Impact of Climate Change on Water Resources (Satuj Basin)

Duration: - 3 years

Total Cost: - 71.080 lakhs

(Rupess Seventy one lac eight thousand only).

Project Team:-

National Institute of Hydrology, Roorkee .

SECTION I

Project Title: Impact of climate change on water resources of Satluj sub-Basin

Duration: 3 years

Total Cost: Rs. 71.080 lakhs

Project Team with PI's and Co-PI's and Fund Break-up:

Sl. No.	Institute/Organisation	PI's and Co-PI's	Fund Break-up (Rs. Lakh)
1	National Institute of Hydrology, Roorkee	Dr. Sharad K Jain, Scientist G – PI Dr. Sanjay K Jain, Scientist F – Co-PI Dr. J V Tyagi, Scientist G-Co-PI Dr. M K Goel, Scientist F- Co-PI Dr. A K Lohani, Scientist F-Co-PI Dr. S P Rai, Scientist E, Co-PI Dr. Surjeet Singh, Scientist E – Co- PI Dr. Renoj Theyyan, Scientist D, Co-PI Dr. Manohar Arora, Scientist C, Co-PI Dr. R V Kale, Scientist B, Co-PI Mr Manish Nema, Scientist B, Co-PI Mr. P K Mishra, Scientist B – Co-PI Mr. P K Agarwal, Scientist B-Co-PI	71.080
		GRAND TOTAL	**Rs. 71.080**

(Rupees Seventy one lakh eight thousand only) .

Proforma of Application for Research Grants

1. Research Station/Institution

Name: **National Institute of Hydrology, Roorkee**
Address: Director, National Institute of Hydrology
Roorkee 247 667
Uttarakhand
Telephone: 01332-272106
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e-mail: dir@nih.ernet.in
Nearest Rail head/Airport: Railway Station: Roorkee
Airport: New Delhi

2. Principal Investigator

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Designation: Scientist F
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3. Co – Investigator(s)

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P K Agarwal	Scientist B	NIH Roorkee	01332 249238(O)	013322 72123	pka@nih.ernet.in

4. Brief bio data of the Investigators

Bio-data of all investigators are attached (**Annexure - I**).

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

Impact of Climate Change on Water Resources of Satluj Basin

6. Track Record and Workload Assessment of the PI

List all the research and consultancy schemes, whether funded by MoWR or any other agency, in which the present PI is/was Principal Investigator, in following groups.

a) Schemes ongoing

1. Ganga river basin environment management plan

2. Cumulative Environment Impact Assessment studies for Satluj Basin in Himachal Pradesh
3. Cumulative Impact Assessment of Alaknanda and Bhagirathi Including Tributaries

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

National Institute of Hydrology, Roorkee

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 Programme
f) Infrastructure Development;
g) Creation of Centres of Excellence

9. Description of the Proposal

It is well known fact that climate change has significant implications for the environment, ecosystems, water resources and virtually every aspect of human life. One of the most important and immediate effects of global warming would be the changes in local and regional water availability. Global warming is likely to have significant impacts on the hydrologic cycle, affecting water resources systems (Arnell, 1999; IPCC, 2001, 2007). Such effects may include the magnitude and timing of runoff, the frequency and intensity of floods and droughts, rainfall patterns, extreme weather events, and the quality and quantity of water availability. These changes, in turn, ultimately influence the water supply system, power generation, food production, sediment transport and deposition, and ecosystem conservation. Some of these effects may not necessarily be negative, but all effects need to be evaluated as early as possible because of the great socio-economic importance of water and other natural resources (Jiang et al., 2008)

Ice and snow are important components of the Earth's climate system and are particularly sensitive to global warming. Over the last few decades, the amount of ice and snow, especially in the Northern Hemisphere, has decreased substantially, mainly due to human-induced global warming. Changes in the volumes and extents of ice and snow have both global and local impacts on climate, ecosystems, river flows and sea water level. Air temperatures are projected to continue increasing in many mountainous regions, which will raise snow lines and cause other changes in mountain snow cover. Millions of people are affected by the ice and snow that accumulate in mountain regions. (IPCC, 2007, Singh and Bengtsson, 2004).

