सरदार वल्लभभाई राष्ट्रीय प्रौद्योगिकी संस्थान, सूरत
SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT
સરદાર વલ્લભભાઈ રાષ્ટ્રીય પ્રૌદ્યોગિકી સંસ્થા, સુરત
SVNIT

Department of Civil Engineering

No. CED/ PLP/ CC/ 1461 / 2015-16

July 20, 2015

To,

Dr. R D Singh
Director, NIH &
Member Secretary, INCCC
National Institute of Hydrology
Jalvigyan Bhawan,
Roorkee-247 667.

Sub: - Revised project proposal for **"Impact of Climate Change on Water Resources of Tapi Basin"**

Ref: - (a) **Your letter no. NIH/CCC/2012, March 2012**
(b) **MoWR letter no. 2/32/2012-NWM(S)/CC & IAD/103 dated 29.02.2012- Minutes of the interactive meeting**
(c) **Our letter No.CED/561/2012-13, May29, 2012**
(d) **Your letter through email, dated June 26, 2015**

Sir,

In continuation to your letter cited at the reference (d) above on aforesaid subject, kindly find enclosed **FIVE copies** of the revised proposal for research project as per revised guidelines, under MoWR, RD&GR Govt. of India, on **'Impact of Climate Change on Water Resources of Tapi Basin'** for your kind perusal and further action. The soft copy of the proposal has already been sent to your good self through the e-mail on June 20, 2015.

I would be grateful, if you kindly intimate us for taking further action from our end.

Yours faithfully

प्रेमल पटेल

Dr. P L Patel
Professor July 20, 2015

CC: (a) The Head, Department of Civil Engineering, SVNIT, Surat: For kind info please.
(b) Dean(R&C), SVNIT, Surat: for kind information please

PROFESSOR
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सरदार वल्लभभाई राष्ट्रीय प्रौद्योगिकी संस्थान, सुरत
Sardar Vallabhbhai National Institute of Technology, Surat

A

RESEARCH PROPOSAL

ON

"IMPACT OF CLIMATE CHANGE ON WATER RESOURCES OF TAPI BASIN"

SUBMITTED TO

INDIAN NATIONAL COMMITTEE ON CLIMATE CHANGE **(INCCC),**

MINISTRY OF WATER RESOURCES,

RIVER DEVELOPMENT & GANGA REJUVENATION

GOVERNMENT OF INDIA

PRINCIPAL INVESTIGATOR

Dr. P.L.PATEL
DEPARTMENT OF CIVIL ENGINEERING
SVNIT-SURAT

CO-INVESTIGATORS

Dr. Rohit Goyal (MNIT-Jaipur)
Dr. Vishnu Prasad (MANIT-Bhopal)
Dr. P V Timbadiya (SVNIT-Surat)

DEPARTMENT OF CIVIL ENGINEERING
(WATER RESOURCES ENGINEERING SECTION)
SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT-395007

Application of Research Grant

1 Project Title:

"Impact of Climate Change on Water Resources of Tapi Basin"

2 Principal Investigator:

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3 Research Station/Institution

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5 Brief Bio-Data of Investigators:

Brief Biodata of Investigators is enclosed at **ANNEXURE – I**

6 Track Record and Workload Assessment of the PI

Enclosed at **ANNEXURE – I**

7 If the scheme is sanctioned, the authority in whose name the payment is to be authorized:

Lead Institute:

i) Name of authorized person holding account with complete address:

Director, SVNIT Surat

ii) Organization Name as per Bank records:

SVNIT Surat

iii) Bank Account No: **10023050019 (current a/c)**

iv) IFSC Code : **SBIN0003320**

v) MICR Code : **395002012**

vi) Bank Name : **State Bank of India**

vii) Bank Branch Address:

S. V. R. Coll of Engg. Tech. (SVRCET) Branch, SVNIT Campus, Ichchhanath, Dist-Surat (Gujarat) – 395007.

viii) Unique Agency code of the Organization and Institute: --------

ix) Telephone & Mobile No : +91-261-2201685
+91-99040 03857

Partner Institute (MNIT Jaipur):

i) Name of authorized person holding account with complete address:

The Registrar, MNIT Jaipur

ii) Organization Name as per Bank records:

Registrar (Sponsored Research) MNIT Jaipur

iii) Bank Account No: 676801700388 **(current a/c)**

iv) IFSC Code : ICIC0006768

v) MICR Code : 302229031

vi) Bank Name : ICICI Bank

vii) Bank Branch Address: Jaipur MREC Branch

Partner Institute (MANIT Bhopal):

i) Name of authorized person holding account with complete address:

