Chandranath Chatterjee

Research Efforts

Chandranath Chatterjee

<u>Research Areas and Work Done</u>

1. Flood inundation modeling, hazard and risk assessment

- **(i)** **Flood risk modeling using satellite remote sensing data for optimal crop planning**
- **(ii)** **Flood inundation modeling and hazard assessment for lower Bharathapuzha basin**
- **(iii)** **Hydrodynamic modeling of a potential emergency flood storage area at the Middle Elbe River, Germany**
- **(iv)** **Site specific flood hazard assessment using MIKE Flood model**
- **(v)** **Hydrological study of NTPC Kahalgaon power station area**

2. Flood estimation using deterministic and probabilistic approaches

- **(i)** **Development of regional flood formulae for gauged and ungauged catchments using L-moments approach**
- **(ii)** **Design flood estimation using HEC-HMS model, L-moment based frequency analysis and CWC method**
- **(iii)** **PMF and Dambreak Flood Estimation for Nagarjunasagar Dam**
- **(iv)** **Development and uncertainty analysis of GIUH based Clark and Nash models**

3. Flood forecasting

- **(i)** **Uncertainty assessment and ensemble flood forecasting using BANNs**

4. Remote sensing and GIS applications in surface water hydrology

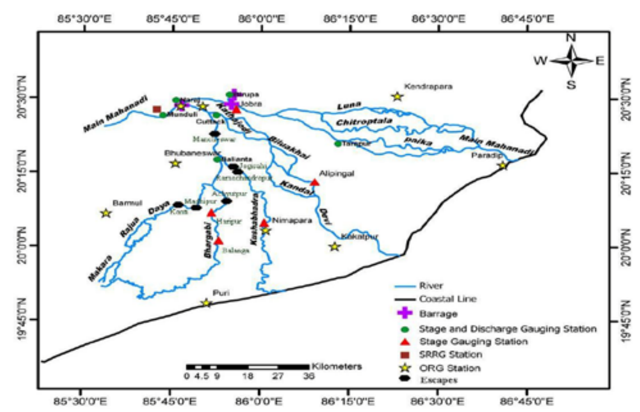
- **(i)** **Evaluation of soil conservation activities of Damodar Valley Corporation**
- **(ii)** **Development of a management model for the waterlogging and drainage congestion problem of Mokama group of Tals in Central Bihar**
- **(iii)** **Evaluation of shifting characteristics of river Ganga from Ara to Patna using RS data**

Flood Inundation Modeling, Hazard and Risk Assessment

Flood risk modeling using satellite remote sensing data for optimal crop planning

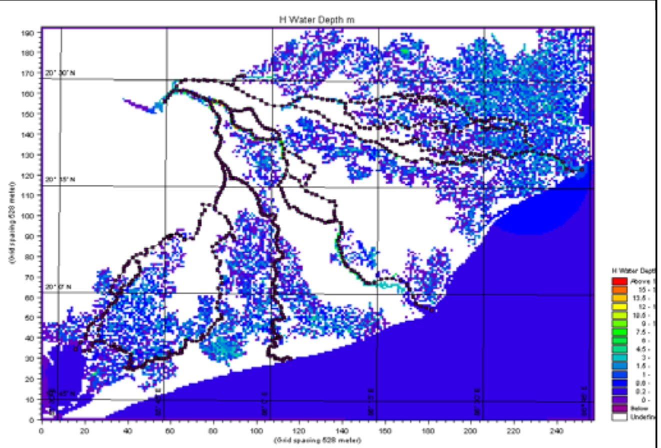
Objectives:

- (i) To assess flood hazard in the delta region of Mahanadi river basin using RS data.
- (ii) To compare the above flood hazard with one using MIKE FLOOD model.
- (iii) To allocate paddy varieties based on flood risk for maximizing net agricultural benefits.

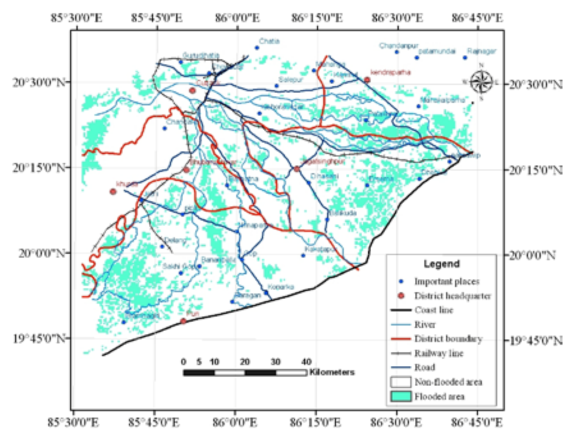


Map of Mahanadi delta with gauging sites

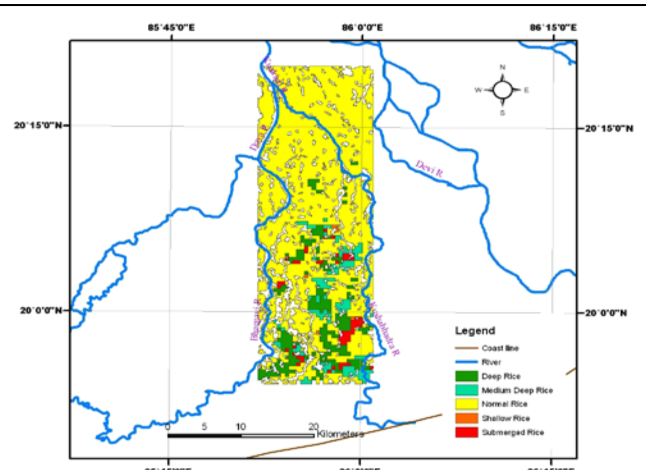
Escapes for diverting flood discharge



Flood hazard map using MIKE FLOOD (100 yr RP)



Flood hazard map using RS data (48 yr RP)



Optimal allocation of rice varieties

- √ The study demonstrates the potential of using the SRTM DEM for flood hazard assessment.
- √ The developed flood hazard maps are useful for (a) providing information for land use planning, (b) forecasting flood inundated areas
- √ The optimal paddy allocation will make the farmers aware about the rice varieties to be grown for maximizing benefits.

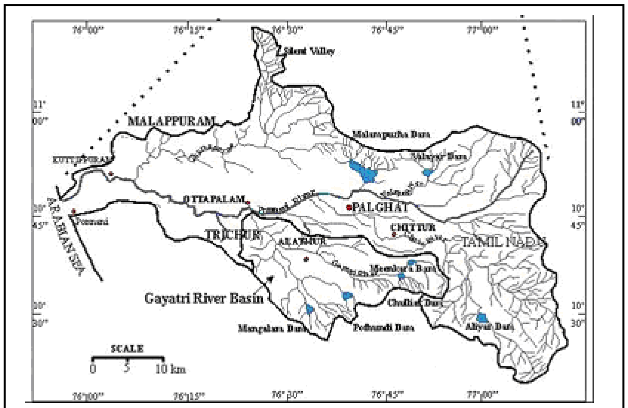
Flood Inundation Modeling and Hazard Assessment for Bharathapuzha Basin

Utility:

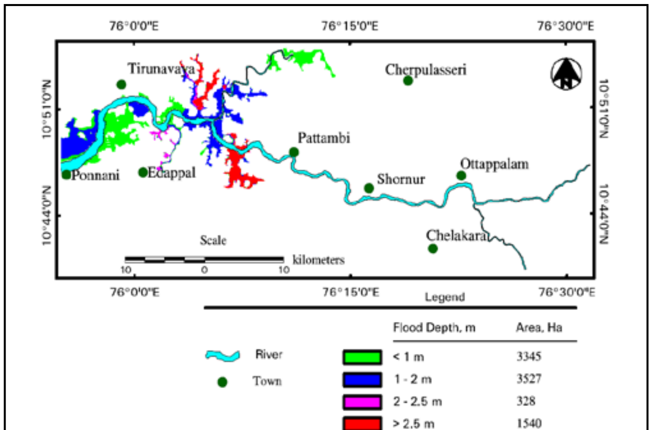
This flood hazard map may be used to regulate different activities in the floodplains as well as to evaluate the flood risk.

