decrease in precipitation has been experienced in many other river basins. The two river basins Sabarmati and Mahi show drastic decreases in precipitation and consequent decrease in total runoff to the tune of two thirds of prevailing runoff. This may lead to severe drought conditions in future in these basins. There has been widespread retreat of glaciers worldwide during the current century (IPCC, 2007). If current warming rates are maintained, Himalayan glacier could decay at very rapid rates, shrinking from the present spread of 500,000 km2 to 100,000 km2 by the 2030s. Many rivers draining glaciated regions, particularly in the Hindu Kush-Himalayas and the South-American Andes, are sustained by glacier melt during the summer season (Singh and Kumar, 1997; Mark and Seltzer, 2003; Singh, 2003; Barnett et al., 2005). Higher temperatures generate increased glacier melt. The entire Hindu Kush-Himalaya ice mass has decreased in the last two decades. Hence, water supply in areas fed by glacial melt water from the Hindu Kush and Himalayas, on which hundreds of millions of people in China and India depend, will be negatively affected (Bernett et al., 2005).

India is especially susceptible to increasing salinity of their groundwater as well as surface water resources, especially along the coast, due to increases in sea level as a direct impact of global warming (Han et al., 1999).

Regional Studies

Rajasthan is a unique region with the major part being a sandy desert and some part as mountainous has not been investigated extensively. There are few studies conducted regarding the metrology, groundwater recharge and existence of palaeo drainage basins. But these studies are highly insufficient to properly understand the hydrology of the region. The region encounters extreme weather phenomenon and Dhar and Rakhecha (1979) studied the incidences of heavy rainfall on Indian desert reporting occasional rainfall of 250-500 mmm in a single day. Groundwater recharge studies using Isotope tracers have been carried out to by Sharma and Gupta (1988), Navada et.al. (1993) and Sukhija et.al. (1996) suggesting 3-15% recharge under different geological and meteorological conditions. The existence on palaeo drainage channels was studied by Khilnani (2009) and related the occurrence of water bearing aquifers and salt lakes with the Vedic rivers. Some recent studies related to canal water management and water logging have been done by Sharma (2001) and Arora and Goyal (2012). Studies related to water conservation and harvesting, and agroforestry were done by Narain et. al. (2005) and khan et. al. (2006). There is a need for further investigation of other studies conducted by other investigators regarding the hydrology of this region before starting further work on hydrological modelling of the region.

A brainstorming meeting involving official from Ministry of Water Resources, Central Water Commission, National Institute of Hydrology and many academic institutions suggested the following actions for effective mitigation/ adaptation measures towards climate change.

- Updating the basin wise water availability
- Coping with the variability in the water sector through development and regulation
- Review of hydrological design and planning criteria under the changed scenario
- Study of Water-Energy-Climate change relationships
- Development of databases and associated tool-boxes for Integrated Water Resources Management (IWRM).

c) Importance of the proposed project in the context of current status

Flow in a river at any point reflects the integrated effect of various, mutually interacting, physical and hydro-climatological processes of the hydrologic cycle. This interaction, which takes place in a natural environment, transforms a climatic input in the form of precipitation into surface and subsurface flows which in turn are modified by human activities as much as by changes that occur in natural processes. The literature has revealed that many studies have been done in the developed countries for assessment of Climate Change on local water resources but in Indian context such studies are lacking. The area of Inland Drainage of Rajasthan is even behind the other river water basins in terms of available data and characterisation of basin. In order to estimate the impact of Climate Change on availability of water for effective planning of Adaptation strategy and identifying extreme events of temperature and precipitation for planning Mitigation strategies it is proposed to take up a comprehensive study of the area.

14 Methodology

To achieve the proposed objectives of this proposal following steps will be taken with specific focus on local conditions:

i. Identification of current knowledge gaps and existing issues,
ii. Conducting applied research on CC related issues/problems,

1) *Identification of current knowledge gaps and existing issues.*

Baseline data will be collected and present understanding of the hydro metrology of the area will be developed based on earlier studies. Current knowledge gaps related to scientific, applied, and social science-related information and existing climate change-related issues will be identified using extensive literature review.

2) *Conducting applied research on climate change-related issues/problems*

Applied research projects will be conducted on different climate change-related issues using experimental and mathematical modelling procedures. Issues identified from step 1 will be guiding-posts for selecting high-priority problems areas and conducting applied research. Some of the identified issues/problems related to different aspects of climate change are presented below:

i. Updating the basin wise water availability,
ii. Development of GIS databases and SWAT hydrological model for Integrated Water Resources Management (IWRM),
iii. Development of Groundwater model in mudflow and study the water quality and quantity parameters
iv. Assessment of climate impact on crop water productivity using FAO AQUA crop model
v. Trend analysis and identification of extreme events, hotspots and vulnerability assessment
vi. Reservoir/canal modelling for water management, water allocation strategy for irrigation/Municipal/industrial uses.
vii. Feasibility of linking of climate, social, and ecology data by employing integrated approaches, such as GIS
viii. Quantifying the uncertainties in climate impact modelling
ix. Development of strategies for cost-effective intervention in water and environmental systems and their consequences for alternative scenarios.
x. Macro scale modelling to study basin hydrology and study the effect due to changes in land use/ land cover.
xi. Identify suitable adaptation policies for water use, cropping patterns, calamity management, reservoir operation policies etc.

All efforts will be made to propose sustainable and vulnerability based climate change impact and adaptation strategies. IPCC (2007) defines adaptation as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. In the context of both social and natural systems, adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities or to cope with the consequences).Adaptation is critical to enable societies to deal with the impacts of both natural and anthropogenic environmental change, especially in low-income countries. The adaptation strategy for a country, a basin or part thereof, refers to a general plan of action for addressing the impacts of climate change, including climate variability and extremes. It will include a mix of policies and measures with the overarching objective of reducing the country's vulnerability. Detailed methodology of the proposed research has been presented in Figure 3 below. Also some of the main processes are explained in subsequent sections.

Hydrological Modelling

SWAT:- In recent years, distributed watershed models are increasingly used to implement alternative management strategies in the areas of water resources allocation, flood control, impact of land use change and climate change, and finally environmental pollution control. SWAT is a well-established physically based distributed models for analyzing the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. SWAT is continuous time, spatially distributed model designed to simulate water, sediment, nutrient and pesticide transport at a catchments scale on a daily time step. It uses hydrologic response units(HRUs) that consist of specific land use, soil and slope characteristics. The HRUs are used to describe spatial heterogeneity in terms of land cover, soil type and slope class within a watershed. The model estimates relevant hydrologic components such as evapotranspiration, surface runoff and peak rate of runoff, groundwater flow and sediment yield for each HRUs unit.Within the SWAT conceptual framework, the representation of the hydrology of a basin is divided into two major parts: (a) the land phase of the hydrological cycle; and (b) the routing of runoff through the river network. The present study concerns the application of a physically based watershed model ArcSWAT to examine the influence of topographic, land use, soil and climatic condition on stream flow. For the land phase water balance, within SWAT evapotranspiration can be calculated using one of three methods: Penman-Monteith, Hargreaves or Priestley-Taylor. For surface runoff calculations, SWAT gives the user two alternatives: (a) the use of the Soil Conservation Service curve number (SCS CN) procedure, and (b) the Green and Ampt infiltration method.The model setup involved five steps: (1) data preparation;(2) sub basin discretization: (3) HRU definition; (4) parameter sensitivity analysis; (5) calibration and uncertainty analysis.

Modflow:- It is a modular three-dimensional finite-difference groundwater model of the U. S. Geological Survey, to the description and prediction of the behaviour of groundwater systems have increased significantly over the last few years. Since the publication of MODFLOW various codes have been developed by numerous investigators. These codes are called packages, models or sometimes simply programs. Modflow will be used to model the groundwater regime in the region and suggesting the adaptation strategy for the basin.