Regions having a large fraction of runoff driven by snowmelt would be especially susceptible to changes in temperature, because temperature determines the fraction of precipitation that falls as snow and is the most important factor in determining the timing of snowmelt. The Himalayan water system is highly dependent on snow and glacier storage and hence susceptible to suffer from the effects of global warming (Singh et al., 2005, Arora et al., 2008).

The Indus basin covers an area of about 1,140,000 sq. km. A large part of the upper basin lies within the Hindu Kush, Karakorum, and Himalayan mountains; Afghanistan, China, India, and Pakistan share the basin territory. Glaciers are a major landscape feature of the region. The drainage area lying in India is 321289 sq. km. which is nearly 9.8% of the total geographical area of the country. Snow and glacial melt contribute more than half of the annual average flow of the Indus River and around 50% of its tributaries. Satluj is a major tributary of Indus.

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

The current proposed research can be classified under the following:

a) Finding answers to as yet un-answered questions. (List the questions)
   Q1. Whether the spatial and temporal water availability in the basin will change with the expected climate changes? If yes then to what extent?
   Q2. Whether existing policies of operating the water resources projects are adequate or some changes are required?
   Q3. How the hydrological extremes would be affected?
   Q4. How the ground water recharge and availability will be affected?
   Q5. What adaptation measures/options are needed to cope with changing climate?
   Q6. Are there any trends in climatic and hydrologic data sets (including extreme rainfall, floods, and droughts) for Indus basin? What can the trends (if evident) be attributed to?

b) Investigation of the behaviour of a natural process. (state what new aspects are to be investigated and why)
   (i) The study would help in estimating the changes in the future hydro-meteorological variables for the study area.
   (ii) The impact on snow and glacier melt, rainfall runoff, total streamflow and ground water would be determined.
   (iii) The behaviour of high flows under the changing climate will be investigated.
   (iv) Whether the ground water recharge will change under changing climate and how the availability will be affected.
(v) The study will try to find if the existing operation policies of water resources projects are adequate in the changed condition or not?
(vi) The study would also look at long term sustainability of water use in the basin.

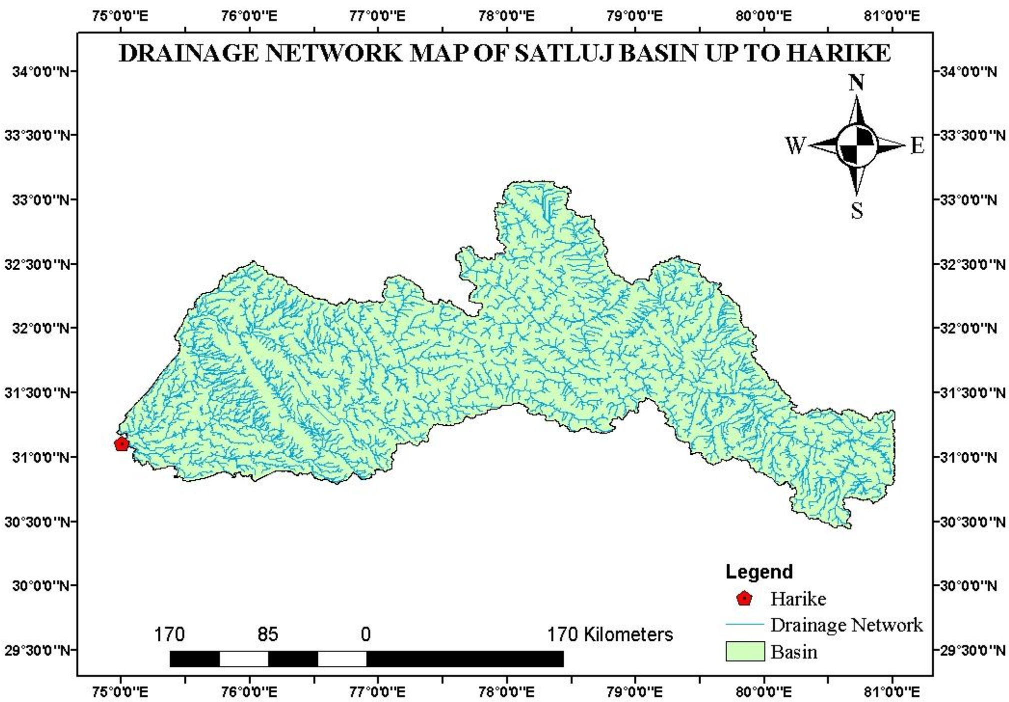
Following are the objectives of the present research proposal:

(i) To analyse trend of rainfall, temperature, and discharge data
(ii) To study the impact of climate change on snow/glacier melt runoff
(iii) To study the impact of climate change on stream flows and the impact on high flows
(iv) To study changes in the water demand in the basin
(v) To understand the impact of climate change on performance of reservoirs
(vi) To develop adaptation strategies for climate change

<u>The Study Area: The Satluj sub-basin</u>

The River Satluj is one of the main tributaries of Indus and has its origin very near to the Indus headwaters. It rises in the lakes of Mansarovar and Rakastal in the Tibetan plateau at an elevation of about 4572 m. The entire area in the Tibetan plateau experiences very less rainfall and has a cold desert climate. The watershed of Spiti river experiences extensive snowfall in the winters and therefore substantially contributes to the Satluj flows in the form of snowmelt runoff in the summer months. There are several other tributaries which join the Satluj River in the downstream and swell its flow. About 11 % area of the total Satluj catchment is covered by glaciers.

The area under study is shown in Fig. 1. In general this area experiences heavy snowfall in the winter season and little rainfall in the summer. The elevation varies from 1500 m to 7026 m for this area. The area-elevation curve suggests that only about 2.6% of the watershed area lies above 5400 m (Fig.1).



11. Contribution to Water Resources Development

The deliverables of the research work would contribute to water resources sector in the following ways:

(i) The regional climate scenarios will guide the policy makers for future planning.

(ii) The modelling results will provide estimate of the future water availability in the basin and would be useful in planning and development works.

(iii) The model results might be used for assessing the effectiveness of the existing flood fighting structures and other infrastructures like bridges, weirs in the area under the flooding condition.

(iv) Performance of reservoirs would be evaluated to assess the impact of climate change and adaptation mearues will be suggested.

(v) The adaptation strategies will help the local population to minimise the risk due to changing climate.

12. Putting the Research to Use

a) Identify the possible end-users for the results of proposed research.
   The possible end-users for the results of the proposed research are:
   - Bhakra Beas Management Board
   - Water Resources Department (WRD), Government of Punjab, J&K and Government of Himachal Pradesh
   - Public Works Department, Government of Punjab, J&K and Government of Himachal Pradesh
   - Public Health Engineering Department, Government of J&K and Government of Himachal Pradesh
   - Ministry of Road Transport, State and Central Government
   - Ministry of Railway, Government of India
   - Ministry of Urban Planning and Development, State and Central Government
   - Ministry of Agriculture
   - Planning Commission
   - Hydropower developers such as SJVNL, NHPC and private operators.

b) List the actions that will be necessary to put the results to use.
   (i) Apprise the officials of the various departments of the findings of the study through reports, seminars, workshops etc.
   (ii) Prepare and demonstrate some case studies to the user organisations showing the effect of particular developmental activities proposed/ being carried out by them in the study area.

c) List the difficulties/problems that may be encountered in putting the results to use.
   (i) Lack of coordination among the various departments.
   (ii) Lack of alternatives for planned developmental projects.
   (iii) Lack of incentive to try new options.
   (iv) Scepticism among the decision makes about the scientific studies.

d) Are the possible end users being involved in the research? If yes then describe how, if not then explain why not.

   The major end user will be the, Government of India and Government of Himachal Pradesh/Jammu and Kashmir. The research proposal is being submitted under the National Action Plan on Climate Change. Under this plan all the river basins of India are being studied and this study is a part of the Indus basin. The results would be disseminated in the form of reports and communication to the relevant government departments.