The Director, MANIT Bhopal

ii) Organization Name as per Bank records:

Maulana Azad National Institute of Technology, Bhopal

iii) Bank Account No: 10021050107 **(current a/c)**

iv) IFSC Code : SBIN0001608

v) MICR Code : 462002014

vi) Bank Name : State Bank of India

vii) Bank Branch Address: MANIT, Bhopal

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

According to the International Panel on Climate Change (IPCC) Scientific assessment report, global average temperature would rise between 1.4° and 5.8° by 2100 with the doubling of CO_2 concentration in the atmosphere. The sea level rise, change in the precipitation pattern and change in other local conditions are expected due to rise in the earth temperature. At present, the Impact of climate change on Water Resources is the most crucial research agenda worldwide (IPCC, 2007).

The Prime Minister of India unveiled the National Action Plan for climate change on 30-06-2008 wherein eight missions including the National Water Mission (NWM) were launched. One of the top agenda of the NWM has been to predict the climate change and its possible impacts on water resources of Indian basins. The Prime Minister had also shown his concern over the depleting water resources in the country and its vulnerability under the changing climatic conditions during India Water week on April 10, 2012. Under NWM, 20 river basins in the country has been identified for detailed study on effect of climate change and its possible impact on water resources of the respective basins. The information on future climate scenarios may help in adapting to the climate change and mitigation of its adverse impacts, like flood and drought etc.

Few studies have been reported in the past in our country on effect of climate change at basin levels (Gosain and Rao, 2003; Rupa Kumar et al., 2006; Hassel and Jones, 1999; IPCC, 1990; and Lal et al. 1992) particularly at very coarser grid level. Prediction of climatic variables,

under changing climatic conditions, at the basin level (fine resolutions) and their use in hydrological/hydraulic modeling is required for prediction of water availability for irrigation, domestic, industrial, power production; and flood and drought conditions at the basin levels.

The Tapi basin spreads in an area of 65145 km^2 which is nearly 2% of the total geographic area of the country. It originates in Multai district of Madhya Pradesh and culminates in the Arabian Sea at the Surat city. The Tapi River is a major source of irrigation and plays major role in agricultural economy of Maharashtra and Gujarat states apart from feeding several domestic water supply schemes, industries and hydropower in its catchment. Apart from aforesaid benefits, major historical floods had occurred in the past in the coastal urban flood plain of the Tapi River in the Surat city. The flood of year 2006 alone had caused a loss of Rs.21000/- Crores and the economy of the country was severely affected for several months after the flood. The rise in temperature, sea level rise and severity of the extremes (flood) in Tapi basin (Gosain and Rao, 2006; Timbadiya et al. 2012), the flood conditions in the coastal flood plain may adversely affect the Surat city in near future. Keeping in view the aggravating situation of the climate change across the globe, in general, and, for the Tapi basin, in particular, hydrological and hydraulic analyses are required to predict the water yield in the basin and status of flood and drought for different future RCP scenarios using downscaled climatic variables like precipitation, temperature (Min., Max., Average), solar radiation, wind velocity, relative humidity and sun shine hours at basin levels.

10 Objectives

The objectives of proposed project, computation of reservoir sedimentation and sediment erosion modeling of catchment, can be described as below:

1. Collection of base line data of Tapi basin which would include stream gauge data, topography, soil, land use/land cover, ground water levels, reservoir and its utilities, cropping pattern of Ukai command area, past floods and tidal levels, vegetation, land management practices, sediment etc.
2. Selection of Hydrological (SWAT/MIKE SHE) and hydraulic models (MIKE FLOOD) and their calibration from past observed data.
3. Parametric and non-parametric tests for trend detection for hydro-meteorological and hydrological variables in the basin.

4. Performance evaluation of Ukai reservoir under changing climatic conditions in fulfilling its requirements of irrigation, hydropower and flood control.
5. Using the output from dynamic/statistical downscaling, prediction of flood situation downstream of Ukai dam in lower Tapi River under changing climatic conditions and preparation of flood risk maps of the Surat city under changing climatic conditions.
6. Organize Workshops during the project duration as capacity building measures and awareness for the stakeholders in the river basin and academic institutions involved in such activities.