Objectives:

- **(i)** **To carry out regional flood frequency analysis to assign different probabilities to extreme flood scenarios,**
- **(ii)** **To calibrate and validate MIKE 11 and MIKE FLOOD models for the study area,**
- **(iii)** **To carry out sensitivity analysis of MIKE 11 and MIKE FLOOD models to different inputs,**
- **(iv)** **To assess flood hazard for the study area based on MIKE FLOOD simulation of extreme flood scenarios.**



Index Map of Bharathapuzha basin



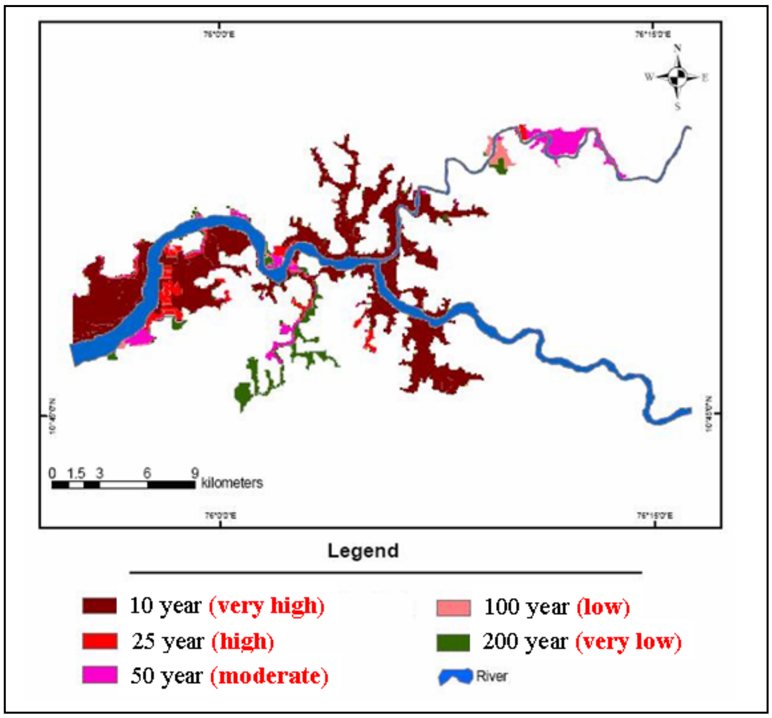
Inundation Area and Depth for 100 Year Flood

Flood hazard is assessed for the lower reaches of Bharathapuzha basin in terms of

- √ **frequency of flooding,**
- √ **depth and duration of flooding,**
- √ **flood wave velocity, and**
- √ **rate of rise of water level.**

The degree of exposure of the receptors (different land-use classes from the land-use/land cover map) to the hazard is assessed in terms of

- √ **the area of different land-use/land cover classes under different depths of maximum flooding.**



Flood Hazard Map for Lower Bharathapuzha Basin

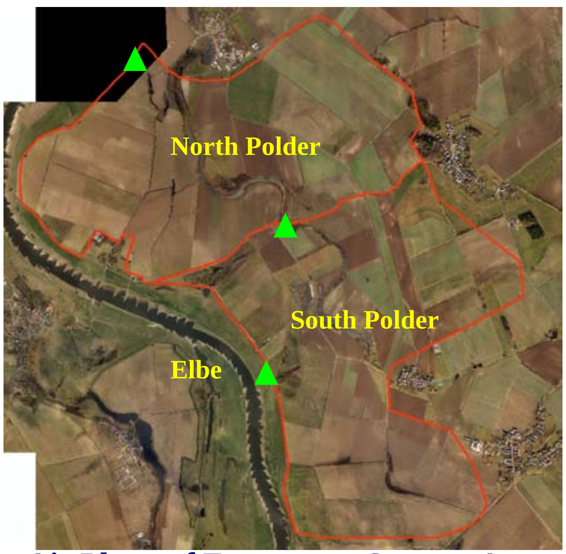
Hydrodynamic Modeling of an Emergency Flood Storage Area at the Elbe River

Utility:

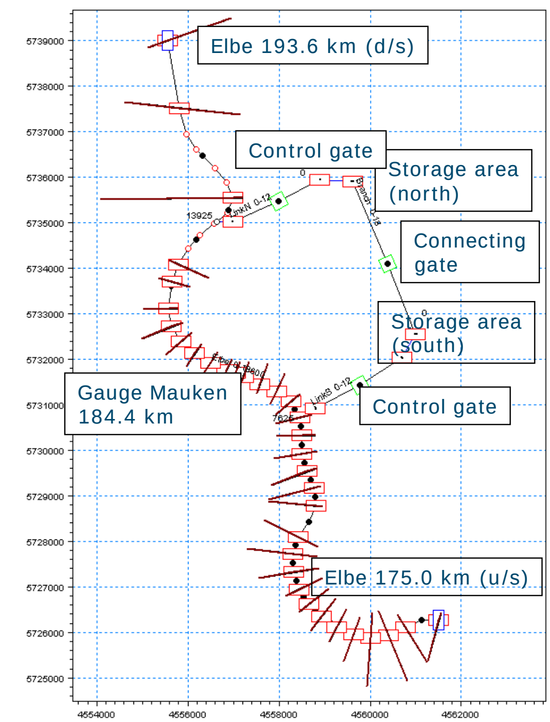
An emergency flood storage area is used to reduce the flood peak in the main river and hence, protect downstream areas from being inundated.

Objectives:

(i) Selection of most suitable hydrodynamic model (1D vs Coupled 1D-2D) for simulation, and
(ii)Simulation of the flooding and emptying processes in the polder using selected model.

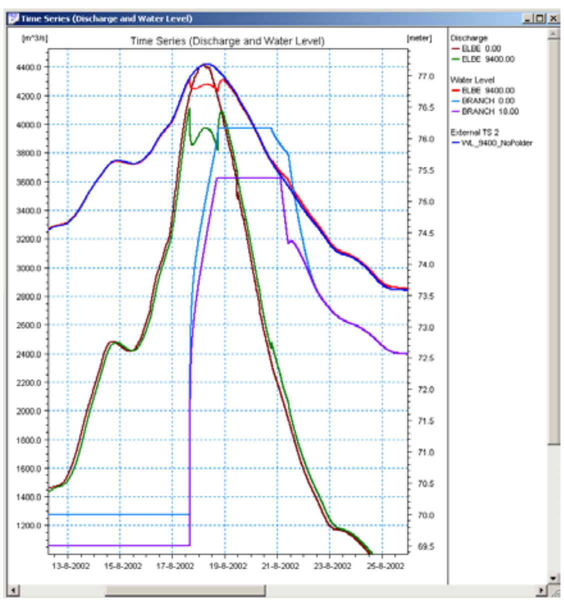


Air Photo of Emergency Storage Area



MIKE 11 Model Layout

A 1D model may be used to study the water level and discharge reductions in the main river while a 1D-2D model may be used when the study of flow dynamics in the polder is of particular interest.



- √ **Detailed sensitivity analysis of the 1D and 1D-2D models is carried out w.r.t. to Manning's n, DEMs of different resolutions, no. of c/s used and the gate opening time as well as gate opening/closing duration.**
- √ **The potential polder is capable of reducing the peak water levels in the Elbe by about 10 to 20 cm.**
- √ **The magnitude of the attenuation depends on**
  - **steepness of the flood hydrograph,**
  - **applied control strategy with well-timed gate operations.**

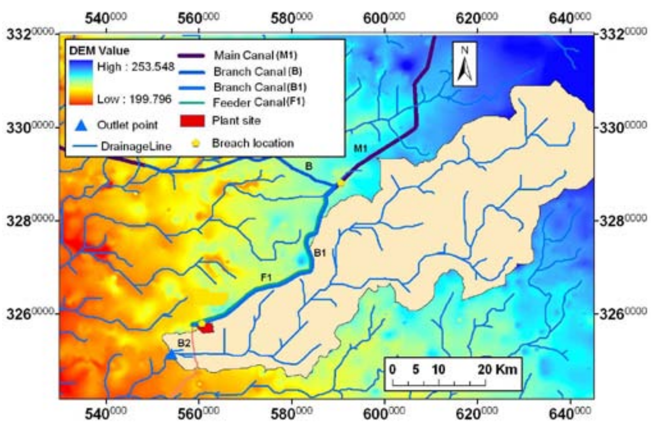
Site Specific Flood Hazard Assessment using MIKE Flood Model

Background:

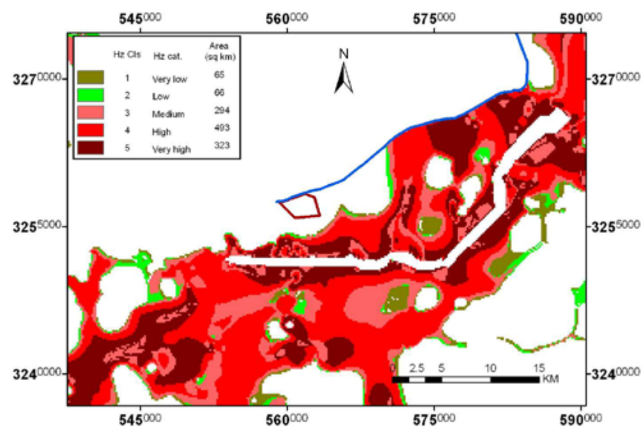
Site specific flood hazard assessment is essential for locations where major industries/plants are proposed. In such an assessment, in addition to natural cause of flooding, the breaches in manmade hydraulic structures liable to cause flooding at a site would be of prime concern which are generally ignored in regional or basin scale hazard assessment.

