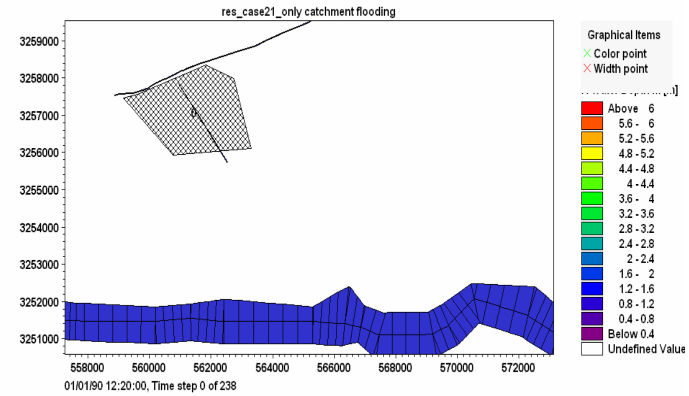
GEOSS Joint Asia-Africa Water Cycle Symposium

Project Design Matrix (PDM) of project under the 2nd phase of the GEOSS Asia Water Cycle Initiative: India

Dr Rakesh Kumar
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - INDIA



Project Design Matrix

- Overall Goal
- Project Purpose
- Outputs
- Activities and Key Leaders

1. Overall Goal

Holistic approach for sustainable development and management of water resources in India

2. Project Purpose

Specific issues/needs in India:

- Water availability is likely to get affected by the impact of climate change.
- Increased intensity and frequency of extreme events including rainfall, floods, droughts and cyclones due to climate change.
- Increase in design flood estimates of the existing hydraulic structures and the hydraulic structures to be constructed in future is expected due the impact of climate change.
- Increasing water demands and utilization due to population growth and developmental activities in the country.
- Modification/ Change in the existing water resources planning, development and management practices of water resources projects including operation policies of the reservoirs due to impact of climate change.
- Gap between developed advanced technologies and their field applications and lack of IWRM approaches in operational practices.

2. Project Purpose

To address these issues/needs, we need to:

- Demonstrate improved capacity in modeling techniques for climate change impact studies.
- Estimate the present water availability and future water availability considering the impact of climate change for the study area.
- Assess climate change impacts on extreme events for some regions of India.
- Estimate design floods for various types of hydraulic structures considering impact of climate change.
- Estimate flood inundation for the present situation and future considering impact of climate change.
- Assess water availability and demands under the changed climatic conditions and update water allocation policies and operation rules for the reservoirs of the study area.
- Promote implementation of the advanced technologies and IWRM approaches in field applications and decision-making process considering impact of climate change.

3. Outputs

Demonstrate improved capacity in modeling techniques for climate change impact studies.

- Improve techniques for GCM output (CMIP5) bias correction and downscaling.
- Develop downscaled and bias corrected products of GCM outputs (CMIP5) over India.
- Select GCMs which can represent the regional climate appropriately.

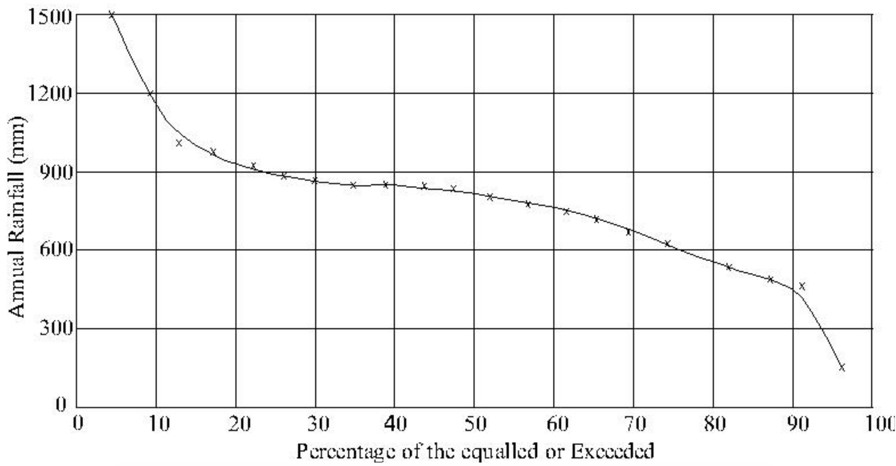
3. Outputs

Estimate the present water availability and future water availability considering the impact of climate change for the study area

Applications of distributed hydrological model(s) (DHM) for converting meteorological data to hydrological information and capable of coupling with GCM outputs.