11 Contribution to Water Resources Development

The change in the climatic condition is being faced by the whole world. The average global temperature has risen by about 0.75° in the last century. Similarly, the significant seal level has taken place (12-22 cm) in the same period. The water resource has become the most fragile resource of river basin and susceptible to the ongoing climate change. The extremes (flood/drought) have become more frequent in the basin and entire humanity is likely to face the menace of the climate change in the near future. The present study would be helpful in prediction of water resources of the basin under changing climatic conditions as follows:

a) Prediction of water yield into the reservoirs under changing climatic conditions which would help the stakeholders in the command area to be resilient in planning their cropping pattern, industrial/domestic water requirements, particularly under the drought conditions.

b) Prediction of flood into the Ukai reservoir, routing the flood in the reservoir and hydraulic routing of the flood in the downstream channel, giving due consideration to the tidal levels, would help in flood predictions in the Surat city under different climatic scenarios. The developed flood risk maps for changing climatic conditions would help the city dwellers in managing and adopting themselves with the severe extremes in future.

12 Putting the Research to Use

The proposed research project is being submitted under National Water Mission (NWM), MoWR, Govt. of India as one of the top priorities of the country. The Stakeholders, like water resources, water supply departments, Govt. of Gujarat and Maharashtra; Surat Municipal

Corporation (SMC) would be the real beneficiary of foregoing project. The findings of the research project can be put into use as under:

a) The findings of the research project will be discussed in the research forum time to time under National Water Mission, and will be made available in the form of research project reports and publications through peer reviewed International /National Journals.

b) The end-users will be invited in the awareness/ capacity building workshops, to be organized during the project duration, to show case the outcome of studies and motivate them to devise the adoptive measures for facing the consequences of climate change, like food/drought conditions, in near future.

The recommendations from the project would help the policy makers, both at central and state level, to initiate appropriate actions which would help the people to adopt themselves from the menace of climate change.

13 Present State of Art

Observed Recent Trends on Climate Change

The earth is experiencing a rapid climate warming which may affect both the natural and human systems in near future. IPCC (2001) has indicated that the average global temperature has increased by 0.6±0.2° per decade since the late 19th century. The rate and duration of warming of the 20th century has been found to be larger than any other time during the last 1000 years (Sharma and Singh, 2007). The IPCC 4th assessment report (IPCC, 2007) depicts a situation characterized by snow cover reduction in northern Hemisphere and glacial retreat almost worldwide. Ranzi and Barontini (2010) presented the variation of temperature, precipitation in Adige river basin in Italy along with variation of runoff at the catchment outlet. The data analyzed by them confirmed an increase of temperature @ 1.5° per century over the last century with acceleration in the last decade of 20th century. Recently, **Timbadiya et al. (2012 a, 2012 b) carried out the trend analysis of observed annual extremes flows at different gauging stations in the Tapi basin in India for duration 1972-2010 and reported that Annual extremes are aggravating in the basin in the recent past.**

Impact of Climate change on Water Resources of River Basin

Gosain et al. (2011) presented a study on assessment of water resources in seventeen Indian basins under changing climatic conditions across the globe. They had used the weather data from PRECIS RCM for Base line (1961-1990), near term (2021-2050) and long term (2071-98) periods for A1B IPCC SRES scenario in aforesaid study. The weather output from RCM data was utilized for possible impacts on the run-off, sediment yield and actual evapo-transpiration of all the basins. **The said study indicated an increase in precipitation by 17.50% and 5.70% with reference to the base line period in the Tapi Basin during the near term and long term respectively**. The analysis related with water yield, evapo-transpiration, sediment yield, floods and drought were under taken in SWAT, a physically based hydrological model, by using the weather data from aforesaid RCM. The majority of northern river systems show an increase in evapo-transpiration during the near term scenarios while majority of southern river systems show the marginal reduction in the evapotranspiration. The Impact analysis on flood had indicated an increase in flooding from 10% to 50% over the existing magnitudes. The foregoing study was dependent on the analysis of outputs from the PRECIS RCM for present (base period) and future (near term and long term) time periods for A1B scenario. The RCM outputs related with climatic variables like precipitation, temperature, solar radiation, wind velocity and relative humidity were not validated with the actual observed data in the river basins.

Raje and Mujumdar (2011) used conditional random field (CRF) method to downscale the outputs from three GCMs under A_2, A_1B and B_1 IPCC scenarios for computations of inflow into Hirakud reservoir for time slices of year 2045-65 and 2075-95 by using actual observed data for years 1959-2005. By simulating the future stream inflow scenarios into Hirakud reservoir, they assessed the performance of the reservoir in fulfilling its requirements, viz. Hydropower, irrigation and flood control, under changing climatic scenarios.