Objective:

To assess the flood hazard (both at regional and local scales) in an area adjacent to a canal, where a major industry/plant has been proposed.



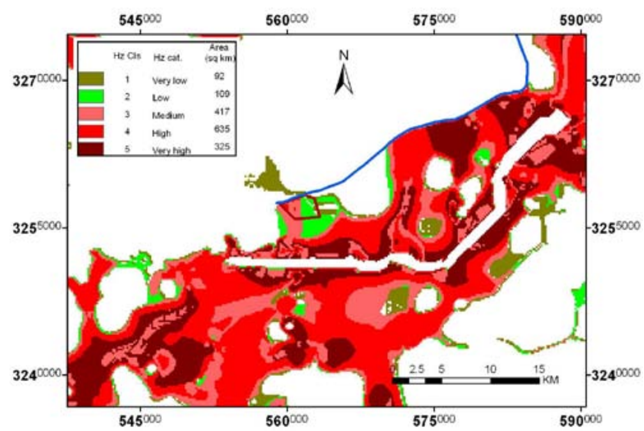
Location map showing plant site



Flood hazard map based on regional assessment

Methodology:

- **In regional flood hazard assessment, the PMF in main river is routed and its flooding impact at the plant site is studied.**
- **In site specific hazard assessment, in addition to PMF in main river, the PMP at plant site and breach in the canals near the plant site have been considered.**
- **A flood hazard classification scheme using three parameters namely the flood depth, cross product of flood depth and velocity, and flood duration have been proposed.**



Flood hazard map based on local assessment

Conclusion:

Flood hazard assessment on regional scale facilitates identification of the safe site while on local scale helps in suggesting flood protection measures.

Hydrological Study of NTPC Kahalgaon Power Station Area

Background:

Flooding due to heavy rainfall at Kahalgaon and its neighbouring areas in the past few years (1995 – 99) resulted in heavy loss to the Kahalgaon Super Thermal Power Project (KhSTPP).

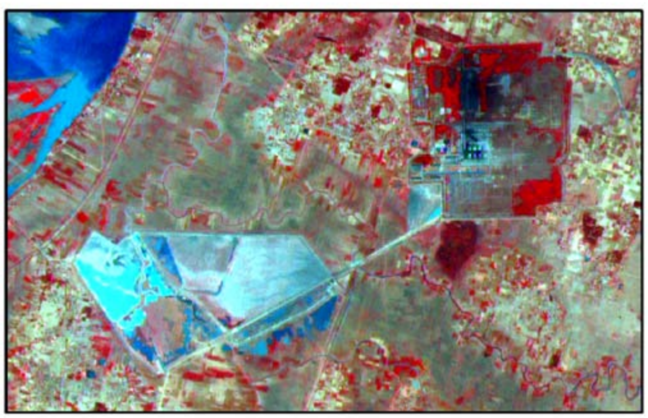
The railway line used for transporting coal to the plant was breached, approach road to the fly ash dyke was damaged, and the plant area along with nearby villages was inundated.

Objective:

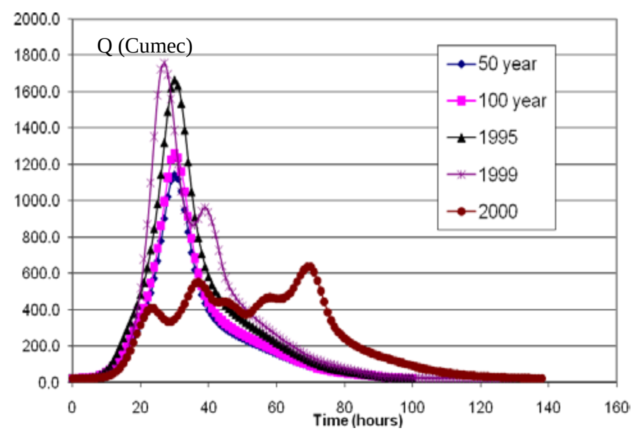
To systematically analyze available data/information and provide likely areas/extent of inundation under different scenarios of rainfall and man-made structures like road/rail embankments, power plants etc. and level of water in river Ganga.

Methodology:

- Event based rainfall–runoff modeling has been carried out using two different approaches for virgin condition prevailing in the catchment using HEC-1 model.
- Flood routing study has been carried out considering various scenarios of developmental activities in the catchment of Koa Nala using DAMBRK package.



Merged IRS-1C LISS-III and PAN image of NTPC power plant at Kahalgaon



Comparison of Hydrographs at PWD Bridge

Recommendations:

- Average elevation of plant area is 34.5 m. The plant has to be protected against the excess water level of 0.6 meter (i.e. EL 35.1 meter) for case of 1999 flooding.
- Proper openings are recommended in the existing structures MGR and Rd2. For example, for the 1999 flood, 300 m extra opening in MGR and 100 m extra opening in Rd2 decreases the maximum water level at MGR from 36.36 m (existing) to 35.42 m.

Flood inundation modeling, hazard and risk assessment

Publications:

1. Patro, S., **Chatterjee, C.**, Singh, R., and Raghuwanshi, N. S. (2009), "Hydrodynamic modelling of a large flood prone river system in India with limited data", Hydrological Processes, Wiley Interscience, 23(19), 2774-2791.

2. Patro, S., **Chatterjee, C.**, Mohanty, S, Singh, R., and Raghuwanshi, N. S. (2009), "Flood inundation modeling using MIKE FLOOD and remote sensing data", Journal of ISRS, Photonirvachak and Springer Verlag, 37, 107-118.

3. **Chatterjee, C.**, Förster, S., and Bronstert, A., (2008), "Comparison of hydrodynamic models of different complexities to model floods with emergency storage areas", Hydrological Processes, Wiley InterScience, 22(24), 4695-4709.

4. Förster, S., **Chatterjee, C.**, and Bronstert, A., (2008), "Hydrodynamic simulation of the operational management of a proposed flood emergency storage area at the middle Elbe River using MIKE 11", River Research Applications, Wiley InterScience, 24(7), 900-913.

Flood Estimation using Deterministic and Probabilistic Approaches

Development of Regional Flood Frequency Relationships using L-moments

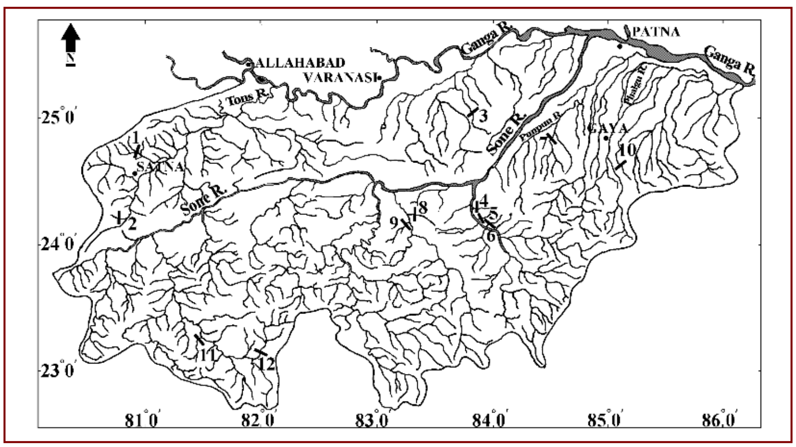
Utility

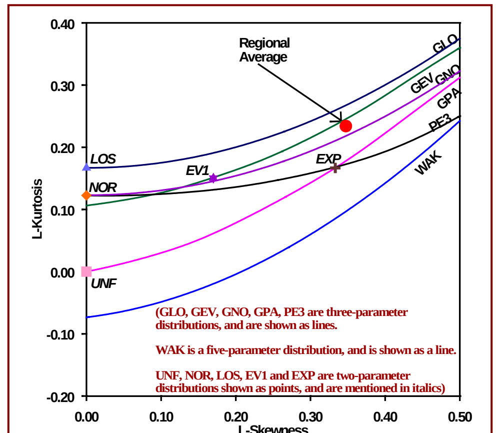
Design flood estimation for almost all types of hydraulic structures viz. check dams, spillways, ponds, agricultural drainage systems, road and railway bridges, barrages, small size dams as well as for flood plain zoning, economic evaluation of flood protection projects etc. (Excluding large and intermediate size dams).