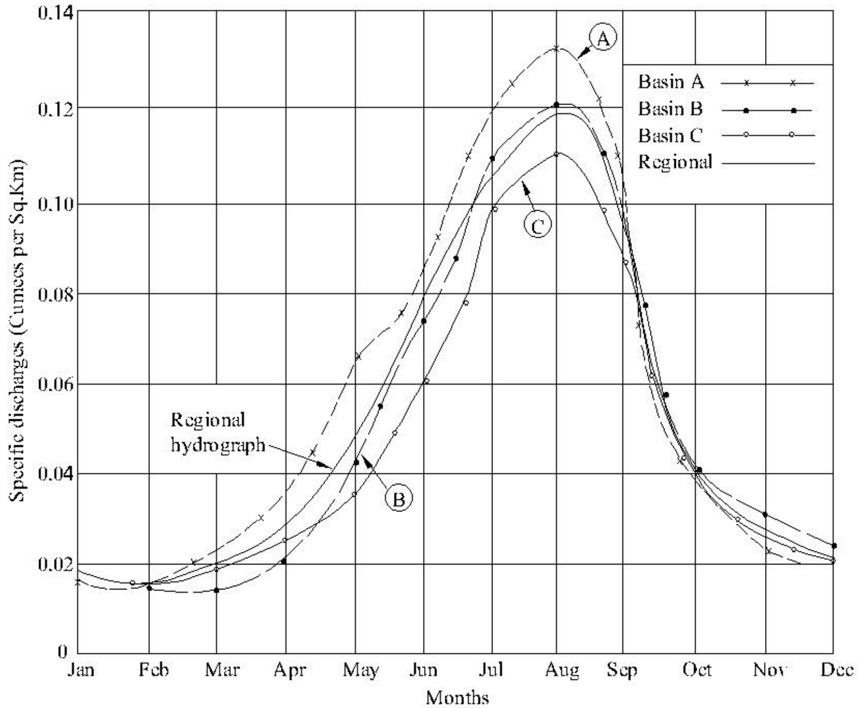
Simulation of distributed hydrological model(s) (DHM) with present and future meteorological, LULC data to estimate water availability at selected locations.

Water availability analysis



Annual rainfall duration curve

Flow Duration Curve for July



Regional hydrographs with 50% dependability

3. Outputs

Assess climate change impacts on extreme events for some regions of India

Carry out DHM(s) simulations using the corrected and downscaled GCM outputs for some regions of India.

Compare changes in frequency and intensity of rainfall, flood, drought, and water-nexus in between present and future.

3. Outputs

Estimate design floods for various types of hydraulic structures considering impact of climate change

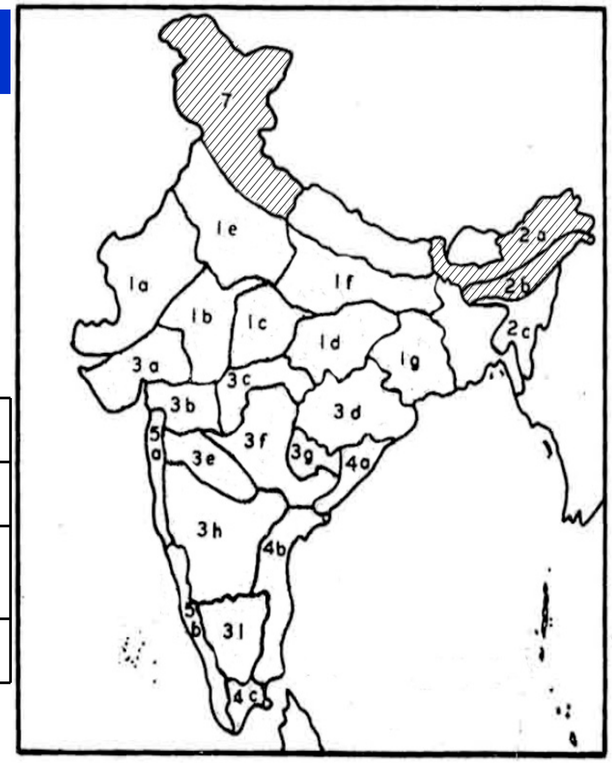
- Estimate floods of various return periods using the L-moments approach of flood frequency analysis for present condition.
- Estimate floods of various return periods using the L-moments approach of flood frequency analysis for future considering the impact of climate change.
- Compare changes in frequency and intensity of rainfall, flood, drought, and water-nexus in between present and future.