Gebre (2011) studied the effect of climate change on water resources availability of Didessa catchment in Blue Nile river basin in Ethopia. He used the downscaled results of ECHAMSM (GCM) through a regional circulation model ($RegCM_3$) for A_1B scenario of the said catchment. The downscaled results (precipitation, temperature, and potential evapotranspiration) were used as input to a distributed hydrological model (HBV-96) for simulating the flow in the study area

during 2031-2040 and 2091-2100. Precipitation and temperature were only downscaled parameters and the assumption of invariant climatic conditions like wind speed, solar radiation and relative humidity, in the future was made in the said analysis. A significant increase in runoff was reported in the projected time period in above study. He also recommended for using multiple GCM, in study of effect of climate change for water resources of river basin to depict the model uncertainty.

Paiva et al. (2011) studied the impact of climate change of Quarai river basin (as part of larger Uruguay and Parana La Plata basin) in South America. They used nine GCMs and six emission scenarios of greenhouse gas emissions to predict the impact of climate change on rainfall and temperature of the said basin. The uncertainty in climate change predictions was assessed by them by comparing the results obtained using different GCMs and different greenhouse gas emission scenarios. The uncertainty due to differences between GCMs greatly surpassed the differences between the greenhouse gas scenarios.

Ngugen and Nguyen (2011) proposed a methodology, called 'Scale invariance concept' to obtain cumulative probability distribution (CDF) of extreme rainfall of smaller duration (e.g., 1 hr rainfall) from statistically downscaled CDF of large duration (e.g., daily rainfall). Such study could be very useful in studying effect of climate change in the analysis of extremes (floods) at basin scales.

Ghosh et al. (2011) employed three GCMs, viz. CCSR/NIES (Centre for Climate System Research/National Institute of Environmental studies), $HadCM_3$ (Hadely Climate Model 3) and coupled global climate model 2 with two scenarios A_2 and B_2 to downscale the stream inflow, with due bias corrections, into Hirakud reservoir. The computed CDF for the downscaled stream flow had shown significant uncertainty, among the GCMs, particularly for medium flows. They had also obtained the possibilistic mean CDF for stream flow into the reservoir by giving suitable weights to each GCMs and scenario depending upon their performance in analyzing the climate condition for base line period. They assess the impact of climate change on existing policy of reservoir operation and found that hydropower production and its reliability will decrease; and vulnerability will increase as result of climate change in the future.

CONCLUDING REMARKS

Recent studies on Tapi basin has indicated an increase in precipitation in future, both in near and long terms, with reference to base line period. The trend analysis of stream flow in the Tapi River, and inflow into Ukai reservoir has also indicated an increasing trend in near future. The downscaled climatic variables of the Tapi basin can be used as inputs to available hydrological and hydraulic models to predict availability of water resource in the Tapi basin at critical locations. Also, the predicted rainfall at the basin level can be downscaled at sub-time period (e g. hourly) to compute event based flood hydrograph in the basin for future time projections. The predicted climatic/hydrologic variables can be useful in the assessment of reservoir performance and would help the stake holders and the policy makers to formulate appropriate adoptive measures in the river basin under the changing climatic conditions.

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Ghosh S., Raje D. and Mujumdar P .P. (2011), Mahanadi Streamflow: Climate Change Impact Assessment and Adaptive Strategies, Proceeding of International symposium on water Resources Management for developing countries due to climate change, March 29, 2011, Water Resources research Centre, Kyoto University, Japan, pp.119-131.

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Resources Management for developing countries due to climate change, March 29, 2011, Water Resources research Centre, Kyoto University, Japan, pp.65-74.

Paiva Radrigo C. D., Collischonn W. and ScheHini E. B. (2011), Climate change Impacts on Watr Resources in the Quarai River Basin; contributed in text book on 'Modelling the Impact of Climate Change on Water Resources, edited by Fung F., Lopez A., and New Mark, Wiley- Blackwell, pp.137-148.

Raje D. and Mujumdar P.P. (2011), Reservoir performance under uncertainty in hydrological Impacts of Climate Change, Advances in Water Resources, Science Direct,30(2010), pp.312-326.

Ranzi Roberto and Barontini S. (2010), Are ther evidences of the Impact of global warming on runoff regimes in the Southern Alps? Proceeding of International workshop on 'Impact of global warming from hydrological and Hydraulic issues', March 12, 2010, DDRI, Kyoto University, Japan.

Sharma K.D. and Singh Pratap (2007), Impacts of climate change on hydrological extremes: Floods and droughts, Hydrology Journal, 30(3-4), pp.129-145.

Timbadiya P. V., Patel P. L. and Porey P. D. (2012 a), Application of innovative trend analysis methodology and distribution fitting: Study on Annual peak inflow into Ukai dam, Gujarat, India, Water and Energy International, CBIP, Vol.69, No.9, Sep.2012, pp.40-44.