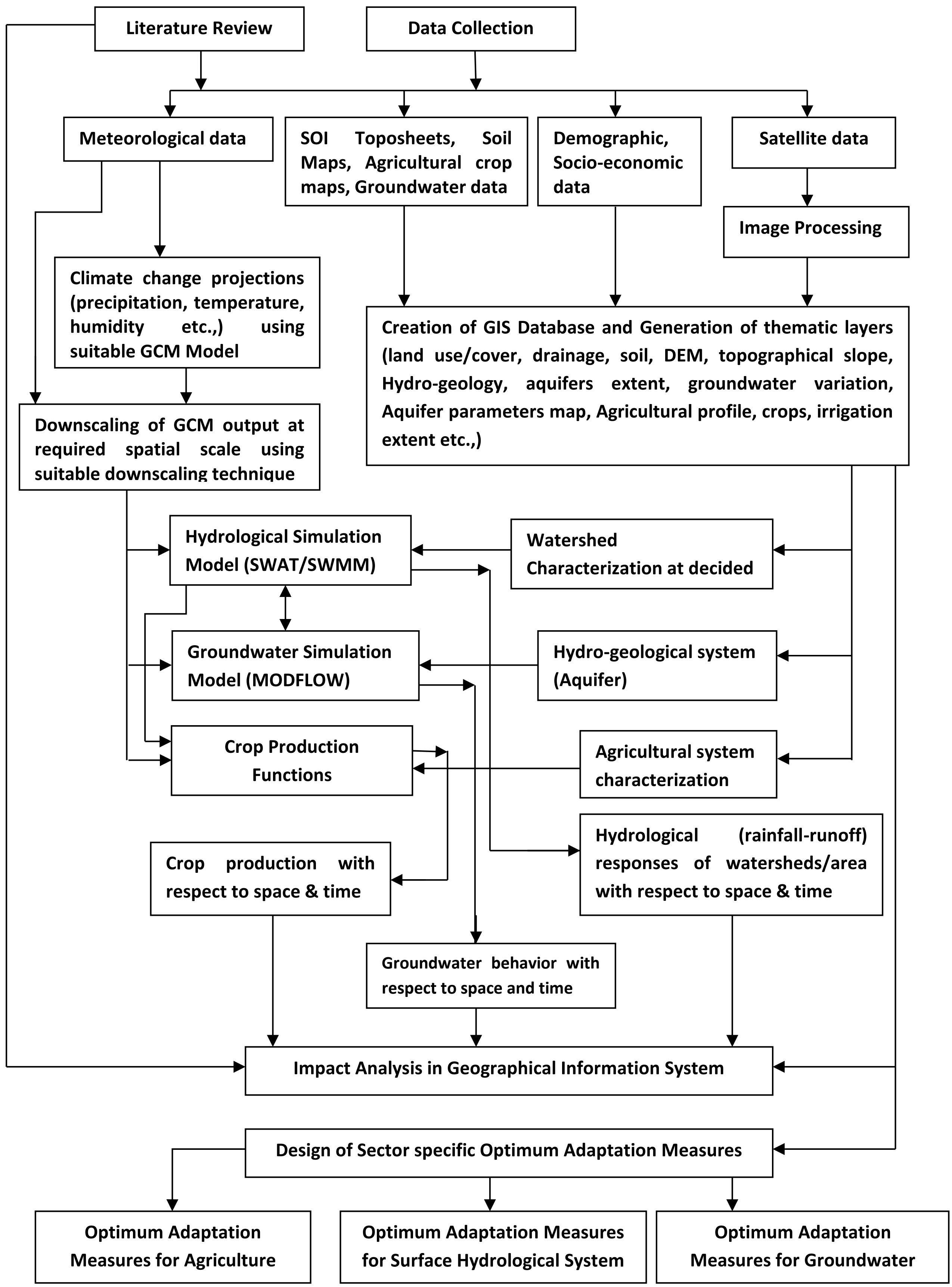

Fig 3: Flow chart of Methodology

Analysis of Trend and Extreme Indices

Extreme weather or climate events have impacts on society, economy and the environment. Analysis of extreme indices is essential as an initial step for climate change impact studies. The climate trend analysis is performed in two parts, i.e., stability of mean and trend in extreme indices.

In the first part, t-test will be applied to check the stability of mean between two subsets of temperature and precipitation time series along with shifts in different normal means. Before developing indices, it is important to check the quality of data and identifies outliers in time series of input data. The outliers are specified as daily values outside a defined range. Kendall's Tau test (non-parametric) will be applied for statistical trend estimation because of its advantage of making no assumption about the statistical distribution (e.g., normality) of the input variables.

In the second part, annual extreme indices related to precipitation and temperature will be calculated on an annual basis for all stations and grid points. Based on the historical datasets and future projection of climatic data, number of extreme indices will be calculated statistically using well defined criterions. This indices will be calculated both on temporal and spatial scale for the river basin. Some of these indicators are Consecutive dry days, consecutive wet days, Cool nights, warm nights, hot days, cool days, very heavy precipitation days, warm spell duration indicators, cold spell duration indicator, etc.

Table 1: List of Extreme Climate Indices

Indicator Code	**Units**	**Indicator name**
CDD	Day	Consecutive dry days
CWD	Day	Consecutive wet days
PRCPTOT	mm	Annual total wet-day precipitation
R10	Day	Number of heavy precipitation days
R20	Day	Number of very heavy precipitation days
R40	Day	Number of days above 40 mm
R95p	mm	Very wet days
R99p	mm	Extremely wet days
RX1day	mm	Max 1-day precipitation amount
RX5day	mm	Max 5-day precipitation amount
SDII	mm/day	Simple daily intensity index
TN10p	Day	Cool nights
TN90p	Day	Warm nights
TNn	°C	Minimum T_{min}
TNx	°C	Maximum T_{min}
TX10p	Day	Cool days

TX90p	Day	Warm days
TXn	°C	Minimum T_{max}
TXx	°C	Maximum T_{max}
WSDI	Day	Warm spell duration indicator
CSDI	Day	Cold spell duration indicator

Dataset Requirement: Historical and projected climatic variables (minimum and maximum temperature, rainfall) both on temporal as well as spatial scale

Crop Modelling

Aqua Crop is a crop water productivity model developed by the Land and Water Division of FAO. It simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production. Aqua Crop attempts to balance accuracy, simplicity, and robustness. It uses a relatively small number of explicit and mostly-intuitive parameters and input variables requiring simple methods for their determination. Initial input data required for the model are Temperature (mean), Rainfall (daily rainfall), Sun radiation (daily) and Regional soil and land properties.

With a daily time step the model simulates successively the following processes:

1. Soil water balance. 2. Crop development. 3. Crop transpiration (Tr). 4. Above ground biomass (B). 5. Partitioning of biomass into yield (Y).

Reservoir and Canal operation

In the western part of Rajasthan there are no major reservoirs but it has the largest canal system in the country. There is an increasing need to model the climate change simulations on operation and water supply response of the canal system. The area has been receiving attention for the presence of palaeo channels containing fresh water. Study by Khilnani (2009) suggest two major palaeo drainage channels exist in the region under study and these provide an opportunity for use of these aquifers as a cyclic storage and supply reservoirs along with the surface sources. An attempt will be made to improve the efficiency of canal system and conjunctive use of ground water wherever possible. The study will focus also calculate the water supply and demand under present and future climate change scenarios. Demand will be estimated for various sectors i.e., agriculture, domestic and industrial. Primary and secondary data both spatial and temporal will be gathered from various state departments. Supply side will be estimated using geospatial database (landuse, soil and even output from hydrological component of the project). Result of this component will be used in identification of vulnerable areas with water scarcity in future climate change scenarios.

Datasets: Climatic variables, RS/GIS datasets (soil, landuse/cover, DEM), soil characteristics, etc.

Deliverables

Successful completion of the project will leads to following deliverables -

- Base line data and information.
- Present status of the study area with reference to hydrology, water availability, water use practices and policies.
- Trend analysis results of hydro-meteorological variables and identification of hydrological extremes.
- Calibrated hydrological model of the study area.
- Quantitative and qualitative impacts of climate change on hydrologic cycle components at selected points for near (2015-2040) and distant future (2040-2100).
- Impacts of climate change on agriculture sector
- Optimum water allocation /use policies for different sectors under different climate change scenarios.
- Impacts of climate change on ground & surface water quality.
- Organisation of a conference/workshop.