Year	Major Developments in Flood Frequency Analysis
1882-1890	Herschel and Freeman – Graphical Procedure
1914	Fuller – Statistical Method
1914	Hazen – Log Normal Procedure
1924	Foster – Pearson type 3 (P3)
1927	Maurice Fréchet
1928	Fisher and Tippett
1941	Gumbel – EV1 Distribution
1954	Chow – Frequency Factor Procedure
1955	Jenkinson – GEV Distribution
1960	Dalrymple - USGS Method
1967	USWRC – Log Pearson type 3 (LP3)
1975	NERC Method, UK
1977	Houghton - Wakeby
1979	Greenwood et.al. – PWM
1982	UUS Advisory Committee on Water Data Bul. 17(B) [LP3]
1988	Ahmad et al - Log-logistic (LLG)
1990	Hosking – L-Moments
1999	Flood Estimation Hand Book, Inst. of Hyd., UK
2007	Griffs and Stedinger – Revised Bulletin 17(B); [L-moments approach]

Regional flood frequency relationship for Gauged Catchments

$$Q_T = \left[-1.016 + 1.927 \left(\frac{1}{T-1} \right)^{-0.165} \right] * \overline{Q}$$

Return Period (Years)								
2	5	10	25	50	100	200	500	1000
Growth Factors $(Q_T / \overline{Q})$								
0.911	1.406	1.753	2.240	2.646	3.09	3.59	4.35	5.006



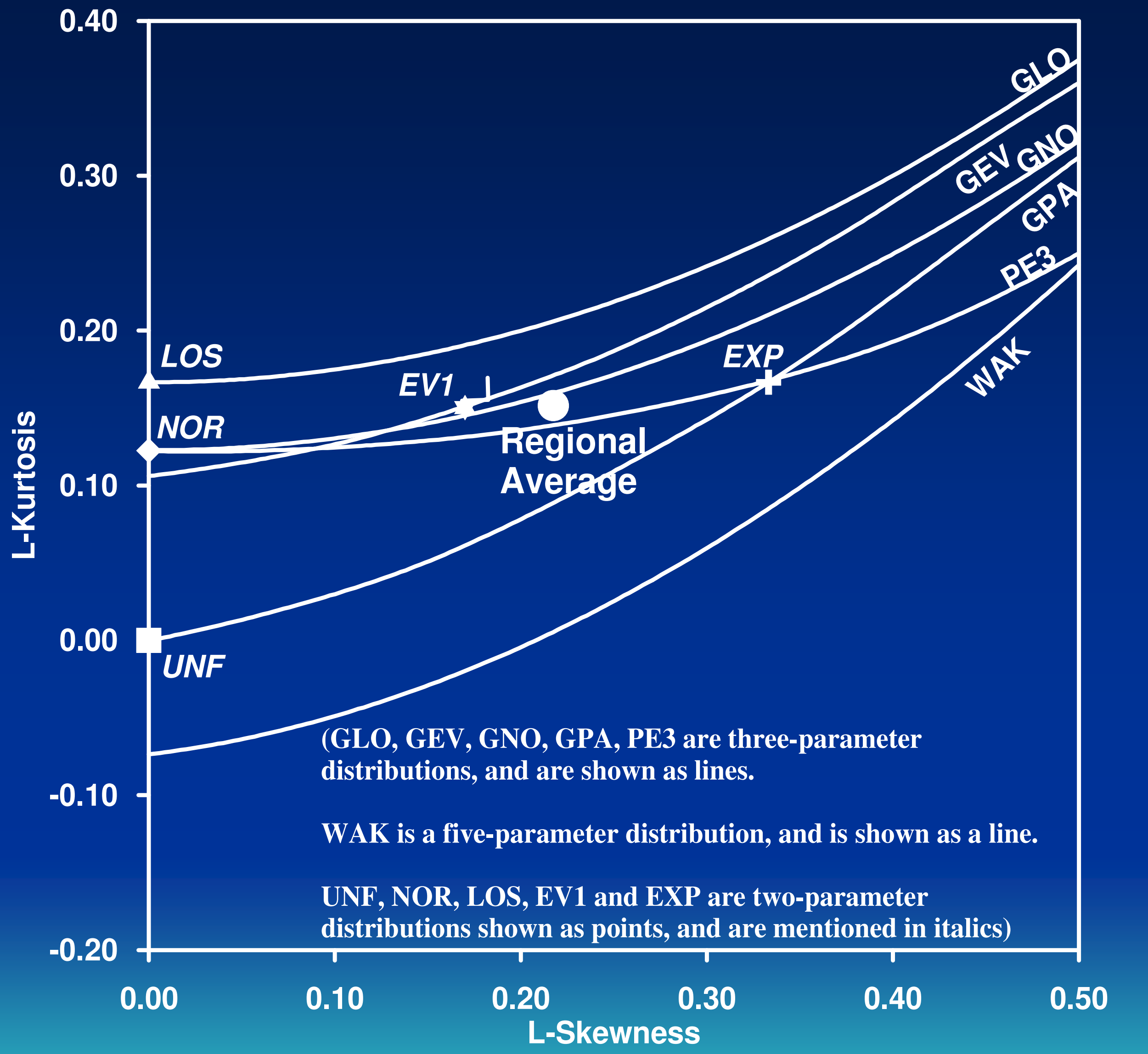
Regional flood frequency relationship for Ungauged Catchments