Timbadiya P. V., Mirajkar A. B. and Patel P.L. (2012 b), Recent trend analysis for annual peak flow in Tapi basin, Presented in India Water Week organized by MoWR, GOI, April 10-14, 2012 (Accepted for publication in Journal of Water and Energy International, CBIP in forthcoming issues)

14 Methodology

The present section describes about the study area (Tapi basin), ongoing studies related to the Tapi basin, scope of work, methodologies and the proposed Team involved in the project with the defined responsibilities**:**

Study area

The Tapi River, with its origin at Multai in Madhya Pradesh, traverses around 720 km distance before meeting with the Arabian Sea just 12 km from the heart of the Surat city. The catchment of the Tapi river is elongated in shape, falling in Madhya Pradesh (9804 km2), Maharashtra (51504 km^2) and Gujarat (3838 km^2) states. Out of several hydraulic structures came into existence on the Tapi river, Ukai dam is one of the important multipurpose dam which was constructed for the providing irrigation in the Southern Gujarat, Controlling the flood in the Surat city and hydropower generation through releases from the dam into Kakrapar weir system. The Index map of Tapi basin, its tributaries and locations of major hydraulic structures on them including the Ukai dam is shown in Fig.1.

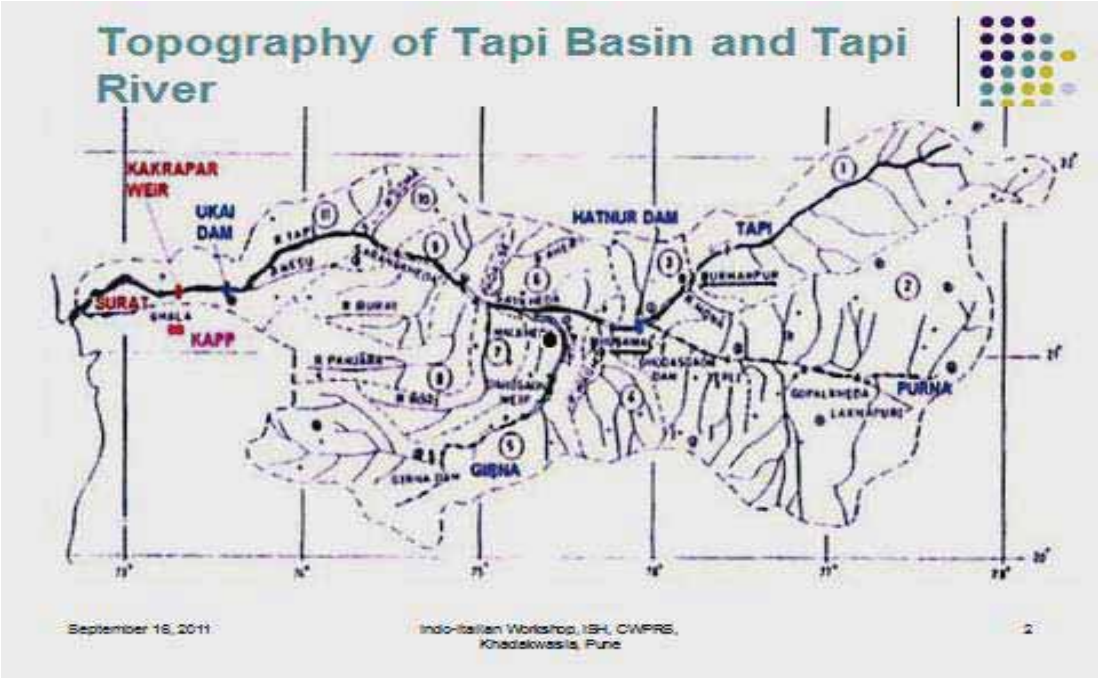

Fig. 1. Geographical view of Tapi Basin

Flood issues related to the Surat city in lower Tapi River

The Surat city is just located 120 km downstream of Ukai dam and faced many major floods in the past. The details of major floods after 1950 and their corresponding levels at the Surat city are shown in Table 1.