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15 Cost Estimates

15.1 Total Cost of the project including overhead charges (if any)

Rs 265.73 lakhs

15.2 Subhead wise Abstract

Subhead	**Amount MNIT**	**Amount CURAJ**	**Amount IITD**
Salary	113.76	22.75	11.23
TE	14.60	3.00	1.50
Infrastructure /Equipments	61.35	1.60	0.00
Experimental Charges	6.00	1.50	1.50
Sub Total	**195.71**	**28.85**	**14.23**
Add Contingency 5 %	9.79	1.44	0.71
Total Rs in lakhs	**205.5**	**30.29**	**14.94**
Institutional over heads 20 % (With limit of R 15.00 lakh maximum)	9.75	3.00	2.25
Grand Total Rs in lakhs	**215.25**	**33.29**	**17.19**

15.3 Justification for Institutional Over Head charges.

The host institute will provide amenities like office space, electricity, internet, administrative assistance in handling the financial support from the funding agency and maintain the records related to this project.

15.4 Amount sought to be released at the start of the work with justification.

The amount of equipment and the salaries of project staff for one year are required to be released in the first installment along with the institute share of 20% or 5 Lakhs for the released amount. This is required as the equipment needs to be purchased in the initial phase of the project to start the work and salaries for at least one year are required so as to appoint project staff with assured salaries of one year. Next installment may be released when utilization of earlier is received by MoWR.

15.5 Subheads wise Details

Salary : Responsibility Matrix

S. No.	Activity	Responsible Expert & Station	Manpower required	Duration (Year)
1	Literature Review & Data Collection	Complete Project Team	RA (01), JRF (04)	1
2	Trend Analysis	Dr. Devesh Sharma CURAJ	RA (1) JRF (1)	2 3
3	Hydrological Modelling : Calibration, validation and generation of hydrologic responses and adaptation measures in allocation/use of water resources	Dr. Mahesh K Jat & Dr. Rohit Goyal MNIT	RA (2) JRF (2)	2 3
4	Development of crop production function and impact analysis, Adaptation of climate change in agriculture sector	Dr. Mahender Choudhary & Dr. Gunwant Sharma	RA (1) JRF (2)	1 2
5	Soil erosion responses under different scenarios	Dr. Mahesh K Jat & Dr. Mahender Choudhary	RA (1)	1
6	Adaptation measures in reservoir/canal operation	Dr. Y.P.Mathur & Dr. Gunwant Sharma	RA (1)	1
7	Water quality assessment	Prof. Sudhir Kumar and Dr. Urmila Brighu MNIT	JRF (1)	2
8	Drainage studies	Prof. B.R.Chahar IITD	JRF (1)	2
9	Water demand management options for different sectors	Dr. Mahesh K .Jat & Dr. Mahender Choudhary	RA (1)	1
10	Mitigation strategies for extreme hydrological events i.e., flood and droughts	Dr. Mahender Choudhary Dr. Mahesh K. Jat & Dr. Devesh Sharma	RA (1)	1

Manpower Requirement and total of amount under salaries head

	MNIT		CURAJ		IITD		Total
Year	No.	Amount	No.	Amount	No.	Amount	
Year 1	RA 3 JRF 5	17.28 18.00	RA 1 JRF 1	5.76 3.6	JRF 1	3.6	31.97
Year 2	RA 3 JRF 5	17.28 18.00	RA 1 JRF 1	5.76 3.6	JRF 1	3.6	31.97
Year 3	RA 4 SRF 5	23.04 20.16	SRF 1	4.03	SRF 1	4.03	33.98
		113.76		**22.75**		**11.23**	**147.74**

Rates as applicable for research staff

Designation	Year 1		Year 2		Year 3	
	Salary Rate/ month	HRA @ 20%	Salary Rate/ month	HRA @ 20%	Salary Rate/ month	HRA @ 20%
JRF/SRF	25000	5000	25000	5000	28000	5600
Research Associate	40000	8000	40000	8000	40000	8000

Grand Total for Salary = Rs. 147.74 lakh

15.6 Man-months utilization table.

As given in responsibility matrix

15.7 Travel Expenditure (TE)

	Budget in Lakhs (in Rupees)			
	1st Year	**2nd Year**	**3rd Year**	**Total in Lakhs**
Travel (In the study area for data collection and verification by Rail/Taxi) @ Rs 10,000/- per trip to field for MNIT Jaipur.	2.5	2.5	1.5	**6.5**
Travel (In the study area for data collection and verification by Rail/Taxi) @ Rs 10,000/- per trip to field for IIT Delhi.	1.1	1.2	0.7	**3.0**
Travel (In the study area for data collection and verification by Rail/Taxi) @ Rs 6,000/- per trip to field for Central Univ. of Rajasthan	0.6	0.6	0.3	**1.5**
Long journey to INC meeting	0.5	0.5	0.5	**1.5**
Attend Conference/workshop/training	1.2	1.2	1.2	**3.6**
Organization of a conference/workshop		3.0		**3.0**
Total	**5.9**	**9**	**4.2**	**19.10**

As commented by the project reviewer it is acknowledged that the project has a good potential for manpower development. In addition to the training of JRF's, provisions for workshop/conference have been made for knowledge sharing and interaction among various stake holders.

15.8 Infrastructure (Purchased items of a permanent nature like equipment, software or data; construction of any buildings etc.)

Sl. No.	Generic name of the Equipment along with make & model	Quantity at MNIT	Estimated Costs in Lacs	Quantity at CURAJ
1	Workstation with printer and peripherals @ Rs 2.24 Lakhs	3	6.72	-
2	Desktops @ Rs 0.8 Lakhs	6	4.80	1.60 for 2
3	GPS @ Rs 2.36 Lakhs	2	4.72	-
4	A0 size scanner & plotter combo	01	11.00	
5	Ground Penetrating Radar	01	26.61	
6	Satellite image (LISS IV and Cartosat) Standard Data for Study area	-	7.00	-
7	Data storage hard disc devices 2 TB @ Rs. 5000.0	10	0.50	
	Total		**61.35**	**1.60**

Proposed equipment includes computational facilities (workstations) as project is computation intensive. Lot of hydrological simulations will be carried out for two basins using workstations. Nine project staff will be working in addition to the faculty of MNIT and therefore total 9 computers (3 workstations and 6 desktop systems) are required. An A0 size scanner and plotter is proposed because of scanning of many big maps like SOI toposheets and other maps which will be required for GIS database creation. Further, a Ground Penetrating Radar (GPR) is proposed to be procured in project for collection of hydro-geological data/information of the study area. Such hydro-geological data (lithologs) are not available for western Rajasthan. Such data is very much essential for groundwater studies and studies related to surface and groundwater interactions. The same equipment will also be used for Mahi basin and Luni basin. MNIT is part of Luni basin investigating team lead by IIT Rajasthan. Two GPS are proposed, which will be required for positional data collection related to various gauging sites and geo-rectification of SOI toposheets and other maps. GPS will also be used for collection of various point data required in GIS database creation.

In addition to the above equipment, the Department of Civil engineering, MNIT Jaipur has ArcGIS licences, ERADAS, ModFlow, computational software like Matlab etc. and hence are not required to be purchased from the project.

15.9 Experimental Charges

Item				**(in Rupees)**
	1st Year	**2nd Year**	**3rd Year**	**Total in Lakhs**
Consumables (MNIT)	2	2	2	6
Consumables (CURAJ)	0.5	0.5	0.5	1.5
Consumables (IITD)	0.5	0.5	0.5	1.5
Total	**3**	**3**	**3**	**9**

16 Work Schedule

a. Probable Date of Commencement : Immediately after the sanction and release of funds

b. Duration of Study : three years

c. Stages of Work and Milestones

Identifiable Milestones of progress	**Months from start**	**Amount to be released Rs in Lakh**
Start	0	Equipment and first year budget = Rs 120.76 Lakhs
Data collection, literature review and calibrated and validated hydrological model	12	As per second year budget except equipment = Rs 46.17 Lakhs
Trend analysis, crop production function, ground & surface water quality data collection, generation of future hydrological responses	24	As per third year budget = Rs 36.48 Lakhs
Climate change impact analysis, adaptation measures on water resources, agriculture and soil erosion, water allocation, demand management and mitigation measures of climate extremes (flood & drought). Report preparation and submission	36	

Following table shows task-wise tentative three-year project.