$$Q_T = \left[-5.654 + 10.724 \left(\frac{1}{T-1} \right)^{-0.165} \right] * A^{0.771}$$

Catch ment Area in Sq Km	Return Period in Years		
	25	50	100
10	73.6	86.9	101.7
25	149.1	176.1	206.2
50	254.5	300.6	351.8
100	434.2	512.9	600.4
500	1501.8	1774.0	2076.4
1000	2562.8	3027.3	3543.3
1600	3682.1	4349.4	5090.8
2000	4373.3	5165.9	6046.5
2200	4706.7	5559.8	6507.5

Catchment area, sample statistics, sample size and discordancy statistic for Mahanadi Subzone 3(d)

Stream Gauging Site	Catchment Area (km^2)	Mean Annual Peak Flood (m^3/s)	Sample Size (Years)	L-CV (τ_2)	L-skew (τ_3)	L-kurtosis (τ_4)	Discordancy Statistic (D_i)
48	109	103.9	30	0.402	0.295	0.1658	0.46
93K	74	153.071	28	0.274	0.1235	0.1974	1.44
59KGP	30	72.897	29	0.4079	0.277	0.178	0.74
308	19	41.222	27	0.3461	0.2339	0.0882	0.87
332NGP	225	188.591	22	0.2899	0.2117	0.202	1.23
59BSP	136	196.227	22	0.4068	0.3471	0.2283	1.48
698	113	247	25	0.424	0.321	0.1356	1.09
121	1150	1003.857	21	0.269	0.1622	0.0787	1.19
332KGP	175	71.833	24	0.3102	0.1569	0.1647	0.51
40K	115	260.667	21	0.3469	0.2328	0.1784	0.14
42	49	53.5	20	0.226	0.0488	0.053	1.92
69	173	238.895	19	0.3457	0.2392	0.1455	0.08
90	190	130.727	11	0.357	0.1566	0.1335	2.11
195	615	963.769	13	0.2394	0.1305	0.1614	1.1
235	312	176.143	14	0.3128	0.2205	0.113	0.63



L- moments ratio diagram for Mahanadi Subzone 3(d)