Table 1: Major Floods in Surat city (After 1950)

Year	Magnitude of Flood (lakhs cusecs)	Flood level (m)	Remarks
Sep. 17, 1959	12.94	11.55	Warning level 8.50 m & Danger level 9.50 m
Aug.06, 1968	15.60	12.08	
Sep.08, 1969	8.56	9.96	
Sep. 08, 1994	5.25	10.10	
Sep.16, 1998	7.00	11.40	
Aug.06, 2006	9.09	12.40	

From Table 1, it can be seen that significant changes have taken place in the Surat city as the level which has been attained in relatively low recent flood (Flood for year 2006), was achieved at relatively higher flood earlier (Flood for Year 1969). The major reasons for reduction in the capacity of the Tapi River at the Surat city could be encroachment in the flood plain in the city due to rapid industrialisation in Hazira belt, siltation in the channel due to effect of tides and construction of river structures like major bridges etc. The flood of Year 2006 alone had caused a direct damage to Rs.21000/- Crores and major activities remained halt for more than one month after the flood. The flooding situations may worsen due to impact of climate change on precipitation of Tapi basin and sea level rise in near future.

Availability of Water Resources

The unprecedented growth and industrialization of the Surat and its adjoining cities and towns, have created huge demands for domestic and industrial water requirement on the Tapi water resource. Also, many river diversion works are being coming up upstream of Ukai dam and, under such circumstances, the inflow of water into reservoir would be insignificant during non-monsoon period of the year. The availability of water and its quality in the Ukai command area may get severe blow under changing climatic scenarios due to rise in temperature, increase in frequency of food and drought and the sea level rise.

Ongoing studies

Keeping in view, the severity of flood situation in the Surat city and increasing demand on the available water resources, a **Nationally Coordinated Project (NCP)**, funded from All India Council for Technical Education (AICTE), New Delhi is under implementation at SVNIT Surat..

The brief outcome of aforesaid activities is summarized as below**:**

a) The data base of Tapi basin is under process of collection from the organisations, like Central Water Commission, Gujarat Water Resources, Water Supply and Kalpsar department, Surat Municipal Corporation and Indian Meteorological, State Water Data Centre (SWDC) Gujarat.

b) The flood prediction model at the Surat city for various releases from Ukai dam, based on one dimensional models, like HEC-RAS and MIKE 11 has already been completed. The model based on 2-D approach using MIKE Flood is under the process of completion.

c) Studies on inflow prediction into Ukai reservoir and reservoir operation have been initiated.

d) Studies on optimal irrigation planning in Ukai irrigation command area in under progress using multi-objective fuzzy linear programming model.

e) A Workshop on 'Flood forecasting and protection measures' 'during Aug.2010 and a National Conference on 'Hydraulics and Water Resource', 'HYDRO-2011' were organised at SVNIT and partly funded from completed NCP project.

f) The personnel from field organisations, Like Central Water and Research Power station (CWPRS, have been enrolled for their PhD/ M Tech (Research) programmes to tackle the problem related the Tapi basin.

Scope of work and methodology

The quantum of work involved in the proposed project "***IMPACT OF CLIMATE CHANGE ON WATER RESOURCES OF TAPI BASIN"*** can be summarized as follows:

a) Development of data base of Tapi basin related with stream gauging data, land use and land cover, topographical maps, soil map; reservoir inflow-outflow, levels, and releases pattern; cropping pattern of Ukai command area including crop calendar; bathymetry of lower Tapi river and Surat city, past flood levels in Surat city; and Tidal levels.

b) Analysis of past data for detection of trend in hydro-meteorological and hydrological variables in Tapi basin.

c) Calibration and validation of selected hydrological and hydraulic models from the base line data

d) Estimation of spatial and temporal water availability in the Tapi basin by using the downscaled Predictands as inputs to the hydrological model.

e) Using downscaled Predictands at the basin level, assess the performance of multipurpose storage reservoir (UKAI reservoir) to fulfill its intended objectives, viz. irrigation, domestic and industrial water supply; hydropower generation and flood control.

The detailed methodologies to achieve aforesaid objectives are depicted in the form of flow chart, see Fig 2.