Task	0-6 months	6-12 months	12-24 months	24-36 months
Knowledge review and issue identifications[1]	X	X		
Setting up of laboratory and field-data collection	X	X	X	
Induction of staffs/research scholars	X			
Experimental and mathematical modelling works on identified issues		X	X	X
Annual progress report submission		X	X	X
Final report submission				X
Knowledge exchange (Workshop/ conference)*			X	

Notes:

a. The work should be divided into milestones 3 to 6 months apart.

b. The milestones are mainly for the purpose of monitoring of progress and release of funds. The funds to be released on achieving various milestones should be indicated.

c. Normally there may be only one release of funds in a financial year.

17 Declaration

1. I have carefully read the terms and conditions of the research grant and agree to abide by them.
2. This is to certify that I have neither submitted this proposal elsewhere for financial support nor have undertaken it at the request of any commercial agency or as a consultancy.

Date 28/06/2012
Place Jaipur

Signature of PI Mahender Choudhary
Name Mahender Choudhary
Designation Associate Professor

18 Endorsement from the Head of the institution

1. The Institute welcome the participation of Dr. Mahender Choudhary as Principal Investigator for above project.
2. The necessary equipment and institutional support as described in item 13.3 will be made available as and when required for the purpose of the project to ensure that the work is taken up on priority and completed on schedule.
3. In the event of foreclosure /discontinuation /cancellation of the scheme for any reason, the entire amount released for the scheme will be fully refunded to the MoWR along with the interest prescribed till the date of return by the institute/ organisation.
4. The Register of permanent and semi-permanent assets acquired out of grants from MoWR will be maintained in Form GFR-19.
5. The assets acquired out of this grant shall be transferred to the desired destination in good & working condition as and when required.

Date: 24/1/14
Place: Jaipur

Seal and signature of the
Head of the organisation

Research & Consultancy
Malaviya National Institute of Technology Jaipur
JAIPUR-302017

** The term "assets" mean (i) immovable property (ii) movable property of a capital nature where the value exceeds Rs. 1,000/ (one thousand).*

Dr. Mahender Choudhary

Dr. Mahender Choudhary, AssociateProfessor, Dept. of Civil Eng., MNIT Jaipur is working in the field of Water resources management and Climate Change Impact on Water Resources. He has research interest and worked in the field of Arid Hydrology, hydrological modeling, water management; artificial ground water recharging and climate change impact studies. Dr. Choudhary has received training at UNESCO-IHE, Delft, The Netherlands on 'Climate change in Integrated Water resources management' and at Hadley Centre, Met Office, UK on 'Regional Climate Modelling using PRECIS'. He has guided one Ph.D. on Urban Water Management and four are under progress out of which one student is working on the impact of Climate Change on Urban Water management. Some of his peer reviewed publications are given below:

- Choudhary, M., Sharma, R., and Kumar, Sudhir, (2012), 'Development of Residential Water Demand Model for Densely Populated Area of Jaipur City', *J. of Water, Sanitation and Hygiene for Development*, doi:10.2166/washdev.2012.029
- Choudhary, M., (2012) "Discussion of "FINITE DEPTH SEEPAGE BELOW FLAT APRONS WITH EQUAL END CUTOFFS" by Arun K. Jain and Lakshmi N. Reddi, Journal of Hydraulic Engineering, Vol. 137, No. 12", *Journal of Hydraulic Engineering*, doi: 10.1061/(ASCE)HY.1943-7900.0000602.
- Gupta, P., Singh, S., Kumar, S., Choudhary, M. and Singh, V., (2012) "Effect of Dust Aerosol in Patients with Asthma", *Journal of Asthma*, doi: 10.3109/02770903.2011.645180.
- Gupta, P., Kumar, S., Choudhary, M. and Singh, V., (2011) "Effect of Desert Storm on Asthma Patients" *Jigyasa*, Vol. 25, 107-110.
- Choudhary, M., and Chahar, B.R., (2006) "Recharge/ Seepage from an Array of Rectangular Channels", *Journal of Hydrology* Vol. 343, 71-79.
- Choudhary, M., and Chahar, B.R., (2006) "Recharge/Seepage from a Trapezoidal Channel.", *Earth & Life*, Vol. 1, No. 4, 18-34
- Choudhary, M., Chahar, B.R., and Satya, S., (2005) "Groundwater Recharging in Arid and Semiarid regions." *Jigyasa*, Vol. 19, 35-39.

Prof. Y.P. Mathur

Prof. Y.P.Mathur is a Professor in the Department of Civil Engineering, MNIT Jaipur since 1999 with more than 30 years of experience. His research interests are Water Resources Management, Reservoir Operations, Environmental Aspects, Stochastic modeling and optimization engineering. He has worked at various administrative and academic positions inside and outside the Institute which include the position of Principal GEC, Kota, Rajasthan. He has guided more than 65 M.Tech. Thesis and handled many prestigious research and consultancy projects.

Papers published

Mathur Y P and Dandekar M M, " Environmental education at cross roads " , J.of Indian association of environmental management, Vol. 16, 1989, pp. 184-189.

Mathur Y P and Kumar P , " Concerns and trends in environmental levels of Nitrates", Indian J. of environmental Health." Vol.32, no.2, 1990,pp 97-108.

Mathur Y.P., Sharma, G., Arora, A., Kashyap, R.P., and Swami, B.L. " Remote Sensing Applications for Monitoring Forest Environment", 2nd All India Environment Congress organized by Indian Institute of Ecology & Environment, 21-22 December 1991, New Delhi.

Mathur Y.P., Sharma, G., and Vasu Deo. "Potentials of Water Harvesting in Arid Regions", National Seminar on Water Harvesting, June 25-26, 1993 at R.E.C., Tiruchirapalli.

Mathur Y P , Gupta R C, " Sustainable development of urban areas with respect to water supply from groundwater ", International Conference on civil Engineering for sustainable development, Feb 13-15th, 1997, Department of civil Engineering, University of Roorkee, Roorkee.

Mathur, Y.P., Sharma, G., & Mathur, S. "A New Method of Alum Dosing for Hand pump Attached Defluoridation Plants", National Workshop on Control and Mitigation of Excess Fluoride in Drinking Water", Organized by UNICEF & PHED, Govt. of Rajasthan, Jaipur, pp. T-2 (64-66) held between Feb. 5-7, 2004.

Y. P. Mathur, Gunwant Sharma, A. W. Pawde "Optimal Operation Scheduling of Irrigation Canals Using Genetic Algorithm" International Journal of Recent Trends in Engineering, Vol. 1, No. 6, May 2009 , pp. 11-15.

Y. P. Mathur , S. J. Nikam **"**review of optimal reservoir operation policies with special referance to upper wardha project**"** In Proc. ofInternational conference on water resources development and management, Oct.23-24,2008, Birla Institute of Technology and Science (BITS), Pilani.

Y. P. Mathur, Shashi Choudhary (2009) ,"Sustainability of Metropolitan cities with respect to water supply". National seminar, Kota,Rajasthan.

Y. P. Mathur , S. J. Nikam (2009), “Electricity Production Opportunities from Multipurpose Reservoir - A Case Study of Upper Wardha Reservoir.”, International Journal of Civil and Structures, *Vol: 2, No: 2, 042 - 047*

Y. P. Mathur , S. J. Nikam (2009), “Optimal Reservoir Operation Policies Using Genetic Algorithm.”, International Journal of Engineering and Technology, Vol. 1, No. 2, June, 2009 , 1793-8236

Y. P. Mathur , S. J. Nikam (2009), “Probability of Meeting Irrigation Demand and Carry over Storages Study of Wardha Reservoir System.”, International Journal of Recent Trends in Engineering, Vol. 1, May 2009

Mathur, Y. P., Rajesh Kumar, and Pawde, A. W. (2009).“Irrigation canal scheduling using particle swarm optimization” *IETECH journal of Civil and Structures,* 2(2) 36-41.

Mathur, Y. P., Rajesh Kumar, and Pawde, A. W. (2010).“A binary particle swarm optimization for generating optimal schedule of lateral canals.”*IES Journal Part A: Civil and Structural Engineering,* Taylor and Francis, 3(2), 2, 1-8.