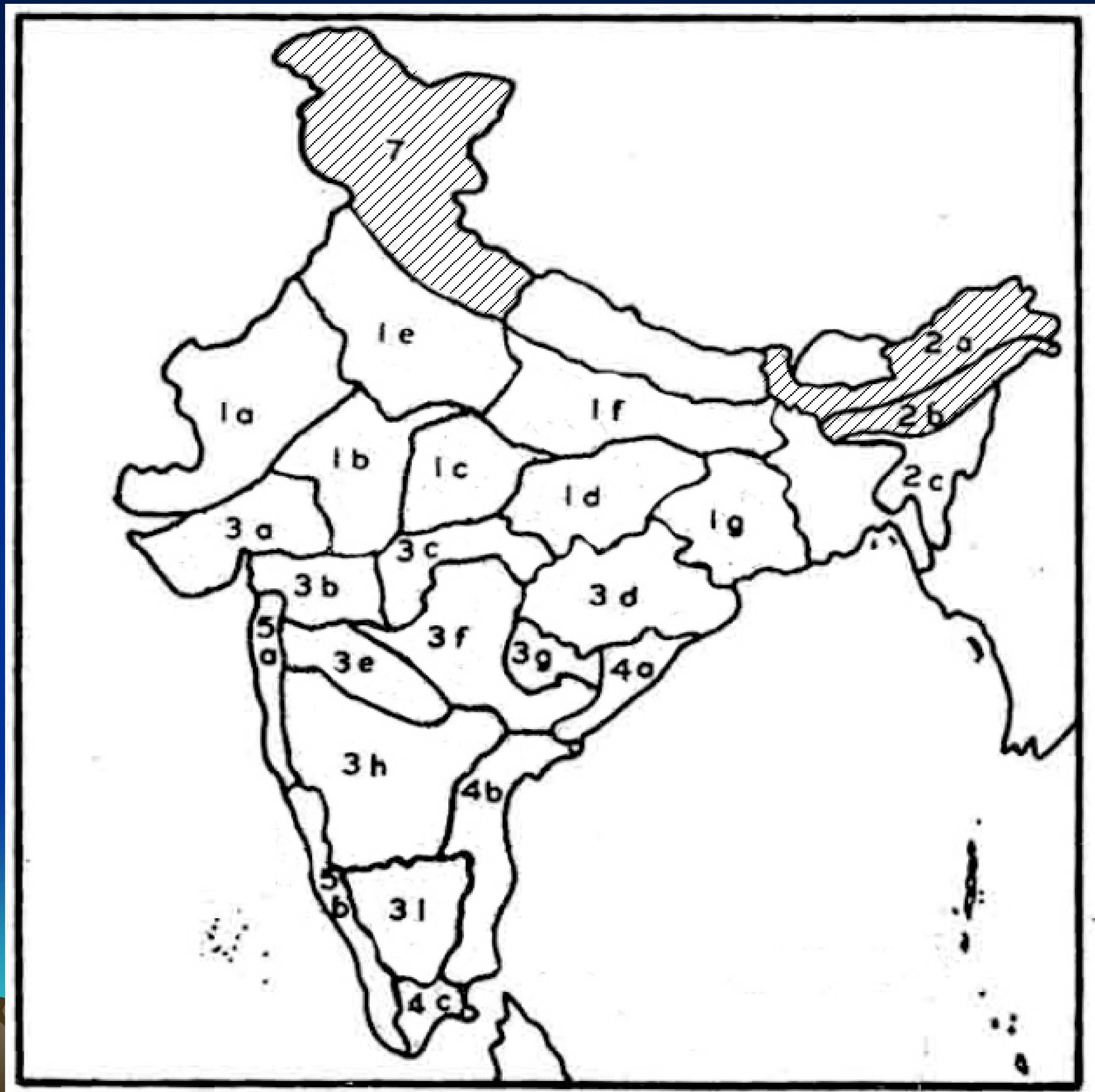
Z_i^{dist} statistic for various distributions for Mahanadi Subzone 3 (d)

Distribution	Z_i^{dist} –statistic
Generalized Normal (GNO)	0.22
Pearson Type III (PE3)	0.62
Generalized Extreme Value (GEV)	0.66
Generalized logistic (GLO)	2.08
Generalized Pareto (GPA)	2.68

Values of Growth Factors for Mahanadi Subzone 3 (d)