Regional flood formulae have been developed using L-moments for the following regions:

- ✓ **Middle Ganga Plains Subzone 1(f),**
- ✓ **Sone Subzone 1(d),**
- ✓ **North Brahmaputra river system, and**
- ✓ **Mahanadi Subzone 3(d).**

Regional Flood Formulae for Small Watersheds of Sone Subzone 1(d)



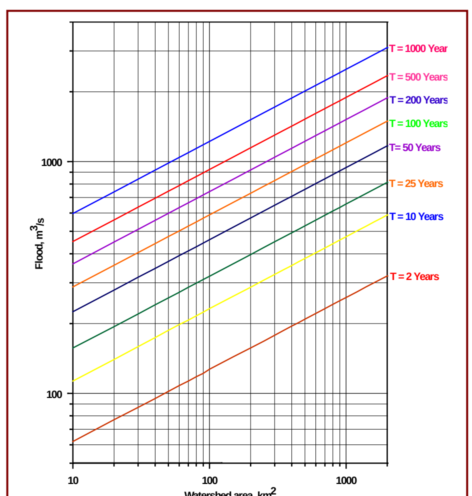


L-moment ratio diagram for Sone Subzone 1(d).

Regional flood formula for gauged watersheds:

$$Q_T = \left[-1.091 + 1.688 \left(-\ln \left(1 - \frac{1}{T} \right) \right)^{-0.260} \right] \times \overline{Q}$$

Return Period	2	5	10	25	50	100	200	500	1000
Growth Factors	0.766	1.402	1.939	2.786	3.563	4.489	5.594	7.393	9.068



Variation of floods of various return periods with watershed area for Sone Subzone 1(d)

Regional flood formula for ungauged watersheds:

$$Q_T = \left[-43.040 + 66.592 \left\{ -\ln \left(1 - \frac{1}{T} \right) \right\}^{-0.26} \right] A^{0.311}$$

<u>**Design flood estimation using HEC-HMS model, L-moment based frequency analysis and CWC method**</u>

Background

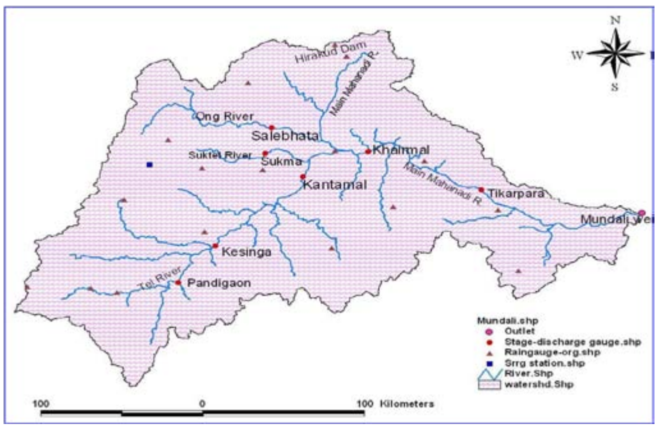
√ **Design flood is defined as the flood which ensures no damage or serious threat to the stability of the structure.**

√ **Depending upon the size and hydraulic head of the structure, choice of the design flood estimation method is made.**

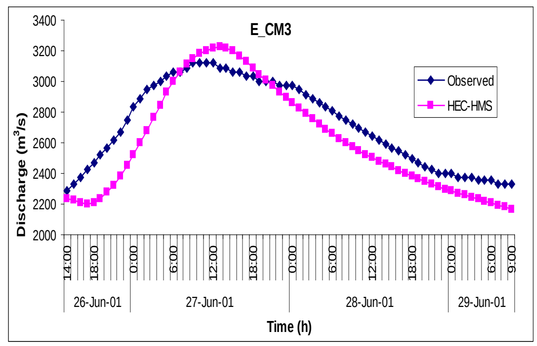
Objectives:

(i) **To derive the design flood hydrograph at Mundali weir using (a) HEC-HMS model and (b) L-moment based regional flood frequency analysis.**

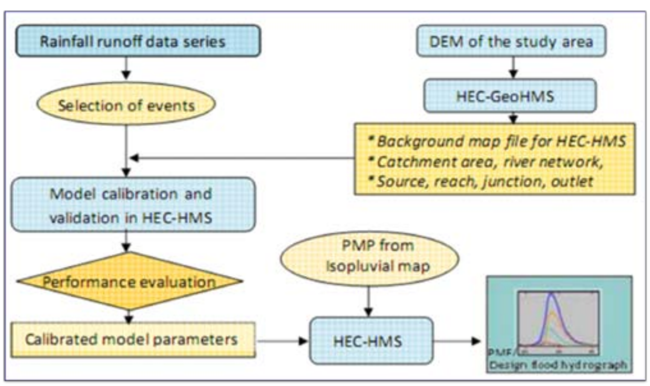
(ii) **To compare the above design flood estimates with Central Water Commission (CWC) unit hydrograph (UH) method.**



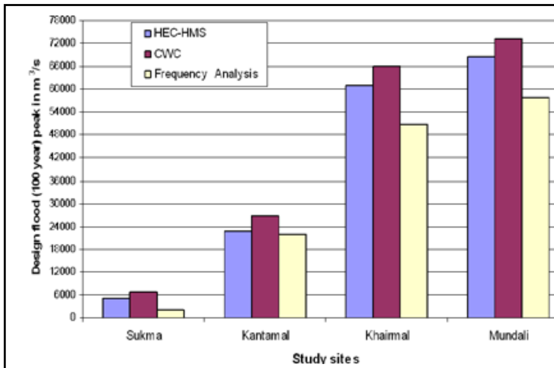
Map of middle reaches of Mahanadi basin



Validation of HEC-HMS model



Flow chart for HEC-HMS model



Comparison of design flood estimates

Findings:

➢ **Estimated 100 year return period design flood peaks at Mundali weir using HEC-HMS, CWC method and regional flood frequency analysis are 68425 m^3/s, 73325 m^3/s and 57852 m^3/s, respectively.**

➢ **Comparison of computed design flood peaks using all methods shows that inspite of limited data availability, the HEC-HMS model provides reasonable values of design flood.**

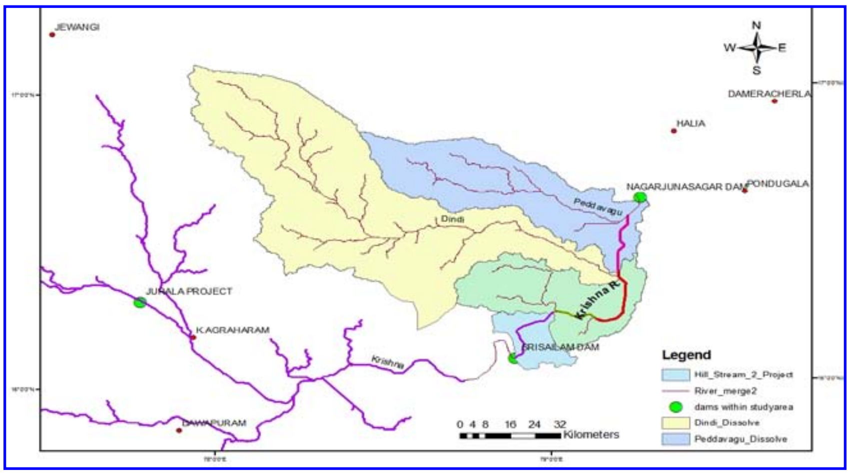
PMF and Dambreak Flood Estimation for Nagarjunasagar Dam

Background:

In October, 2009, Srisailam dam (located 122 km u/s of NS dam) experienced record inflow of 71,900 cumecs which is very close to its PMF value of 73,800 cumecs. This huge inflow threatened the dam and the impact of the resulting flood affected a population of 18.16 lakh and caused an estimated damage of around Rs. 13,000 crores.

Objective:

- **To estimate the PMF of Nagarjunasagar dam, and**
- **To estimate the dam break flood (of Srisailam dam) at Nagarjunasagar dam.**



Sub-basins between Srisailam dam and Nagarjunasagar dam

Methodology:

- **The catchment area between the Srisailam and Nagarjunasagar dams is subjected to 1, 2 and 3 day PMP values (along with time distribution) obtained from IITM.**
- **The PMF of Srisailam dam is used as the upstream discharge source and CWC unit hydrograph approach is used in HEC-HMS model to obtain the PMF of NS dam.**
- **Subsequently, a dam break scenario of Srisailam dam is simulated using MIKE 11 model.**

Results:

- **The PMF peak for Nagarjunasagar dam is estimated to be 77,945 cumecs.**
- **Failure of only five monolithic slabs up to the bed level of Srisailam reservoir causes a peak flood of 1,23,381 cumecs at Nagarjunasagar dam.**
- **This dam break flood is much higher than the PMF estimate of NS dam and would only take 12 hours to reach NS dam providing little time for taking up any preventive measures.**

Flood Estimation by GIS based GIUH Clark and Nash Models

Advantages:

The developed GIUH models are especially useful for estimation of floods for the ungauged catchments where the conventional data like rainfall and toposheets are generally available but the required short interval runoff data are not available for many of the small to medium size catchments.