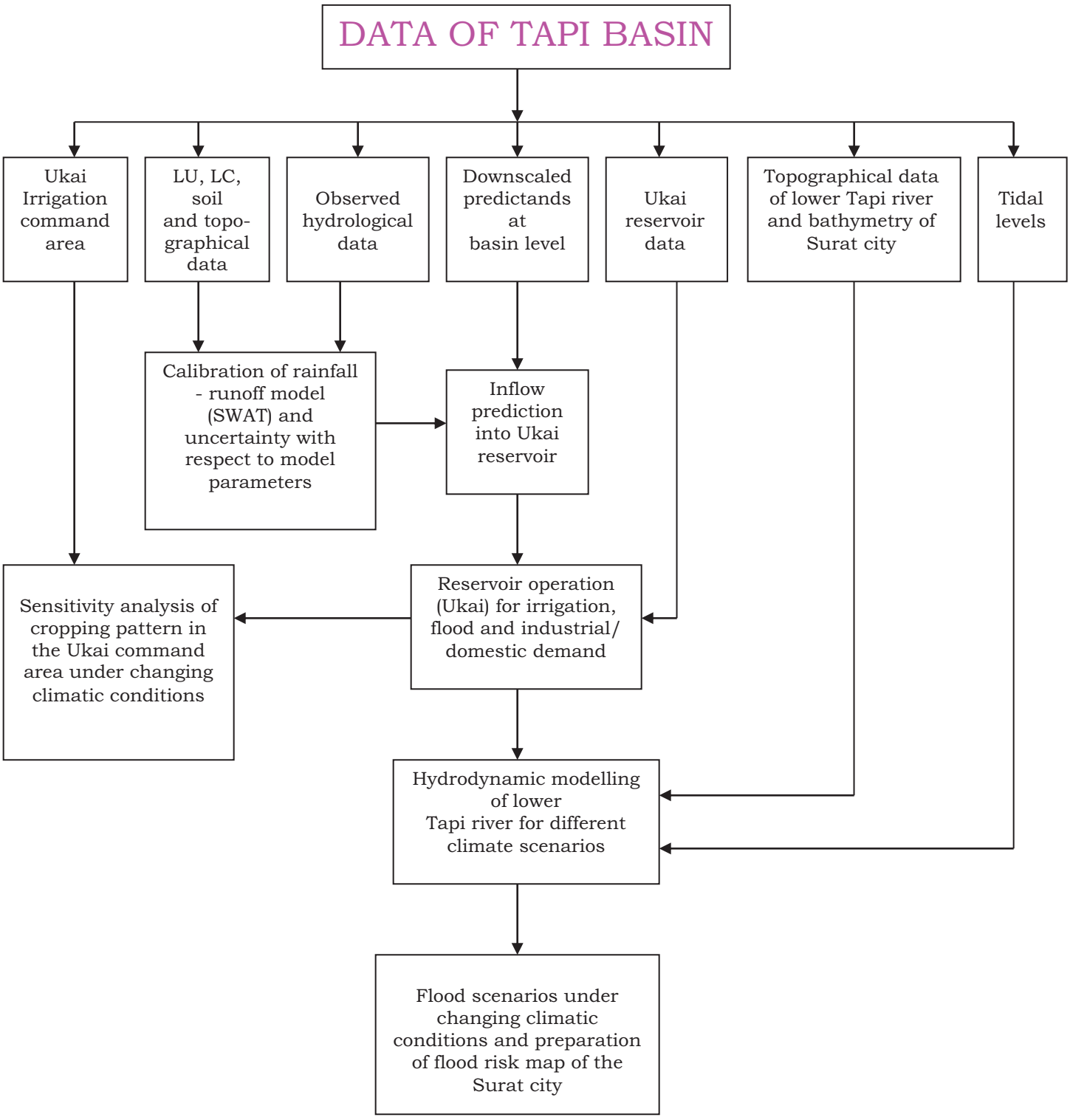

Fig. 2. Methodology for Hydrologic and Hydraulic Analyses under changing Climate conditions

The following team would be involved in execution of aforesaid project:

a) Sardar Vallabhbhai National Institute of Technology Surat (SV NIT) : **Lead Institute**

b) Malaviya National Institute of Technology Jaipur: **Co-coordinating Institute**

c) Maulana Azad National Institute of Technology Bhopal: **Co-coordinating Institute**

The responsibility of the Institutes, involved in the project, is described in succeeding paragraphs:

SVNIT Surat

a) Collection/extraction of data, with the help of associate institutes, related to stream gauging, land use and land cover, topographical maps, soil map; reservoir inflow-outflow, levels, and releases pattern; cropping pattern of Ukai command area including crop calendar; bathymetry of lower Tapi river and Surat city, past flood levels in Surat city; and Tidal levels.

b) Development of rainfall-runoff and sediment yield model for Purna catchment (subcatchment-2, see Fig.3) for present as well future scenarios.

c) Detection of trend in hydro-meteorological variables (as per TOR-2) in the sub-catchment of Tapi basin identified for the study.

d) Assessment of reservoir (Ukai) behavior under changing climatic conditions vis-à-vis present condition, and propose revised rule curve for its operation, if required.

e) Sensitivity analysis of cropping pattern in Ukai command area under revised water yield in Ukai reservoir under changing climatic conditions.

f) Calibration of hydraulic model (MIKE Flood) and prediction of flood situations in the downstream of Ukai reservoir under present and changing climatic situations.