13. Present State of Art

Trend analysis

Since the TAR there have been many studies related to trends in river flows during the 20th century at scales ranging from catchment to global. Some of these studies have detected significant trends in some indicators of river flow, and some have demonstrated statistically significant links with trends in temperature or precipitation; but no globally homogeneous trend has been reported. Many studies, however, have found no trends, or have been unable to separate the effects of variations in temperature and precipitation from the effects of human interventions in the catchment, such as land-use change and reservoir construction.

Surface water runoff modelling

Over the past decade many studies into the impacts of climate change on water resources have been carried out (Leavesley, 1994; Arnell, 1998). These studies all have used models to translate the assumed climate changes into hydrological responses. Depending on the objectives of the study, the spatial and temporal scales, and the data availability, different model conceptualisations and parameterisations have been applied (Leavesley, 1994).

Most of the studies carried out recently show that the total annual river runoff over the whole land surface is projected to increase, even though there are regions with significant increase and significant decrease in runoff.

The current state of Technology and Research clearly shows that linking climate change with water resources is the core area of research worldwide in the field of flood management. At the international level, methods for future water availability assessment and mapping are still under development. However, considering the magnitude and severity of the climate change impacts in India, it is surprising that these techniques have not been applied in India.

The Soil and Water Assessment Tool, SWAT (Arnold et al., 1998; Neitsch et al., 2005) model is proposed in the present study for hydrologic modelling. Since the overall long-term objective of the program is to assess the potential impacts of climate change on the hydrologic regimes, the SWAT model which contains the hydrologic modules was selected. SWAT is being widely used internationally for water resources assessment due to its effectiveness in modelling the hydrological processes, landuse and management practices. SWAT is also considered appropriate for this study as it has been extensively and successfully used in other snowmelt-dominated regions to simulate hydrologic response (e.g., Abbaspour et al., 2007; Ahl et al., 2008; Levesque et al., 2008).

In the proposed work downscaled outputs will be used in hydrologic model SWAT, to simulate hydrologic variables such as soil moisture and runoff.

Ground water modelling

Visual MODFLOW is the most commonly used modeling environment for practical applications in three-dimensional groundwater flow simulations. This fully-integrated package combines MODFLOW, MODFLOWSURFACT, MODPATH, ZoneBudget, MT3Dxx/RT3D, MGO, and WinPEST with the most intuitive and powerful graphical interface available. This software requires a number of data viz. surface topography, aquifer geometry and properties, various boundary conditions, well details, groundwater levels, recharge, groundwater draft, stream geometry and levels, etc. The model is calibrated using the steady-state simulation for 365 days and the calculated and observed heads are compared. Some of the parameters values are adjusted during a series of trial runs until a better match are obtained. The model is then calibrated for transient-simulation for rest of the period using computed heads from the steady state condition as the initial heads. After a number of trial runs, computed heads are brought to reasonably match the observed heads. The model input parameters and results can be visualized in 2D (cross-section and plan view) or 3D at any time during the development of the model, or the display of the results.

Snowmelt runoff modelling

The conversion of snow and ice into water is called snowmelt, which needs input of energy (heat). Hence the process of snowmelt is linked to the flow and storage of energy into and through the snowpack (USACE, 1998). Snowmelt models have two basic approaches towards calculating the amount of snowmelt occurring from a snowpack: energy budget method and temperature index method. The energy budget approach attempts to make the process as physically based as possible. The goal is to simulate all energy fluxes occurring within the snowpack to give an accurate account of total snowmelt in response to each of these energy fluxes over time and space. This approach is extremely data intensive, requiring vast amounts of input data either to force an initial run of a model, or to calibrate it based on historical data before running a forecast. Too often, this approach suffers from inadequate data supply or simply that the level of data is unwarranted for the purpose at hand. In light of the intensive data requirements necessary for the energy budget approach, an alternative method known as the temperature index or degree day approach allows for snowmelt calculation with much less data input. The basis of the temperature index approach is that there is a high correlation between snowmelt and air temperature due to the high correlation of air temperature with the energy balance components which make up the energy budget equation (Semádeni- Davies, 1997; Ohmura, 2001; Hock, 2003).