Index map of Ajay river basin

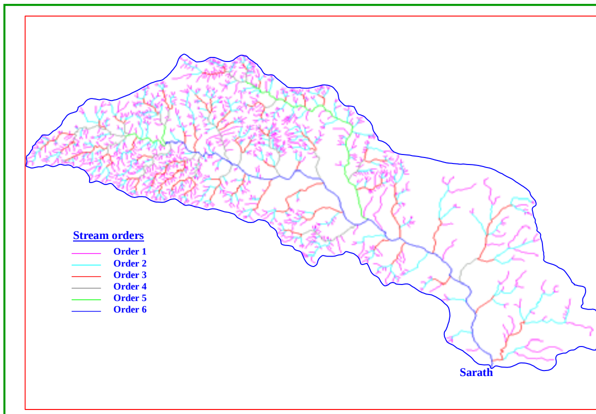
- **Flood estimation by GIUH based Clark and Nash Models**

$$q_p = 1.31\, R_L^{0.43}\, V / L_\Omega$$

$$t_p = 0.44\,(L_\Omega / V)(R_B / R_A)^{0.55}(R_L)^{-0.38}$$

- **Evaluation of Geomorphological Parameters using GIS**
  - ✓ bifurcation ratio (R_B),
  - ✓ length ratio (R_L),
  - ✓ area ratio (R_A),
  - ✓ length of the highest order stream (L_Ω),
  - ✓ length of the main steam (L), and
  - ✓ time area (TA) diagram of the catchment

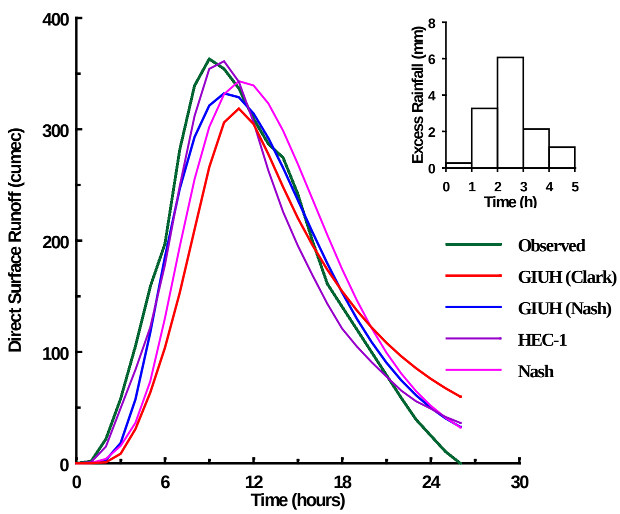
- **Uncertainty Analysis of the Parameters**



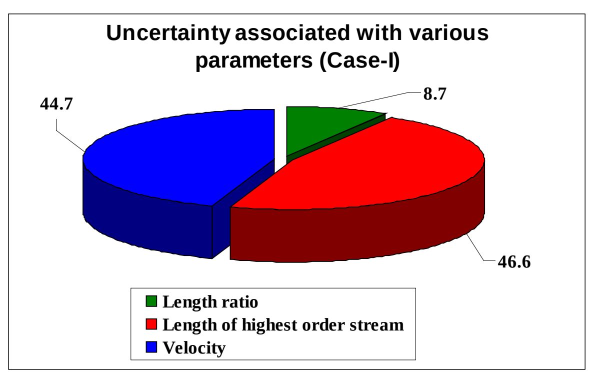
Drainage network map of Ajay catchment upto Sarath gauging site

Relative sensitivity coefficients (S_r)

Sl.	Parameter	Parameter value	S_r
1	R_L	2.375	0.430
2	L_Ω	59.67 km	-0.999
3	V	2.5 m/s	0.975



Comparison of observed and computed direct surface runoff hydrographs (Event No. 1)



Flood estimation using deterministic and probabilistic approaches

Publications:

Book Chapter

Kumar, R., and **C. Chatterjee** (2011), Development of regional flood frequency relationships for gauged and ungauged catchments using L-moments, in *IN EXTREMIS: Disruptive Events and Trends in Climate and Hydrology*, edited by J. P. Kropp and H. J. Schellnhuber, pp. 105-127, Springer.

Journals

1. Kumar, R., **Chatterjee, C.**, Singh, R. D., Lohani, A. K., and Kumar, S., (2007), "Runoff estimation for an ungauged catchment using geomorphological instantaneous unit hydrograph (GIUH)", Hydrological Processes, Wiley InterScience, 21, 1829-1840.

2. Kumar, R., Singh, R. D., **Chatterjee, C.**, Mani, P., and Panigrahy, N., (2007), "Advance deterministic and probabilistic modeling for design flood estimation", Journal of Institution of Engineers (I), Civil Divn., 88, 13-19.

3. Sahoo, B., **Chatterjee, C.**, Raghuwanshi, N. S., Singh, R., and Kumar, R., (2006), "Flood estimation by GIUH based Clark and Nash models", Journal of Hydrologic Engineering, American Society of Civil Engineers, 11(6), 515-525.

4. Kumar R. and **Chatterjee C.**, (2006), Closure to discussion on "Regional flood frequency analysis using L-moments for North Brahmaputra region of India" by V. V. Srinivas and A. Ramachandra Rao, Journal of Hydrologic Engineering, American Society of Civil Engineers, 11(4), 380-382.

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7. Kumar R., **Chatterjee C.**, Singh R.D., Lohani A.K. and Kumar S., (2004), "GIUH based Clark and Nash models for runoff estimation for an ungauged basin and their uncertainty analysis", International Journal of River Basin Management, 2(4), 281-290.

8. Kumar, R., **Chatterjee, C.**, Panigrahi, N., Patwari, B. C., and Singh, R. D. (2003). "Development of regional flood formula using L-moments for North Brahmaputra river system". Journal of the Institution of Engineers (I), Civil Engineering Division, Vol. 84, May, pp. 57-63.

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10. Kumar, R., **Chatterjee, C.**, and Kumar, S. (2003). “Regional flood formulas using L-moments for small watersheds of Sone subzone of India”. Journal of Applied Engineering in Agriculture, American Society of Agricultural Engineers, USA, 19(1), January, pp. 47-53.

11. Kumar, R., **Chatterjee, C.**, Singh, R. D., Lohani, A. K., and Nema, R. K. (2002). "Flood estimation for ungauged catchments using GIS and GIUH-based Nash model". Asian-Pacific Remote Sensing and GIS Journal, Economic and Social Commission for Asia and the Pacific, United Nations, New York, 15, December, pp. 11-20.

12. Kumar, R., **Chatterjee, C.**, Kumar, S., Jain, S. K., Lohani, A. K., and Singh, R. D. (2001). “Intercomparison of responses of HEC-1 package and Nash model”. Hydrology Journal of IAH, Roorkee, 24(3), September, pp. 13-24.

13. Kumar, R., **Chatterjee, C.**, Lohani, A. K., Kumar, S., and Singh, R. D. (2002). "Sensitivity analysis of the GIUH based Clark model for a catchment". Water Resources Management, Kluwer Academic Publishers, Netherlands, 16, August, pp. 263-278.

14. **Chatterjee, C.**, Jha, R., Lohani, A. K., Kumar, R., and Singh, R. (2002). "Estimation of SCS curve numbers for a basin using rainfall-runoff data". Indian Society for Hydraulics Journal of Hydraulic Engineering, 8(1), March, pp. 40-49.

15. Kumar, R., **Chatterjee, C.**, Kumar, S., Lohani, A. K., and Singh, R. D. (2002). “Estimation of direct surface runoff hydrograph for a basin using HEC-1 Package and Nash model”. Journal of the Institution of Engineers (I), Civil Engineering Division, Vol. 82, February, pp. 181-185.

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Flood Forecasting

Uncertainty Assessment and Ensemble Flood Forecasting using WBNNs

Utility:

Flood forecasting with sufficient lead time is desirable for evacuation actions.

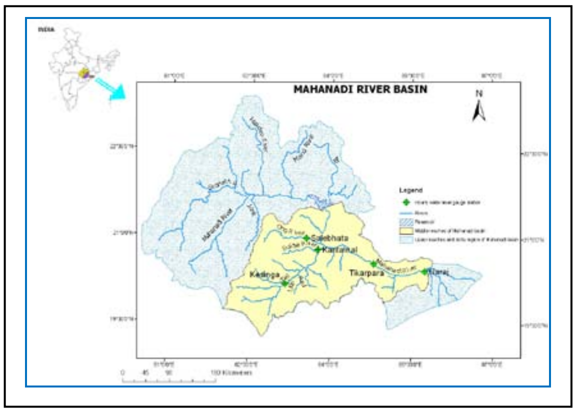
Existing Flood Forecasting Technique in India

Gauge to Gauge Correlation.