MNIT Jaipur

a) Development of rainfall-runoff and sediment yield model for upper Tapi basin (sub-catchments 1, 3, 4, see Fig.3) after taking input from SVNIT for Purna catchment at the junction of Tapi River.

b) Detection of trend in hydro-meteorological variables (as per TOR-2) in the sub-catchment of Tapi basin identified for the study.

c) Performance evaluation of Hathnur reservoir under changing climatic conditions for both observed as well as future RCP scenario.

d) To assist lead Institute in collection/extraction of field data**.**

MANIT Bhopal

a) Development of rainfall-runoff and sediment yield model for Sub catchments 5,6,7,8,9,10,11, see Fig.4; and compute the inflow into Ukai reservoir after taking input from the MNIT Jaipur.

b) Detection of trend in hydro-meteorological variables (as per TOR-2) in the sub-catchment of Tapi basin identified for the study**.**

c) Performance evaluation of Girna reservoir under changing climatic conditions for both observed as well as future RCP scenario.

d) To assist lead Institute in collection/extraction of field data**.**

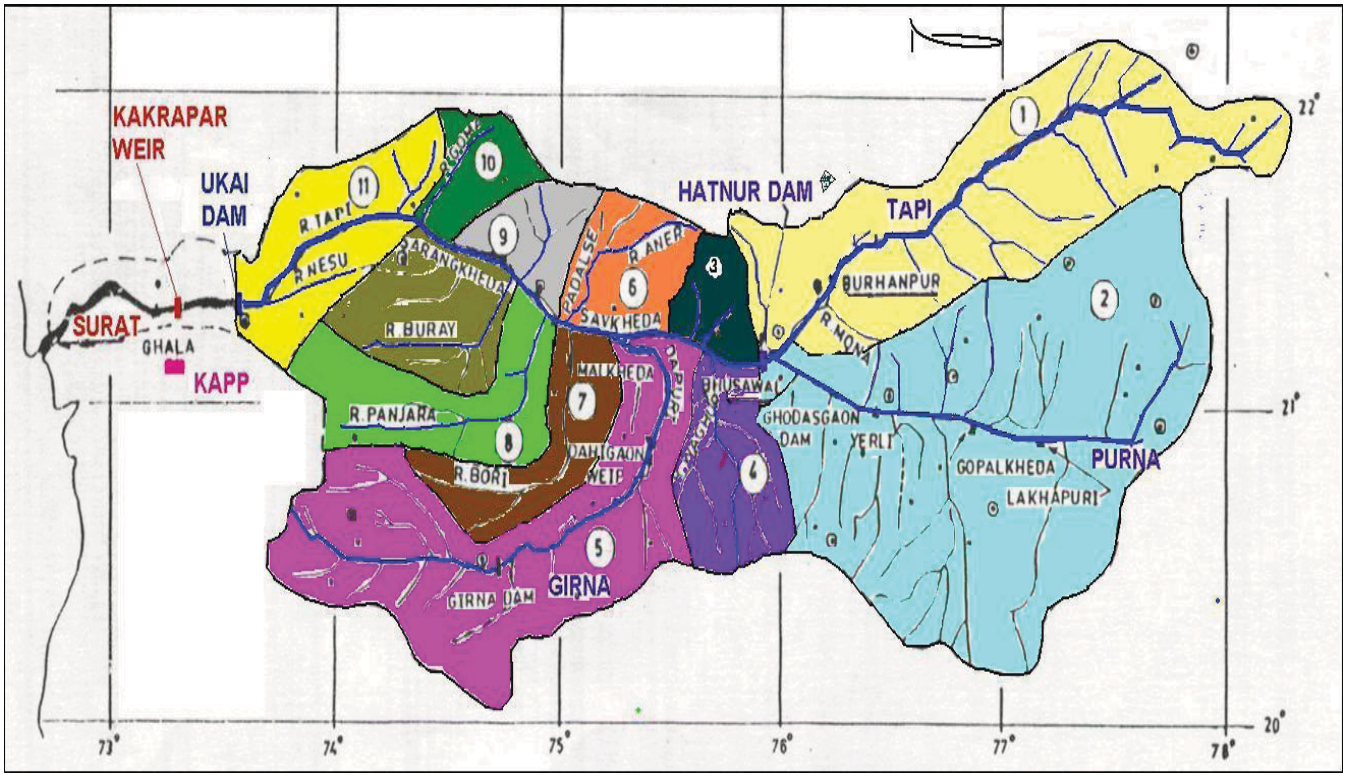

Fig.4 Description of the Catchment of Tapi Basin