There are several temperature index based snowmelt models like SNOWMOD, the SSARR Model, the HEC-1 and HEC-1F Models, the NWSRFS Model, the PRMS Model, the SRM, the GAWSER Model. The Snow Melt Runoff (SRM) model is widely used for snowmelt modeling in Himalayan basin. The SRM uses snow-covered area as input instead of snowfall data, but it does not simulate the base flow component of runoff. In other words, SRM does not consider the contribution to the groundwater reservoir from snowmelt or rainfall, nor its delayed contribution to the stream flow in the form of base flow, which can be an important component of runoff in the Himalayan Rivers, and plays an important role in making these rivers perennial. Almost all the stream flow during winter, when no rainfall or snowmelt occurs, is generated from the base flow (Singh and Jain, 2003). A snowmelt model (SNOWMOD) has been developed at NIH (Jain, 2001, Singh and Jain, 2002). The output of the model gives the individual contribution from the snow/glacier melt, rainfall contribution and the baseflow contribution. It is a temperature index model, which is designed to simulate daily stream flow for mountainous basins having contribution from both snowmelt and rainfall. The generation of stream flow from such basins involves the determination of the input derived from snowmelt and rain, and its transformation into runoff. It is a semi-distributed model and for simulating the stream flow, the basin is divided into a number of elevation zones and various hydrological processes relevant to snowmelt and rainfall runoff are evaluated for each zone. The model achieves three operations at each time step. At first, the available meteorological data are extrapolated at different altitude zones. Then the rate of snowmelt is calculated at each time step. Finally, the snowmelt runoff from SCA and rainfall runoff from SFA (snow-free area) are integrated, and these components are routed separately with proper accounting of base flow to the outlet of the basin. The model optimizes the parameters used in routing of the snowmelt runoff and rainfall runoff.

The model has been applied to simulate the flows of Satluj River upto Bhakra, Beas up to Pandoh, Chenab River up to Salal, Dokriani Glacier melt stream and the Bhagirathi River up to Bhojwasa and Tehri (Jain & Singh, 2003, Jain, 2010 and Arora et al. 2008). In Beas basin study area taken is up to Pandoh dam. The stream flow has been computed for the years from 1990 to 2002 in the existing conditions. Then effect of different changed climate scenarios on the melt runoff as well as stream flow has been studied. Daily snowmelt runoff was simulated for the study basin for hypothetical scenarios T+1, T+2 and T+3°C and precipitation of 10% over the study period of 12 years (1990-2002). The model has also been applied for a river basin in Bhutan Himalaya (Jain et al. 2012).

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14. Methodology

A brief description of the methodology for climate change impact assessment and adaptation strategies for Satluj basin is outlined next.

Trend Analysis

One of the commonly used tools for detecting changes in climatic and hydrologic time series is trend analysis. Trend analysis of a time series consists of computing the magnitude of trend and its statistical significance. In general, the magnitude of trend in a time series is determined either using regression analysis (parametric test) or using Sen's estimator method (non-parametric method) (Sen, 1968). Both these methods assume a linear trend in the time series. Sen's estimator has been widely used for determining the magnitude of trend in hydro-meteorological time series. To ascertain the presence of statistically significant trend in hydrologic climatic variables such as temperature and precipitation with reference to climate change, nonparametric Mann-Kendall (MK) test has been employed by a number of researchers. The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend.

Quantification of Impact of Climate Change on surface water

Impact of climate change on water availability at various gauging sites and critical locations within the basin would be assessed in terms of change in flow duration curves. Changes in irrigation water demands corresponding to various climate change scenarios would be estimated based on downscaled projections of climate variables which influence evapotranspiration.

For hydrologic modelling, first step is to set-up, calibrate, and validate a hydrological model for the study catchment. The model should be sensitive to the climate variables under consideration (say, temperature, precipitation, snow cover etc.). The models used in the study will be calibrated and validated on historical data. The validated models will be used with downscaled climate scenarios to project basin wide effects of climate change. These projected hydrological scenarios will be compared with a baseline scenario (the baseline period will be selected based on available data and following IPCC guidelines) to quantify changes in hydrological components.