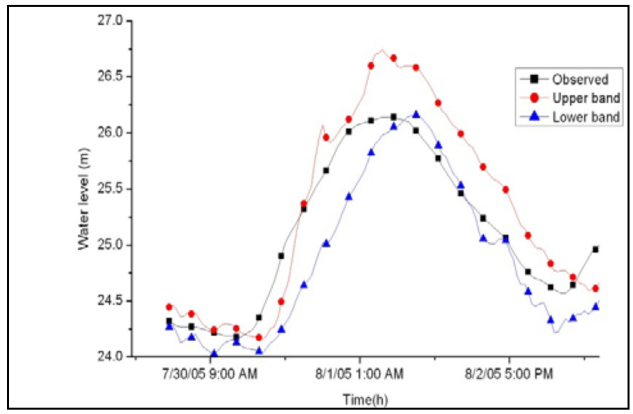
Objectives:

(i) To model the hourly water level forecasts using wavelet bootstrap based NNs (WBNNs),

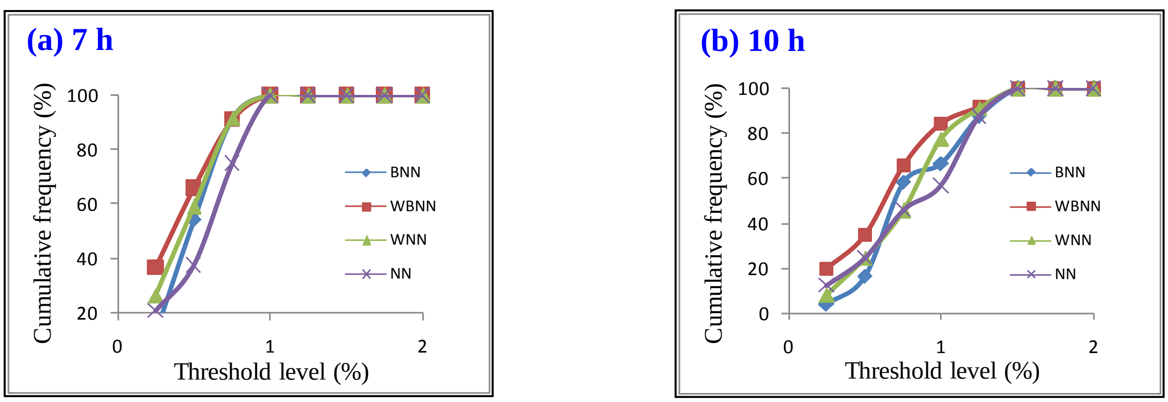
(ii) To quantify the uncertainty associated with hourly water level forecasts using WBNNs.



Index map of Mahanadi River basin



Confidence bands for WBNN model



Distribution of forecast errors for (a) 7 h and (b) 10 h lead times for high water level profile

- **WBNN model performs better than NN, BNN, WNN as well as MLR models.**
- **It also satisfies the CWC performance evaluation criterion reasonably well.**
- **Reliability of forecasts is improved by the confidence bands of WBNN model forecasts.**
- **Higher order neural network (HONN) model and self organising map (SOM) are also used to improve the forecasting performance.**
- **A user friendly software is developed for hourly water level forecasting at Naraj gauging station using the developed WBNN model.**

Flood forecasting

Publications:

1. Tiwari, M. K., Song, K. Y., **Chatterjee, C.** and Gupta, M. M. (2012) "Improving reliability of river flow forecasting using neural networks, wavelets and self organising maps" Journal of Hydroinformatics, (In Press)

2. Tiwari, M. K., Song, K. Y., **Chatterjee, C.** and Gupta, M. M. (2012), "River- flow forecasting using higher-order neural networks", Journal of Hydrologic Engineering, ASCE, 17(5), 655-666.

3. Tiwari, M. K. and **Chatterjee, C.** (2011), "A new Wavelet-Bootstrap-ANN hybrid model for daily discharge forecasting", Journal of Hydroinformatics, 13(3), 500-519. doi: 10.2166/hydro.2

4. Tiwari, M. K. and **Chatterjee, C.** (2010), "Development of an accurate and reliable hourly flood forecasting model using Wavelet- Bootstrap-ANN hybrid approach", Journal of Hydrology, Elsevier, 394, 458-470.

5. Tiwari, M. K. and **Chatterjee, C.** (2010), "Uncertainty assessment and ensemble flood forecasting using bootstrap based artificial neural networks (BANNs)", Journal of Hydrology, Elsevier, 382, 20-33.

6. Mukerji, A., **Chatterjee, C.** and Raghuwanshi, N. S. (2009), "Flood forecasting using ANN, Neuro-Fuzzy and Neuro-GA models", Journal of Hydrologic Engineering, American Society of Civil Engineers, 14(6), 647-652.

7. Kumar, S., Kumar, R., Chakravorty, B., **Chatterjee, C.**, and Pandey, N. G. (2003). "An artificial neural network approach for flood forecasting". Journal of the Institution of Engineers (India), Computer Engineering Division, Vol. 84, November, pp. 52-55.

Remote Sensing and GIS Applications in Surface Water Hydrology

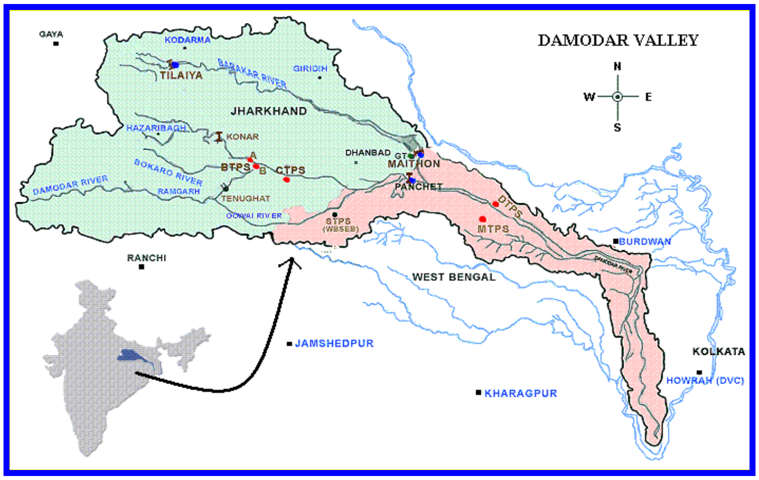
Evaluation of Soil Conservation Activities of Damodar Valley Corporation

Objectives:

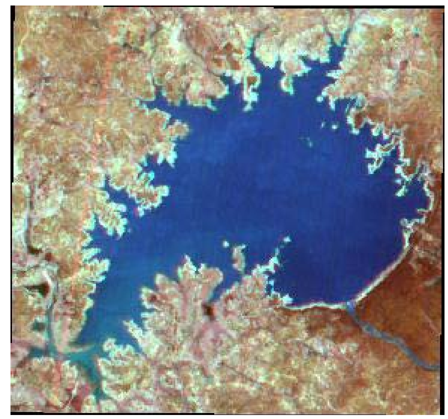
(i) To evaluate the effectiveness of soil conservation program on

- √ **runoff and sediment yield, and**
- √ **sedimentation and effective lives of DVC reservoirs.**

(ii) To propose a soil conservation plan for enhancing the lives of major reservoirs of DVC

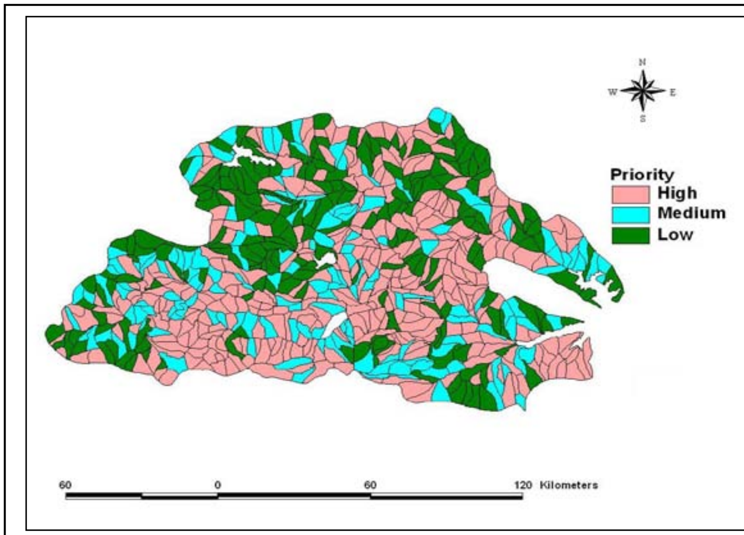


Damodar catchment, Jharkhand



Satellite image of Konar reservoir

- √ **Currently, 319, 113 and 189 micro-watersheds found to be under high, medium and low categories.**
- √ **In the first category all the sub-watersheds near the reservoirs with high priority class needs to be taken up for treatment followed by micro-watershed having average annual sedimentation rate > 40, 30-40, 25-30, 20-25, 15-20 and 5-15 t/ha, respectively.**



Priority map based on AVSWAT model simulations

- **With the current sedimentation rate, the lives of Konar, Panchet, Tilaiya and Maithon reservoirs are found to be 239, 136, 82 and 74 years, respectively.**
- **The lives would increase to 241, 220, 111 and 240 years, respectively if the proposed soil conservation measures are adopted in the catchments in a sequential manner.**

Development of a Water Management Model for the Drainage Congestion Problem of Mokama Group of Tals in Central Bihar

Problem:

- Surface waterlogging in the Tal (the most fertile stretch of land in Bihar) during monsoon months over an area of 1062 km^2 and consequent loss of agricultural production.
- Agricultural activities in the command areas of the upstream catchment suffer due to shortage of water.