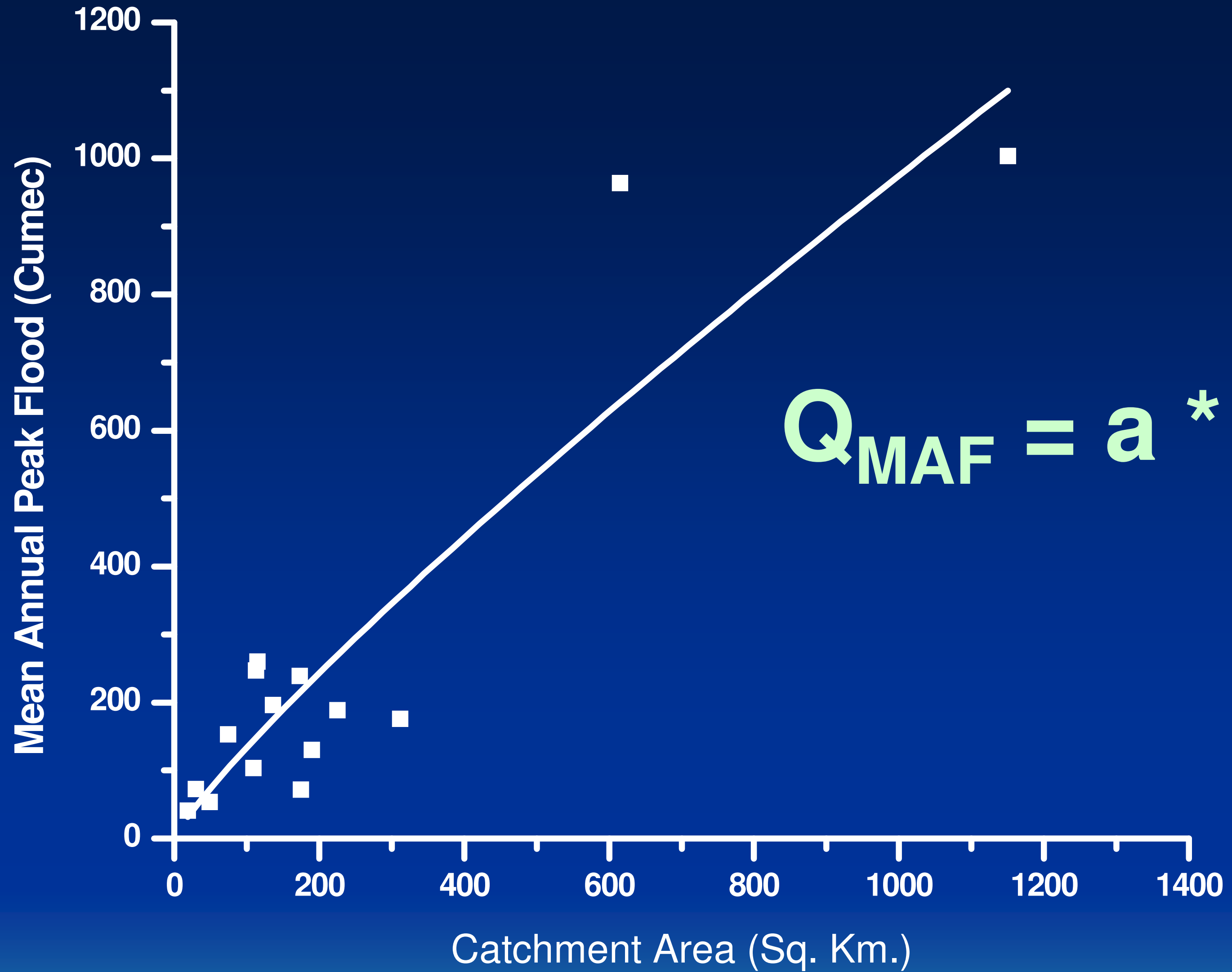
Distri-bution	Return period (Years)						
	2	10	25	50	100	200	1000
	Growth factors						
GNO	0.870	1.821	2.331	2.723	3.125	3.538	4.552
PE3	0.866	1.843	2.213	2.683	3.028	3.366	4.134
GEV	0.872	1.809	2.332	2.745	3.175	3.627	4.767
WAK	0.865	1.848	2.353	2.712	3.052	3.374	4.058