Projected rainfall and streamflow data would be used to investigate the implications of climate change on distribution of floods. The flood hydrographs at selected sites in the basin obtained from hydrological models will be analysed to detect possible changes in frequency and duration of floods.

For hydroligc modelling, SWAT model will be applied. SWAT is a semi-distributed, continuous watershed modelling system, which simulates different hydrologic responses using process- based equations. The model computes the water balance from a range of hydrologic processes such as evapotranspiration, snow accumulation, snowmelt, infiltration and generation of surface and subsurface flow components. Spatial variability within a watershed is represented by dividing the area into multiple sub-watersheds, which are further subdivided into hydrologic response units (HRUs) based on soil, land cover and slope characteristics. SWAT uses a temperature-index approach to estimate snow accumulation and melt. Snowmelt is calculated as a linear function of the difference between average snowpack maximum temperature and threshold temperature for snowmelt. Snowmelt is included with rainfall in the calculation of infiltration and runoff. SWAT does not include an explicit module to handle snow melt processes in the frozen soil, but includes a provision for adjusting infiltration and estimating runoff when the soil is frozen (Neitsch et al., 2005). Despite this limitation, SWAT was considered to be the most appropriate integrated model currently available for application in this coldregions environment. SWAT computes actual soil water evaporation using an exponential function of soil depth and water content. The model generates surface runoff using a modified Soil Conservation Service (SCS) curve number method based on local land use, soil type, and antecedent moisture conditions. Groundwater flow contribution to total stream flow is simulated by routing the shallow aquifer storage component to the stream. Runoff is routed through the channel network using the variable storage routing method or the Muskingum method (Neitsch et al., 2005). For snowmelt runoff modelling, anoter model, SNOWMOD model, after proper training and validation, will be forced with climate scenarios to generate future projections of timing and magnitude of snow and glacial melt discharge.

Quantification of Impact of Climate Change on Groundwater

The potential impacts of climate change on water resources have long been recognized although there has been comparatively little research relating to groundwater. The methodology consists of five main steps. First, the climate change scenarios need to be formulated for the future years such as 2050 and 2100. This is done by assigning actual changes of climatic variables based on GCM predictions on a seasonal and/or annual basis for the future years relative to the present year. Second, generate future climate based on these climate change scenarios. This is done using the statistical techniques. Third, based on these scenarios and present situation, groundwater recharge is estimated. Fourth, the groundwater levels are simulated for the present condition and for the future years using a groundwater model e.g. MODFLOW. Finally, the changes on groundwater due to the climate change are quantified.

The main tasks that are involved in such a study are:

1. Describe morphology and hydrogeology of the study area.
2. Undertake statistical analysis to separate climate into regional and local events.
3. Define methodology for estimating the groundwater recharge under both current and future climate conditions and for the range of climate-change scenarios for the study area.
4. Use of a computer code (such as MODFLOW) to estimate the groundwater levels based on available precipitation and temperature records and anticipated changes to these parameters.
5. Quantification of changes due to the climate change impacts.

Recommendations for adaptation measures/options to mitigate adverse impacts of climate changes in the study basin would be framed.

Data to be used:

Following are the data to be collected and used:

(i) Survey of India Toposheets of the study area in the scale of 1:50,000 and 1:2,50,000.
(ii) Contour maps of the study area, SRTM data/ASTER
(iii) Satellite imageries for snow cover area assessment and preparing land use maps for the study period.
(iv) River morphology data C cross-sections at key locations.
(v) Hydro-meteorological data at daily and monthly scale.
(vi) Daily flow data at all the gauging sites for the study period.
(vii) Details of the soil, vegetation etc in the study area.
(viii) Data of groundwater wells, abstraction etc.
(ix) Details of embankments, guide banks, barrages, aqueducts, flood protection works etc. in the floodplain. The information about the breaches in the embankments, if any.
(x) Working tables of all the reservoirs on daily/weekly intervals.
(xi) Details of hydropower projects and power generated by them.
(xii) Details of canal network in the study area and water releases into them.
(xiii) Data of population, livestock in the basin