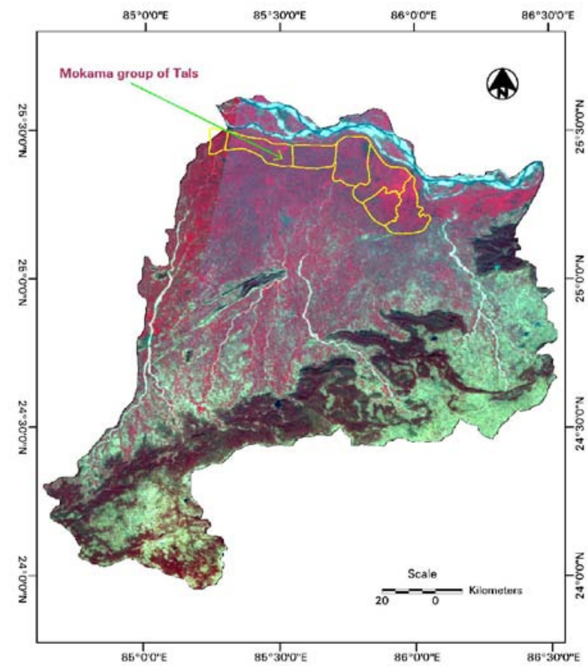


Fig. Mosaic FCC image of Kiul-Harohar basin prepared from four scenes of IRS-1C LISS-III data of February 06, 2001 and February 11, 2001

Past Work:

A number of experts and committees reviewed the problems:

- Dr. K. L. Rao (the then Union Minister, Irrigation), 1970 and 1972.
- Mr. C. C. Patel, Secretary, Irrigation, GOI (1976).
- Mokama Tal Technical cum Development Committee (1988).

However, no rigorous mathematical work was carried out to obtain a solution.

Formulation of an Optimization Model:

- ✓ Developed an optimization model with the objective of minimization of waterlogged area in the Mokama group of Tals.
- ✓ Studied the effect of varying inflows on the waterlogging conditions in the Tal and the cropping conditions in the upstream catchment.

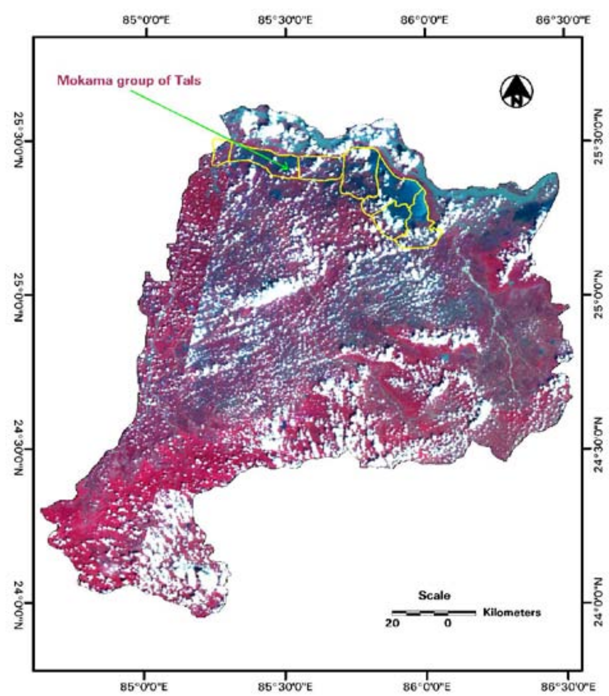
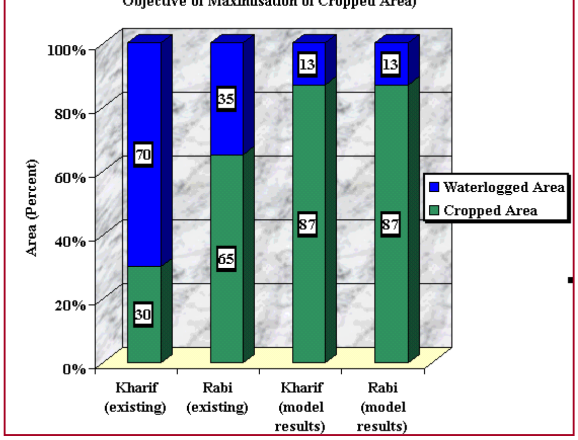


Fig. Mosaic FCC image of Kiul-Harohar basin prepared from four scenes of IRS-1C LISS-III data of September 21, 1999 and September 15, 2001

Result

Figure 6.4: Comparison of Existing Cropped and Waterlogged Area in Mokama Group of Tals with those of Model Results (under the Objective of Maximisation of Cropped Area)



Evaluation of Shifting Pattern of River Ganga between Ara and Patna using Satellite Remote Sensing Data

Data Used:

IRS 1C LISS-III & PAN data of 2000
IRS 1C LISS-III & PAN data of 1996
IRS 1A LISS-II data of 1989
SOI toposheet of 1974-76

Critical locations where major shifting has occurred:

(i) Neknamtola – 2.76 km
(ii) Jirakhantola – 1.22 km
(iii) Ami near Dighwara – 2.18 km
(iv) Daudpur near Danapur – 1.45 km (Widening – 3.8 km)
(v) Sabbalpur near Hajipur – 2.43 km

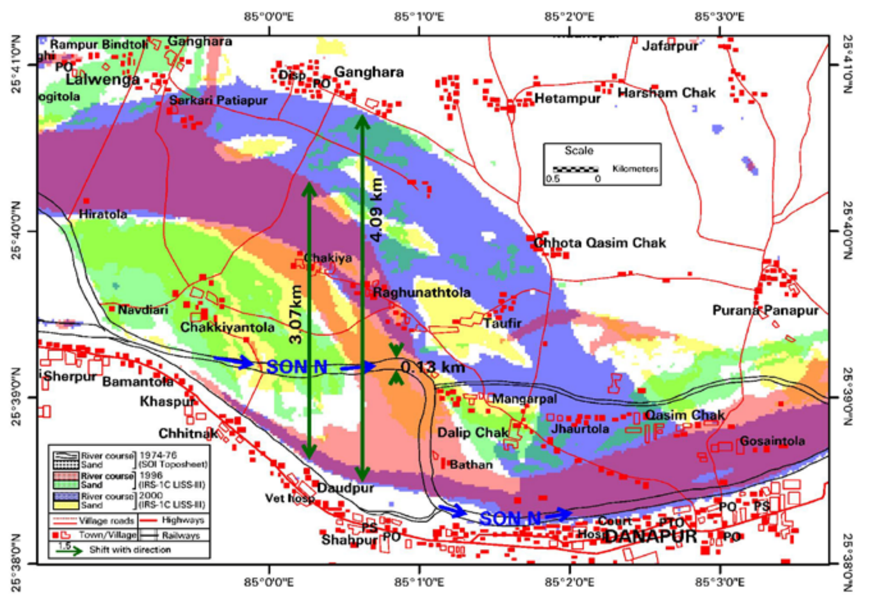


Fig. Details of widening of river Ganga at Daudpur near Danapur as obtained from SOI toposheet (1974-76) and IRS-1C LISS-III data (1996 and 2000)

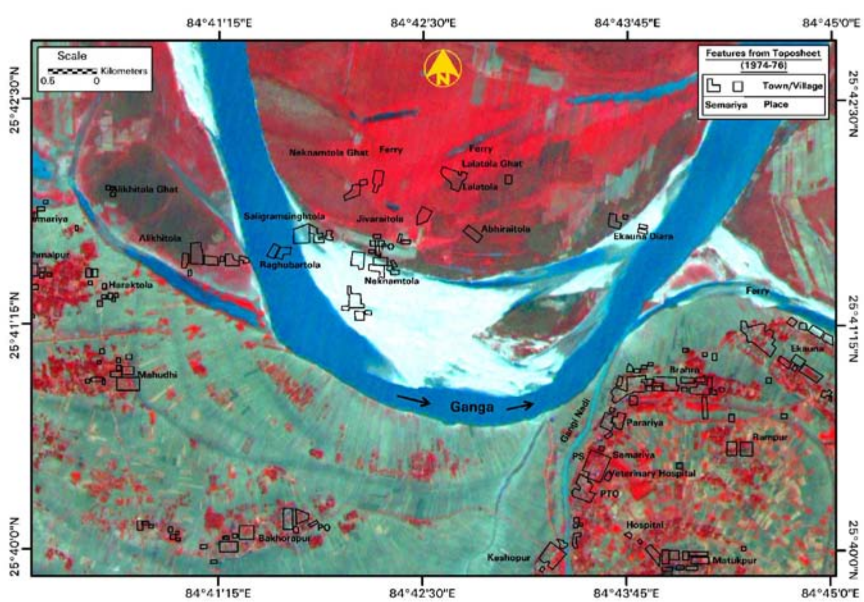


Fig. Merged IRS-1C LISS-III and PAN image of the year 2000 showing the course of river Ganga and various settlements near Neknamtola

✓ **Villages/Townships that have been severely affected are identified.**

✓ **Villages/Townships that are likely to be affected in near future are also identified.**

Remote sensing and GIS applications in surface water hydrology

Publications:

1. Lohani, A. K., **Chatterjee, C.**, Kumar, R., and Singh, R. D. (2009), “Management model for waterlogging and drainage congestion problem of Mokama tal area”, Journal of the Institution of Engineers (I), 90, 28-32.