Jain, J.K., Mathur, Y.P. and Sharma, G., “User’s Assessment of Existing Bus Transportation System –A Case Study of Jaipur”, International Conference on Developments in Road Transportation (DRT-2010) October 8-10,2010, pp.304-311, Department of Civil Engineering, National Institute of Technology, Rourkela, Odisha, India

Jain, J.K., Mathur, Y.P. and Sharma, G., "Urban Travel Characteristics: A Case Study of Jaipur".National Workshop on "Road Infrastructure and Traffic Planning in Jaipur City" 29 January, 2011 Jaipur

Ph.D Guidance

1) Jain J K , “ Study of urban travel characteristics for optimal design of rod transportation system with special reference to desire lines for Jaipur”. (submitted)

2) Shashi Choudhary ” Study of long distance water transmission with special reference to Bisalpur - Jaipur water supply projecty”. (under progress).

3) S. J. Nikam, “Optimal Operation of Reservoir System with special Reference to Upper Wardha System”. (submitted).

4) A.W.Pawde” Optimal Water Scheduling of Irrigation Canal System: With Special Reference to Upper Wardha System”. (submitted).

Dr. Mahesh Kumar Jat

Dr. Mahesh Kumar has more than 13 years of teaching and research experience in the field of remote sensing and GIS technologies. He has to his credit 28 research articles out of which 19 are in Referred journals. He has guided 8 M. Tech and 1 Ph.D. thesis and 07 Ph.D thesis's are under progress. His research interests are application of GIS technologies in the field of water resources conservation and management in Urban and Natural watersheds. Presently is working on a relevant research project on "Climate Change Impact of Urban Hydrology" funded by AICTE under Nationally Coordinated Project. Some of his relevant journal articles are listed below:

1. Rohitashw Kumar, **Mahesh Kumar** and Vijay Shankar (2011),Methods to estimate irrigated reference crop evapotranspiration- A review, International Journal of Water Science & Technology, IWA Publication, Reference No: WST-WSTWS-EM111094R2 (Accepted)
2. Rohitashw Kumar, Vijay Shankar and **Mahesh Kumar** (2011),Evaluation of Evapotranspiration Models for Pea (Pisum Sativum) in Mid Hill Zone-India, Universal Journal of Environmental Research and Technology,Volume 1, Issue 3: 329-337.
3. Santosh Pingale, Deepak Khare, H. C. Sharma &**Mahesh K Jat** (2009) “Design of Water Harvesting Structure based on Supply and Demand of Water in a Hilly Watershed”. Journal of Environmental Research and Development, Vol. 3, No. 3, 645-653.
4. **Jat, Mahesh K**umar, Khare, D., and Garg, P. K., (2009), Degradation of watershed health due to 38Urbanisation: a remote sensing and GIS based assessment, Urban Water Journal, Volume 6, Issue 3, 251-263.
5. **Jat, Mahesh K.**, Khare, D., and Garg, P. K., (2009), Urbanisation and its impact on groundwater: A remote sensing and GIS based assessment approach, The Environmentalist, Volume 29, Issue 1, 17-32.
6. **Jat, Mahesh K.**, Garg, P. K., and Khare, D., (2008), Monitoring and Modelling of Urban sprawl Using Remote Sensing and GIS Techniques, International Journal of Applied Earth Observation and Geoinformation, 10, 26-43. Elsevier Sciences Ltd.
7. **Jat, Mahesh Kumar**, Garg, P. K., and Khare, D., (2007), Modelling of urban growth using spatial analysis techniques: A case study of Ajmer city (India), International Journal of Remote Sensing, Taylor and Francis Ltd, 29: 2, 543-567 (2007).
8. **Jat, Mahesh K.,** Khare, D., and Garg, P. K., (2007), Classification of Spectrally Mixing Land Use Classes: A Case Study of an Urban Fringe, International Journal of Applied Remote Sensing, Spectrum Sciences Inc., Vol. 1, No. 1, 29-43.

9. Khare, D., **Jat, Mahesh Kumar** , and Devasunder, J. K., (2007), Assessment of water resources allocation options: conjunctive use planning in a link canal command, Resource Conservation and Recycling, Elsevier Sciences Ltd., 51 (2007), 487-506.
10. Khare, D., **Jat, Mahesh Kumar**, and Ediwahyunan, (2006), Assessment of conjunctive use planning options: a case study of Sapon irrigation command area of Indonesia, Journal of Hydrology, Elsevier Sciences Ltd, 328, 764-777.
11. Pareek, N., **Jat, M. K.**, and Jain, S. K., (2006), Utilization of Brackish water, protect the quality of upper fresh water layer in Coastal areas, The Environmentalist, Springer Verlag, Environmentalist (2006) 26:237–246.
12. **Jat,** Mahesh K., Khare, D., and Garg, P. K., (2009), Cost Models/Functions for Waste Water Treatment, Journal of Indian Water Works Association (IWWA). (Accepted)
13. Jat, Mahesh K., Khare, D., and Garg, P. K., (2008), Cost Models/Functions for Water Treatment, Journal of Indian Water Works Association (IWWA), January-March, 2008.
14. Khare, D., Garg, P. K., Jat, Mahesh Kumar and Dhore K., (2007), Selection of Optimum Canal Alignment Using GIS: River Interlinking Perspective, Indian Journal Power and River Valley Development, March-April, 112-121.
15. Jat, Mahesh K., Khare, D., and Garg, P. K., (2006), Assessment of groundwater recharge using water level fluctuation methodology in GIS environment, Indian Journal of Power and Valley Development, Vol. 56, No. 5&6, 165-172.
16. Jat, M. K., Khare, D., and Garg, P. K., (2005), Integrated water management in urban areas: Ecological and economic advantages, Journal of Indian Building Congress, Vol. 12, No 1, 186-193, July 2005.
17. Durbude, D. G., Jat, Mahesh Kumar, Shravankumar, G., and Singh, R. K., (2005), Application of remote sensing and GIS for the planning of water harvesting structures, Indian Journal of Power and Valley Development, Vol. 55, No. 6, 165-174, June 2005.

Details of Sponsored Research Project

S. No.	Title of Project	Completed/ In progress	Duration	Amount/ Grant (Rs.)	Sponsoring Agency	Co-Investigator
1	GIS based Distributed Groundwater Modelling	Submitted	2 Year	15 Lac	DST	Mahender Choudhary
2	Assessment of Climate Change & Its Impact on Urban Hydrology: Indian Perspective	In Progress	3 Year	40.00 lakh	AICTE NCP	Dr. Deepak Khare, IIT Roorkee
3	Water management plan for Jawaharlal Navodaya Vidyalaya Paota	Completed	2 Year	6.90 Lac	DST	Mahender Choudhary

Dr. Rohit Goyal

Dr. Rohit Goyal is a Professor in the Department of Civil Engineering, MNIT Jaipur since 2006 with more than 25 years of experience. His research interests involve application of RS&GIS for water resources modeling, groundwater modeling, drainage, seepage etc. he has guided three Ph.D. thesis and handled many research and consultancy projects.

Some of his selected refereed papers are as below:

1. A.N. Arora, Rohit Goyal (2012), "Predictive Modeling of Groundwater Flow of Indira Gandhi Nahar Pariyojna, Stage-I", ISH Journal of Hydraulic Engineering, Taylor & Francis online, Accepted for publication. Production tracking number: TISH 695447.
2. Vijai Singhal and Rohit Goyal (2012), "A methodology based on spatial distribution of parameters for understanding affect of rainfall and vegetation density on groundwater recharge", European Journal of Sustainable Development, Vol. 1, Iss. 2, May 2012.
3. A.N. Arora, Rohit Goyal (2012), "Groundwater model of waterlogged area of Indira Gandhi Nahar Pariyojna, Stage I", ISH Journal of Hydraulic Engineering, Taylor & Francis online, Vol. 18, Iss. 1. Pp. 45-53.
4. Vijai Singhal and Rohit Goyal (2011), "Development of conceptual groundwater flow model for Pali Area, India", African Journal of Environmental Science and Technology Vol. 5(12), pp. 1085 -1092, December.
5. Vijai Singhal, Rohit Goyal (2011), "GIS Based Methodology for Groundwater Flow Estimation across the Boundary of the Study Area in Groundwater Flow Modeling", International Journal of Water Resource and Protection, Volume 03, Number 11. November.
6. Bhaduri, M., Goyal, Rohit, Gupta, A.B. (2009), "Ground Water Quality in Sanganer Area of Rajasthan", *J. Hydraulic Eng.*, ISH, 15(3), Nov., 65-74.
7. Kushwaha, R.K., Pandit, M.K. and Goyal, Rohit (2009), "MODFLOW Based Groundwater Resource Evaluation and Prediction in Mendha Sub-Basin, NE Rajasthan", *J. Geological Society of India*, Vol.74, October, pp.449-458.
8. Goyal, Rohit and Arora, A.N. (2005), "Ground Water Modeling of Waterlogged Area in Hanumangarh & Sriganganagar Districts of Rajasthan", Bhu-Jal, Rajasthan Special Issue, *J. Central Ground Water Board*, Ministry of Water Resources, Govt. of India, 20(3&4), Jul-Dec., 52-60.
9. Arora, A.N., Dhaneria, K.S., Goyal, Rohit and Kashyap, R.P. (2005), "Socioeconomic Impacts of Waterlogging – A Case Study of Indira Gandhi Nahar Pariyojna, Stage 1" *J. IWRS*, 25(1), Jan., 67-82.
10. Dhamaniya A. and Goyal Rohit. (2004). "Use of GIS in Transportation Planning of Jaipur City." *J. GIS@Development*, 8(11), Nov., 38-43.
11. Goyal, Rohit. (2003). "Design and analysis of interceptor drains: analytical solution." *J. Hydraulic Eng.*, ISH, 9(1), Mar., 1-13.
12. Goyal, Rohit. (2003). "Design and analysis of interceptor drains: effect of parameters." *J. Hydraulic Eng.*, ISH, 9(1), Mar., 61-71.
13. Arora, A.N. and Goyal Rohit. (2002). "Environmental and socio-economical impacts of waterlogging in Hanumangarh and Sri Gangannagar districts." *J. Nature, Environment and Pollution Technology*, 1(3), Sept., 307-316.
14. Goyal, Rohit, and Chawla, A.S. (1997). "Seepage from canals with infiltration from the free surface zone." *J. Irrig. Drain. Eng.*, ASCE, 123(4), 257-263.

15. Goyal, Rohit, Chakraborti, A.K. and Sharma, G. (1995). "Comparative Study of Physical Characteristics of Asan River Watershed derived from Multi-Satellites Images." *J. Indian Soc. of Hydrologists,* Vol. XVIII, No. 1&2, Jan., 49-61.
16. Goyal, Rohit, Porey, P.D. and Garde, R.J. (1994). "Some Studies on Subcritical Expanding Transitions in Open Channel." *J. Central Board of Irrigation and Power*, 51(4), Oct., 75-82.
17. Goyal, Rohit and Chawla, A.S. (1994). "Estimation of Seepage from Canals Founded on Finite Pervious Media with Asymmetrically Placed Drains." *59th Research and Development Session*, Proc. Central Board of Irrigation and Power, Vol. II Civil, Feb., 99-107.

Some of his completed projects

1. Department of Science & Technology, Govt. of Rajasthan funded student research project titled "Quantization and Management of Urban Storm Drainage", 2006
2. Department of Science & Technology, Govt. of Rajasthan funded student research project titled "Development of GIS Based Decision Support System for Environmental Planning of Jaipur City", 2004.
3. Principal Investigator for MHRD funded research project titled "Waterlogging Studies of River Ghagger and IGNP Command Area, Hanumangarh and Sri Ganganagar Districts", 2000-2003.
4. MHRD funded Modernization & Removal of Obsolescence project on "Development and Modernization of Remote Sensing & Survey Lab. for Department", 2000-2003.
5. Principal Investigator for AICTE Career Award project titled "Estimation of Seepage from Canals for Waterlogging Applications", 1995-98.
6. Member for "Monitoring and Evaluation for Renovation/ Upgradation of Facilities under World Bank Assisted, Rajasthan Health System Development Project." Consultancy Project by RHSDP, Govt. of Rajasthan, Jaipur, April 2007-July 2008. (Rs. 10.0 lacs).
7. Coordinator for "Checking of Design of Storm Water Drain Amanishah Ka Nallah." Consultancy Project by JDA, Jaipur, Jan. - June 2007. (Rs. 28,000/-).
8. Team Member for "Quality Assurance of Construction of Road and CD Work at IID Centre Bayana." Consultancy Project of RIICO Industrial. March, 2006 onwards (Rs. 20,000/- Approx.)
9. Sector Specialist/Advisor for Yamuna Action Plan under the Post Evaluation Data Collection Survey (PEDCS) 2004 on JBIC-OPMAC financed projects in India, Sept.-Dec. 2004. (Rs. 9.6 Lacs).
10. Team Member for "Limited External Environmental Audit for MP-DPIP." Consultancy project by DPIP, MP, 2004 (Rs. 3.0 Lacs).
11. Coordinator for "State Level Guidelines for Planning, Design, Construction and Maintenance of Anicuts & Check Dams", UNICEF Rajasthan Field Office, Jaipur Nov. 2002 (Rs. 30,000.00).
12. Team member for "Environmental Assessment & Monitoring of DPIP Project", consultancy project by Government of Rajasthan, Jaipur, 2000-2007 (Rs. 40.0 Lacs).
13. Team member for consultancy project as "Environmental Specialist" for MIS Development of Pollution Control Board, Rajasthan, Jan.-March 2002 (Rs. 50,000.00).
14. "Yamuna Water Irrigation Project – Gurgaon Canal, Project Survey and Preparation of Project Report", NGO, Institute of Sustainable Development, Tonk, June-July 1998.

Prof. Sudhir Kumar

Dr.Sudhir Kumar Professor since 2007 in civil Engineering with specialization in Environment Engineering has guided 2 PhDs on Water Management and 2 are under progress. He has organized short course on Water Management and Sustainable Development. His PhD was also from Water Quality aspects and its health impacts. He also guided dissertation and Seminars on Water Management and Climate Change. He has attended/visited UK, France for academic assignments of Water Management. His contributions are for research and consultancy on Water Shed Management. His contributions are for delivering in Expert Lecture/Chairperson/Keynote speaker in several national conferences on climate change. His teaching subject on Sustainable Development with specific topic of Climate Change and he has developed water management course in M.Tech Environment Engineering. Some of his recent publications are as follows:

- Choudhary, M., Sharma, R., and **Kumar, Sudhir**, (2012), “Development of Residential Water Demand Model for Densely Populated Area of Jaipur City”, *Journal of Water, Sanitation and Hygiene for Development,* IWA Publishing, Vol. 2, No.1, 10-19
- Parul Gupta, Sheetu Singh, **Sudhir Kumar**, Mahender Choudhary, and Virendra Singh, (2012) “Effect of Dust Aerosol in Patients with Asthma” *Journal of Asthma,* Vol. 49, No. 2 : Pages 134-138 (doi: 10.3109/02770903.2011.645180)
- Parul Gupta, **Sudhir Kumar**, and Mahender Choudhary (2011) “Desert Dust Storm impact on Asthma Patients” *Jigyasa,* Vol. 25, 107-110.
- Choudhary, M., **Kumar S.,** (2004) “Effect of Viscosity over settling property of Activated Sludge ” Proceedings of International Conference on *Solid Waste Management,* Philadelphia, USA
- **Kumar S**., Choudhary M., (2004) “Enhancement of biogas production by food waste with Iron ” Proceedings of International Conference on *Solid Waste Management,* Philadelphia, USA
- Sharma, R., Choudhary, M., Jat, M. K., and **Kumar, Sudhir**, (2003), Assessment of groundwater pollution through GIS, Proceedings of International Symposium on *Water Resources Planning and Management* (ISWRPM-2003), 11-12 October, BITS, Pilani (India), 196-201.
- **Kumar,S**. and Choudhary,M (2001) “Needs and Challenges for Institutional Development”, Proceedings of 31st ISTE annual Convention and National Seminar on *Integrated Human Values in Technical Education*,Dec.,27-29,Bhubaneswar,Orissa,India

Dr. Gunwant Sharma

Prof. Gunwant Sharma obtained B.E. in Civil Engineering (Hons) from M.B.M Engineering College, Jodhpur in 1985. M.Tech. (Water Resources Engineering) from IIT, Mumbai in 1987. Obtained P.G. Diploma in Remote Sensing Applications to Water Resources in 1990 from Indian Institute of Remote Sensing (IIRS), Dehradun and completed Ph.D. from University of Rajasthan in the Year 2000.Presently working as Professor in Civil Engineering Department, MNIT, Jaipur since Oct. 2006 he has a total UG & PG teaching experience of 23 years.Main fields of interest: Water Resources Engineering, Remote Sensing & GIS. He has organized many short courses for prestigious organisations like AICTE – ISTE, NABARD, UNICEF –RIDF etc.