15. Cost Estimates

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

Rs 71.080 Lakh (Rupees Seventy One lakh eighty thousand only)

15.2 Subhead wise Abstract

Subhead	**Amount (Rs.in lakhs)**
Salary	24.480
TE	21.000
Infrastructure/Equipment	6.600
Experimental Charges	16.500
Sub Total	**68.580**
Contigency	0.500
Sub-Total	69.080
Overhead	2.000
Grand Total	**71.080**
GRAND TOTAL	**Rs. 71.080**

*(**Note:** In this table of abstract, it is not necessary to indicate year-wise provisions. The release of funds will be tied down with milestones of progress and not with passage of time)*

15.3 Justification for Institutional Over Head charges.

The National Institute of Hydrology, Roorkee will provide the required infrastructural and logistic support for carrying out the project. NIH has well equipped library facilities which will be used. Internet and e-mail facilities are also available which will be used. Also, the Institute have excellent computational facilities which will be used. Furthermore, the expertise available in the Institute in the area of water resources can be utilized. Any other facilities available in the Institute and required for the project will be used.

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

The budget for the first year is Rs. 25.194 lakh (approx) and it primarily consists of the cost of data, software and hardware on which the further progress of the study depends. The cost of the computer peripherals and software is around 6.6 lakh for which budget requirement has been placed in first year requirement. The cost of data and stationary is 16.50 lakhs which has been divided in three years. Rest amount is for consumables salary and travel. So at the start of the project about 25.194 lakh would be required. However, the budget requirement has to be observed on yearly basis.

15.5 Subheads wise Details

Salary

Designation	Year 1			Year 2			Year 3		
	Rate/Month	Month	Amt (Rs)	Rate/ Month	Month	Amt (Rs)	Rate/ Month	Month	Amt (Rs)
Research Associate (2)	22000	12*2	528000	22000	12*2	528000	22000	12*2	528000
JRF (2)	12000	12*2	288000	12000	12*2	288000	12000	12*2	288000
Totals	816000			816000			816000		

Grand Total for Salary 24.48 lakhs

15.6 Man-months utilisation table.

(For each of the research staff, list the activities and the months (from start in which be/she will be carrying out each of these activities thus justifying the total man-months)

The proposed work will require extensive modeling work. Reseach Associate and JRF will work for data collection, data base preparation and field work during the project.

15.7Travel Expenditure (TE)

(Give the break-up for the provision for TE indicating the places to be visited, purpose, number of visits to each place by air/rail/road with approximate fares for each type of journey and provision, for DA. The mode of journey allowed (air/rail/road) will be as per the TE entitlement rules of the host institute.)

The travel cost includes the provision for DA

TE for officials of NIH, Roorkee (all figures in Rs. Lakh)				
Mode of Journey	No. of	Place of visit	Approx. cost	Remarks

	Journey			
Air	5	Nangal, Rampur, Chandigarh, New Delhi Field visits	0.40x5 = 2.0	Same for Year 1,2& 3
Rail	8	--do--	2.00	
Road	12	--do--	3.00	
		Total	7.0	21.00

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

Computer & peripherals					
	Ist Year	IInd Year	III year		
Laptop	3x0.50 =1.50	2x0.50 =1.00	-	2.50	Dual Core, 2GB RAM, 80 GB HDD, DVD R+RW
PC Desktop	3x0.50 =1.50	2x0.50 =1.00	-	2.50	Dual Core, 2GB RAM, 160 GB HDD, DVD R+RW, 19" TFT Monitor, Portable HDD
Printer	1.0 + 0.60		-	1.6	High resolution A4/A3 colour laserjet printer

Total **6.6 Lakh**

(Give details indicating specifications, quantity and rate. Estimated cost for all items of commercial nature should be supported by proforma invoices.)