2. **Chatterjee C.**, Kumar R., Chakravorty B, Lohani A.K. and Kumar S., (2005), “Integrating remote sensing and GIS techniques with groundwater flow modeling for assessment of waterlogged areas”, Water Resources Management, Springer Science, 19, 539-554.

3. Lohani A.K, Ghosh N.C. and **Chatterjee C.**, (2004), “Development of a management model for a surface waterlogged and drainage congested area”, Water Resources Management, Springer Science, 18(5), 497-518.

4. **Chatterjee, C.**, Kumar, R., and Mani, P. (2003). “Delineation of surface waterlogged areas in parts of Bihar using IRS-1C LISS-III data”. Journal of ISRS, Photonirvachak and Springer Verlag, Vol. 31, No. 1, March, pp. 57-65.

5. Mani, P., Kumar, R., and **Chatterjee, C.** (2003). “Erosion study of a part of Majuli river-island using remote sensing data”. Journal of ISRS, Photonirvachak and Springer Verlag, Vol. 31, No. 1, March, pp. 11-18.

6. Lohani, A. K., **Chatterjee, C.**, and Kumar, R. (2002). "Estimation of waterlogging and water storage capacity of Mokama Tal area in Bihar using remote sensing and GIS". GIS India, Hyderabad, May, pp. 10-14.

7. Kumar, R., Lohani, A. K., Kumar, S., **Chatterjee, C.**, and Nema, R. K. (2001). “GIS based morphometric analysis of Ajay river basin upto Sarath gauging site of South Bihar”. Journal of Applied Hydrology, Association of Hydrologists of India, XIV(4), pp. 45-54.

8. **Chatterjee, C.**, Jha, R., Lohani, A. K., Kumar, R., and Singh, R. (2001). "Runoff curve number estimation for a basin using remote sensing and GIS". Asian-Pacific Remote Sensing and GIS Journal, Bangkok, 14, December, pp. 1-7.

Ph.D. Work

Discharge Characteristics of Chimney Weir under Free and Submerged Flow Conditions

Advantages of Chimney Weir:
- ✓ Simple relationship
- ✓ Higher indication accuracy
- ✓ Simple geometric profile

Gaps:
- ✓ Linear relationship developed only for 2θ between 30^0 and 90^0
- ✓ No studies conducted on the effect of weir- and channel-geometry.
- ✓ No study on submerged flow conditions.

Development of Theoretical Flow Equations:

(a) A linear head-discharge relationship is developed for Chimney weir

$$q = 2\, C_{d1} \sqrt{2g}\, 0.4481\ w \sqrt{d}\, (h - 0.0817d\ );$$

$$0.22d \le h \le 2.43d \quad \text{and} \quad p = 0.735\ d$$

(b) A theoretical submerged flow equation for chimney weir is also developed.

Experimentation:
- ✓ Experiments conducted with chimney weirs having 3 different vertex angles at 6 crest heights and 3 channel widths, both under free and submerged flow conditions.
- ✓ A total number of 1057 experimental runs (644 for free-flow case and 413 for submerged-flow case) were conducted.

Results:

1) The coefficient of discharge, C_{dl}, in the linear head-discharge relationship is found to vary with h/d, w/d, h/(h+P) and w/c.

$$C_{dl} = 0.599 - 0.174\left(\frac{h}{d}\right) + 0.060\left(\frac{h}{d}\right)^2 + 0.034\left(\frac{w}{d}\right) + 0.109\left(\frac{h}{h+P}\right) + 0.096\left(\frac{w}{C}\right)$$

2) Based on experiments conducted, following equation is developed for the submerged flow coefficient of discharge, C_{ds}.

$$C_{ds} = 0.632 - 0.076\left(\frac{P}{h_1}\right) + 0.013\left(\frac{P}{h_1}\right)^2 + 0.037\left(\frac{w}{d}\right)$$

3) The developed theoretical submerged flow equation considerably improves the discharge prediction when compared with the standard submergence formulae for sharp-crested weirs developed by Villemonte and Mavis.

4) A simple empirical equation is also developed for submerged flow conditions.

$$\frac{q}{q_1} = 0.985 + 0.208\left(\frac{h_2}{h_1}\right) - 0.898\left(\frac{h_2}{h_1}\right)^2 - 0.010\left(\frac{P}{h_1}\right) - 0.011\left(\frac{w}{d}\right)$$

Ph.D. Work

Publications:

1. **Chatterjee, C.**, Singh, R., Kar, S. K. (2002). “Discharge characteristics of chimney weir under free-flow conditions”. Journal of Irrigation and Drainage Engineering, American Society of Civil Engineers, 128(3), June, pp. 175-179.

2. **Chatterjee, C.**, Singh, R., Kar, S. K., Panda, S. N., and Bohara, S. L. (1998). “Flow characteristics of chimney weir under submergence”. Journal of Irrigation and Drainage Engineering, American Society of Civil Engineers, 124(2), March-April, pp. 96-101.

3. **Chatterjee, C.**, Singh, R., and Satyanarayana, T. (1997). “Discharge characteristics of chimney weir”. Journal of Institution of Engineers (I), 77, February, pp. 190-194.

CHANDRANATH CHATTERJEE **Date of Birth: 28.11.1969**

1. EDUCATIONAL QUALIFICATIONS:

Degree	Institution	Year	Specializn.	Divisn.	% Marks	Rank
Ph.D.	IIT Kharagpur	1999	Hydrometry	-	-	-
M.Tech.	IIT Kharagpur	1994	Soil & Water Cons. Engg.	-	9.52/ 10	**First in Specialn.**
B.Tech.	CAET, OUAT, BBSR	1992	Agricultural Engg.	First (Hons)	8.65/ 10	**Univ. Gold Medal**
H.S.	BJB College, BBSR	1988	PCM, English, Stats	First	88.9%	-
AISSE	D. M. School, BBSR	1986	Science, Engl., Maths	First	76.4%	-

2. EXPERIENCE

University / Organization	Designation	From	To	Total Period	Nature of Experience
IIT Kharagpur, AgFE Dept.	Assoc. Prof.	14.06.2010	Till date	2 years	Teaching & Research
IIT Kharagpur, AgFE Dept.	Asst. Prof.	10.05.2004	14.06.2010	6 years	Teaching & Research
Potsdam Univ., Germany	Humboldt Fellow	01.09.2005	30.08.2006	1 year	Post-doc (flood management)
NIH, Roorkee	Scientist 'C'	10.02.2000	10.05.2004	4 years	Research in hydrology
NIH, Roorkee	Scientist 'B'	10.02.1997	10.02.2000	3 years	Research in hydrology

3. AWARDS & HONOURS	1. **Alexander-von-Humboldt Foundation Research Fellowship, 2005** 2. Best research paper award of Institution of Engineers (I), MoWR, 2004 3. Certificate of Merit of the Institution of Engineers (I), 2002 4. Reddy award for best M.Tech. thesis, 1994, ISAE 5. University gold medal in B.Tech. (Agril. Engrg.), 1992

4. PUBLICATIONS	**Completed**	**Under review**
(a) Refereed journals	**40**	**3**
(b) Proceedings of seminars / conferences	48	1
5. RESEARCH GUIDANCE	**Completed**	**In progress**
(a) Guidance at doctoral level	2	6
(b) Guidance at masters level	33	2
6. SPONSORED RESEARCH (**Funding Agencies: DST, ISRO, SAC, European Commission, INCOH**)	**Completed**	**On-Going**
	7	3
7. CONSULTANCY (**Funding Agencies: DVC, IWMI, DRDA, NTPC, Govt. of Andhra Pradesh**)	**Completed**	**On-Going**
	5	1