Books/ Monographs Published:

1. Social Aspects in Engineering (Co-authors Dr. Gunwant Sharma and Dr. Sanjay Mathur)

2. "Guidelines for Planning. Design, Construction and Maintenance of Anicuts & Check Dams." , Nov. 2003. (with 7 other faculty members of civil engineering department.) Prepared for UNICEF

3. "Manual for Planning. Design, Construction and Maintenance of Anicuts & Check Dams." , Nov. 2003. (with 3 other faculty members of civil engineering department.) Prepared for UNICEF

4. "Desk review of water resources management practices in Rajasthan" prepared for UNICEF

Papers published

Has more than 30 papers published in National journals/ Books/ International and National conferences, seminars and symposia.

Ph.D. & M.Tech Guidance:

Guided (02) Ph.D These, and (04) more are under progress in the field of Water Resources, Environmental Engg and Transportation Engineering and guided about 45 M.Tech Dissertations

Consultancy Projects: Involved in more than 50 consultancy projects.

Dr. Urmila Brighu

Dr. Urmila Brighu obtained B.E. in Civil Engineering (Hons) from M.B.M Engineering College, Jodhpur in 1991. M.Tech. (Environmental Engineering) from IIT, Kanpur in 1997. and completed Ph.D. under the prestigious Commonwealth Scholarship at Cranfield University, UK in 2009 on Urban water utility management.

She is self motivated academically brilliant environmental engineer with excellent communication skills, am result oriented and organised to achieve tight deadlines. She is teaching variety of courses in civil engineering for the Undergraduate course including Water Supply and Sanitation/Public Health Engineering, Solid waste Management. For the Postgraduate course she is taking Physico-Chemical Processes for water and Wastewater Treatment and Chemistry for Environmental Engineering, Air pollution control, Air and water quality modelling, WATSAN Management, Water quality testing laboratory courses

PROJECTS

- Have been a research partner for a case study in India for a DFID funded project on ‘Regulating public private partnership for the poor’. Research was co-ordinated by Dr Richard Franceys, IWE, Cranfield University, UK
- Have been actively associated with all the capacity building projects undertaken by the department of Civil Engineering, MNIT, Jaipur for NGOs, communities and water sector professionals funded by ADB for RUIDP (Rajasthan Urban Infrastructure Development Project) and the World Bank for DPIP, Rajasthan
- Consultancy project for restoration of lakes under National Lake Conservation Programme (NLCP) of Government of India
- Consultancy project for comparison of technologies for defluoridation of groundwater
- Supervision for undergraduate projects in water and sanitation and postgraduate projects in the subject areas of water and wastewater treatment and management, solid waste management and air pollution

Dr. B. R. Chahar

Dr. B. R. Chahar is Associate Professor in Civil Engineering at IIT Delhi with 20 years of teaching and research experience in the field of Water resources Eng. His research interests are mainly in the Canal Design, Groundwater Modelling and Recharge, Seepage and Drainage, Stream - Aquifer interaction, Numerical Techniques and Optimization. He has undertaken several research and consultancy assignments. He has guided 3 Ph.D.'s and 4 are under progress. Some of his Journal publications are as follows:

1. **Chahar, B.R.** (2012). "Discussion of 'Simplified Accurate Solution for Design of Erodible Trapezoidal Channels' by by Ali R. Vatankhah and Said M. Easa" *J. Hydrologic Engineering*, ASCE, Vol 138, In print,
2. Swamee, P. K., and **Chahar, B.R.** (2012). "Optimal Alignment of a Canal Route." *Proc. ICE,Water Management*, Vol 165, In Print.
3. **Chahar, B.R.**, and Vadodaria, G. P. (2012). "Steady Subsurface Drainage of Ponded Surface by an Array of Parallel Ditches." *J. Hydrologic Engineering*, ASCE, Vol 138, in print, ahead of print available, doi:http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.0000518.
4. **Chahar, B.R.**, Graillot, D., and Gaur, S.(2012). "Storm Water Management through Infiltration Trenches." *J. Irrig. And Drain. Engrg.*, ASCE, Vol 138(3), 274-281.
5. Gaur S., **Chahar B.R**., and Graillot D. (2011) "Analytic elements method and particle swarm optimization based simulation–optimization model for groundwater management." *Journal of Hydrology* Vol 402(3-4), 217-227.
6. Gaur S., **Chahar B.R**., and Graillot D. (2011) "Combined use of groundwater modeling and potential zone analysis for management of groundwater." *International Journal of Applied Earth Observation and Geoinformation*, Vol 13(1), 127-139.
7. **Chahar, B.R.** and Basu S. (2010). "Closure to Discussion on 'Optimal Design of Curved Bed Trapezoidal Canal Sections' by Adrian Laycock." *Water Management*, Proc. ICE, Thomas Telford, Vol 163 (WM8), 431-432.
8. **Chahar, B.R.** (2010). "Discussion of 'Least-Cost And Most Efficient Channel Cross Sections' by Gerald E. Blackler and James C. Y. Guo." *J. Irrig. And Drain. Engrg.*, ASCE, Vol 136(8), 579-580.
9. **Chahar, B.R.**, and Vadodaria, G. P. (2010). "Optimal Spacing in an Array of Ditches for Subsurface Drainage." *J. Irrig. And Drain. Engrg.*, ASCE, Vol 136(1), 63-67.
10. **Chahar, B.R.** (2009). "Seepage from a Special Class of a Curved Channel with Drainage Layer at Shallow Depth." *Water Resource Research*, Vol. 45, W09423, doi:10.1029/2009WR007899.
11. **Chahar, B.R.**, and Basu S. (2009). "Optimal Design of Curved Bed Trapezoidal Canal Sections." *J. Water Management*, Proc. ICE, Thomas Telford, Vol 162 (WM3), 233-240.
12. **Chahar, B.R.**, and Vadodaria, G. P. (2008). "Steady Subsurface Drainage of Homogeneous Soil by Ditches." *J. Water Management*, Proc. ICE, Thomas Telford, Vol 161 (WM6), 303-311.
13. **Chahar, B.R.**, and Vadodaria, G. P. (2008). "Drainage of Ponded Surface by an Array of Ditches." *J. Irrig. And Drain. Engrg.*, ASCE, Vol. 134(6), 815-823.

14. Choudhary, M., and **Chahar, B.R.** (2007). "Recharge/Seepage from An Array of Rectangular Channels." *Journal of Hydrology*, Vol 343(1-2), 71-79, doi: 10.1016/j.jhydrol.2007.06.009
15. **Chahar, B.R.** (2007). "Optimal Design of a special Class of Curvilinear Bottomed Channel Section." *J. Hydraulic Engrg.*, ASCE, Vol. 133(5), 571-576.
16. **Chahar, B.R.** (2007). "Analysis of Seepage from Polygon Channels." *J. Hydraulic Engrg.*, ASCE, Vol. 133(4), 451-460.
17. **Chahar, B.R.** (2006). "Discussion on 'Seepage through a Levee' by G. C. Mishra and A. K. Singh." *International J. of Geomechanics*, ASCE, Vol. 6(3), 209-211.
18. **Chahar, B.R.** (2006). "Closure to Discussion on 'Determination of Length of a Horizontal Drain in Homogeneous Earth Dams' by Rajesh Srivatsava." *J. Irrig. And Drain. Engrg.*, ASCE, Vol. 132(1), 88-90.
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Dr. Devesh Sharma

Dr. Devesh Sharma is working as Assistant Professor in Department of Environmental Science at Central University of Rajasthan (CURAJ), Kishangarh, Ajmer. He obtained his Doctor of Engineering Degree in Integrated Water Resources Management from the Asian Institute of Technology, Bangkok in 2007. Before joining CURAJ, he was faculty at TERI University, New Delhi and adjunct professional at TERI for more than two and half years. He has also worked as consultant (Water Resources) at International Water Management Institute, New Delhi, in CPWF-Basin Focal Project for Indus-Gangetic Basin. His research interests include integrated water resources management, climate change and water resources, water resources systems. He has also been involved in various sponsored and consultancy projects related to various issues in water and agriculture sectors such as soil and water conservation, integrated water resources management, groundwater management, water productivity and livelihood enhancement, climate change and water resources. He has published his research work in various international and national Journals.