15.9 Experimental Charges

List of items and estimated cost (in lakh)

Data (Meteorological/ hydrological/ soil/ topographical and satellite data)			
Satellite data			
Cartosat	10x0.25	2.50	
IRS L3/ PAN/ WiFs	40x0.10	4.00	
Topomaps/ soil maps/ Meteorological data/ hydrological data	2.0x1	2.00	
Stationary and Consumables	3.00x1	3.00	
Field Survey etc.	5.00x1	5.00	
	Total	16.50	

16. Work Schedule

a) Probable Date of Commencement: July, 2015
b) Duration of Study: 3 years

c) Stages of Work and Milestones

Sl. No.	Identifiable Milestones of Progress	Months from start	Amount to be released (in Rs. Lakh)
Start		0	**25.194**
1.	Collection of data	1-9	
2.	Procurement of Software (like Digital Image Processing, GIS, etc.), Computers, Scanners, Printer, Plotter, GPS, etc.	1-12	
3.	Procurement of SOI toposheets, scanning, digitization and preparation of base map.	4-12	
4.	Processing of Hydromet & spatial data	4-12	
5.	Processing of flow data	4-15	**21.00**
6.	Trend analysis of hydro-meteorological data	4-18	
7.	Downscaling of GCM data and bias correction	8-22	
8.	Remote sensing analysis including preparation of DEM	7-22	
9.	Set up and calibration of model	9-18	**22.386**
10.	Validation of model	19-24	
11.	Assessment of existing structures and policies	25-30	
12.	Finalisation of adaptation strategies	31-33	
13.	Report Preparation and finalisation of results	28-36	
	Sub-Total		**68.58**
	Contigency		**0.50**
	Sub Total		**69.08**
	Add Overhead		**2.000**
	Total		**71.080**
	GRAND TOTAL		**71.080**

DELIVERABLES:

- Compilation of Baseline data, information and past studies pertaining to the Study basin
- Trend analysis for hydrologic and hydro-meteorological variables
- Calibration and Validation of hydrologic model for the basin
- Impacts on water availability at some critical locations in the basin,
- Impacts on irrigation water demands, for different scenarios
- Identification of hydrologic extremes from the baseline data
- Impacts on snow and glacier melt
- Recommendations for adaptation options.

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 financial support nor have undertaken it at the request of any commercial agency or as a consultancy.

Date………. **Signature of PI**
Place **Name**
Designation

18. Endorsement from the Head of the institution

1. The Institute/ Organisation welcome the participation of **Dr. Sharad Kumar Jain, Scientist F, Water Resources Systems Division** as Principal Investigator for above project.
2. The necessary equipment and institutional support as described in item 15.3 will be made available as and when required for the purpose of the project to ensure that the work is taken up to 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 form 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: **Seal and signature of the**
Place: **Head of the organisation**

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

Responsibility Matrix

Name of PI: Dr. Sharad K Jain, Scientist G	**Activity**
Satluj basin : NIH	
Dr. Sanjay K Jain, Mr DS Rathore, Dr. SP Rai, Mr M K Nema, Mr. P K Mishra, Dr MS Rao, and Mr. P K Agarwal	Data collection and data base creation
Dr. Manohar Arora, Mr MK Nema, Dr. Surjeet Singh, Dr. A K Lohani,	Trend Analysis
Dr JV Tyagi, Dr. Sanjay K Jain, Dr. Sharad K Jain, Dr. A K Lohani, Dr. M K Goel, Dr. Manohar Arora, Mr. P K Mishra, Mr MK Nema	Hydrological Modelling using SWAT/ VIC and water availability
Dr. Sanjay Jain, Dr. Manohar Arora and Dr. Renoj Theyyan	SNOWMOD snowmelt runoff modelling
Dr. M K Goel, Dr. Sharad K Jain and Dr. A K Lohani, Mr P K Mishra	Impacts on water demands
Dr. Surjeet Singh, Dr Sudhir Kumar, Dr MS Rao, Dr. M K Goel,and Dr. S P Rai	Ground water modelling (MODFLOW)
Dr. A K Lohani, Er. D S Rathore, and Dr RV Kale	Flood Studies
All scientists	Adaptation measures/options