Some of his relevant publications are listed below:

1. Wafa Singh and **Devesh Sharma** (2011). Situation Analysis of Water Supply System of Amritsar city, India. VATTEN 67:175–184, ISSN 0042-2886.
2. Mohammad Waheed and **Devesh Sharma** (2011). Assessing the impact of Climate Change on water balance of the Amu Darya River, Afghanistan. International Conference on Green Chemistry organized by Central University of Rajasthan, 7-9 December, Jaipur, Rajasthan
3. **Devesh Sharma** (2011). International Workshop on Adaptation and mitigation options for tackling the impacts of climate change on water resources jointly organised by the Department of Civil Engineering, ITM University, Gurgaon and Water sciences Division, UNESCO, New Delhi, March 14-15.
4. **Devesh Sharma,** M.S. Babel, Virendra Kumar (2010).“An Approach for Efficient RainwaterManagement for Agriculture in Arid Region of Rajasthan, India”. International Journal of Water Resources and Environmental Management, Serial Publication, Volume (1), pp. 39-52, ISSN: 2229-5933.
5. **Devesh Sharma**, A. Das Gupta, M. S. Babel (2007). Spatial disaggregation of bias-correctedGCM precipitation for improved hydrologic simulation: Ping River Basin, Thailand. Published in Hydrology and Earth System Sciences, Volume 11(4), 1373-1390, doi:10.5194/hess-11-1373-2007
6. **Devesh Sharma** and Aastha Gulati (2009). Impact of climate change on floods in south Asia:a need of integrated floods management wheel approach. International Conference on climate change & sustainable management of natural resources, ITM Universe, Gwalior (M.P.), India, 10-12 November.
7. Bharat R Sharma and **Devesh Sharma** (2008). Impact of Climate Change on Water Resources and Glacier Melt and Potential Adaptations for Indian Agriculture. 33rd Indian Agricultural Universities Association Vice Chancellors‟ Annual Convention on “Climate Change and its Effect on Agriculture”, Anand Agricultural University, Anand (Gujarat), India, December 4-5, 2008.

8. **Devesh Sharma** (2008). Impact of Climate Change on Floods: Imperatives for Preventionand Preparedness in South Asia. Workshop on Regional Cooperation for Flood Mitigation, NASC Complex, Pusa, New Delhi, 03 November 2008.
9. **Devesh Sharma**, Virendra Kumar and K.D. Sharma (2007). Distributed Numerical RainfallRunoff Modelling in Small Arid Watershed Using Remote Sensing and Geographic Information System. CD Proceedings of International Agricultural Engineering Conference held at Asian Institute of Technology, Bangkok, Thailand, 3-6 December 2007.
10. **Devesh Sharma**, A. Das Gupta, M. S. Babel (2006). Application of bias-correctiontechniques on ECHAM4/OPYC SRES scenarios for Thailand. Proceedings of an International Perspective on Environmental and Water Resources Conference (CDROM), ASCE-EWRI, 18-20 December, New Delhi, India.
11. **Devesh Sharma**, A. Das Gupta, M. S. Babel (2006). Trends in extreme rainfall andtemperature indices for two river basins of Thailand. 3rd APHW International Conference on “Wise Water Resources Management towards Sustainable Growth and Poverty Reduction”, Bangkok, 16-18 October.
12. **Devesh Sharma** (2006). Application of Geographic Information System for Rainwater Management in Small Arid Watershed of Rajasthan, India. Conference Proceeding of Map Asia.
13. **Devesh Sharma**, A. Das Gupta, M. S. Babel (2005). Spatial rainfall disaggregation approach using multiplicative random cascade model in two river basins of Thailand. International Workshop on Numerical Simulation for Disastrous Phenomena organized by SET/AIT and GSIC/TOKYO TECH, Asian Institute of Technology, Thailand, 8 December.
14. **Devesh Sharma** and M.S. Babel. Trends in Extreme Rainfall and Temperature Indices in the Western Thailand. International Journal of Climatology, DOI: 10.1002/joc.3846
15. **Devesh Sharma** and M.S. Babel (2013). Application of downscaled precipitation for hydrological climate change impact assessment in the Ping River Basin of Thailand. Climate Dynamics, 41 (9-10), pp 2589-2602
16. Mohammad Waheed Ibrahimzada and **Devesh Sharma**. Vulnerability Assessment on Water Resources in Amu Darya River Basin, Afghanistan. International Journal of Environmental Science, Volume 3(2), 802-812, ISSN 0976 – 4402, doi:10.6088/ijes.2012030132007.
17. **Devesh Sharma** (2012). Situation Analysis of Flood Disaster in South and Southeast Asia – A Need of Integrated Approach. International Journal of Science, Environment and Technology, Vol 1(3), 167-173, ISSN: 2277-663X
18. Mamta Mehra, **Devesh Sharma** and Prachi Kathuria (2012). Groundwater Use Dynamics: Analyzing Performance of Microirrigation System- A case study of Mewat District, Haryana, India. International Journal of Environmental Science, Volume 3(1), 471-480, ISSN 0976 – 4402, doi: 10.6088/ijes.2012030131045.

Annexure-2

Endorsement from collaborating Institution/Agency

I have gone through the Research proposal entitled Climate Change Impacts Studies for Rajasthan (Areas of Inland Drainage and Mahi Basin) submitted by Dr. Mahender Choudhary *(Name of PI)* of MNIT Jaipur *(Name of the collaborating Institution/Agency)* for MoWR funding and noted the obligations and responsibilities indicated in our name which are as below :

a. Proposed activities of research work (list activities)

S. No.	Activity	Responsible Expert & Station	Manpower required	Duration (Year)
1	Literature review	Prof. B.R.Chahar IITD	JRF (1)	1
2	Drainage studies	Prof. B.R.Chahar IITD	JRF (1)	2

b. Estimated cost for the proposed activities (mention amount in Rs.)
Rs 11.61 lakhs

c. Share of Overhead charges and Contingency (Taken together)
Rs 12.36 lakhs

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities. The Dean, IRD (on behalf of IIT Delhi), will endorse my participation in this project on a separate letterhead.

(PI of the collaborating Institution/Agency)
Seal/Stamp

Date: January, 22, 2014
Place: New Delhi

Dr. B. R. Chahar
Professor
Department of Civil Engineering
Indian Institute of Technology Delhi
Hauz Khas, New Delhi-110016, India

राजस्थान केन्द्रीय विश्वविद्यालय
(संसद के अधिनियम के तहत स्थापित केन्द्रीय विश्वविद्यालय)
राष्ट्रीय राजमार्ग–8, बांदरसिन्दरी
किशनगढ़ - 305801
जिला – अजमेर (राजस्थान) भारत
दूरभाष (कार्यालय) : +91-1463-238755
टैलीफैक्स : +91-1463-238722
वेबसाईट : http://www.curaj.ac.in
ईमेल : info@curaj.ac.in

Central University of Rajasthan
(A Central University by an Act of Parliament)
N.H.8, Bandarsindri
Kishangarh-305801
District - Ajmer (Rajasthan) INDIA
Phone (Office) : +91-1463-238755
Telefax : +91-1463-238722
Website : http://www.curaj.ac.in
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Endorsement from collaborating Institution/Agency

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a. Proposed activities of research work (list activities)

S. No.	Activity	Responsible Expert & Station	Manpower Required	Duration (Year)
1	Literature review & Trend Analysis	Dr. Devesh Sharma CURAJ	RA (1) JRF (1)	2 3
2	Mitigation strategies for extreme hydrological events i.e., flood and droughts	Dr. Devesh Sharma with MNIT Jaipur	RA (1)	1

b. Estimated cost for the proposed activities (mention amount in Rs.) - Rs. 21.08 lakh

c. Share of Overhead charges and Contingency (Taken together) - Rs. 23.13 lakh

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities.

(Head of the collaborating Institution/Agency)
Seal/Stamp
Registrar
Central University of Rajasthan

Date: 23-01-2014
Place: Bandarsindri, CURAJ