Location of 17 Subzones of India



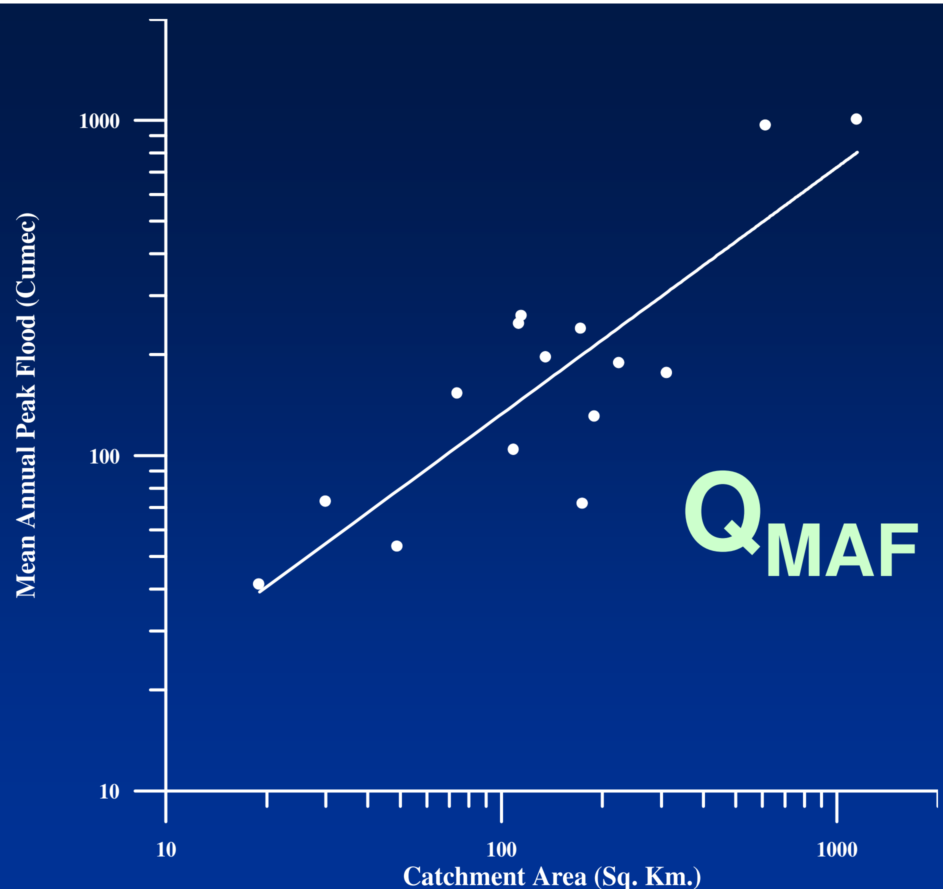
Robust distributions for 17 Subzones of India

S. No.	Subzone	Robust Distribution
1	1 (b)	PE3
2	1 (d)	GEV
3	1 (e)	GPA
4	1 (f)	GEV
5	1 (g)	GEV
6	2 (a)	PE3
7	2 (b)	GNO
8	3 (a)	PE3
9	3 (b)	GNO
10	3 (c)	PE3
11	3 (d)	GNO
12	3 (e)	GPA
13	3 (f)	PE3
14	3 (h)	GPA
15	3 (i)	PE3
16	4 (b)	PE3
17	Zone 7	GLO



$$Q_{MAF} = a * A^b$$

Variation of mean annual peak flood with catchment area for Mahanadi Subzone 3(d) using LMA



$$Q_{MAF} = a * A^b$$

Variation of mean annual peak flood with catchment area for Subzone 3(d) using the conventional least squares approach

SZ 3 (d)	a	b	CORR	EFF	RMSE	MAE
LMA	2.519	0.863	0.913	0.834	118.881	88.326
LS	4.483	0.736	0.911	0.747	146.910	97.902

DEVELOPMENT OF REGIONAL FLOOD FREQUENCY RELATIONSHIPS FOR UNGAUGED CATCHMENTS USING L-MOMENTS

Regional flood frequency relationships developed for gauged catchments are coupled with the regional relationship between mean annual peak flood and catchment areas and following form of regional flood frequency relationship is developed:

$$Q_T = C_T * A^b$$

Q_T is flood for T-year return period, C_T is a regional coefficient, A is catchment area and b is regional coefficient.

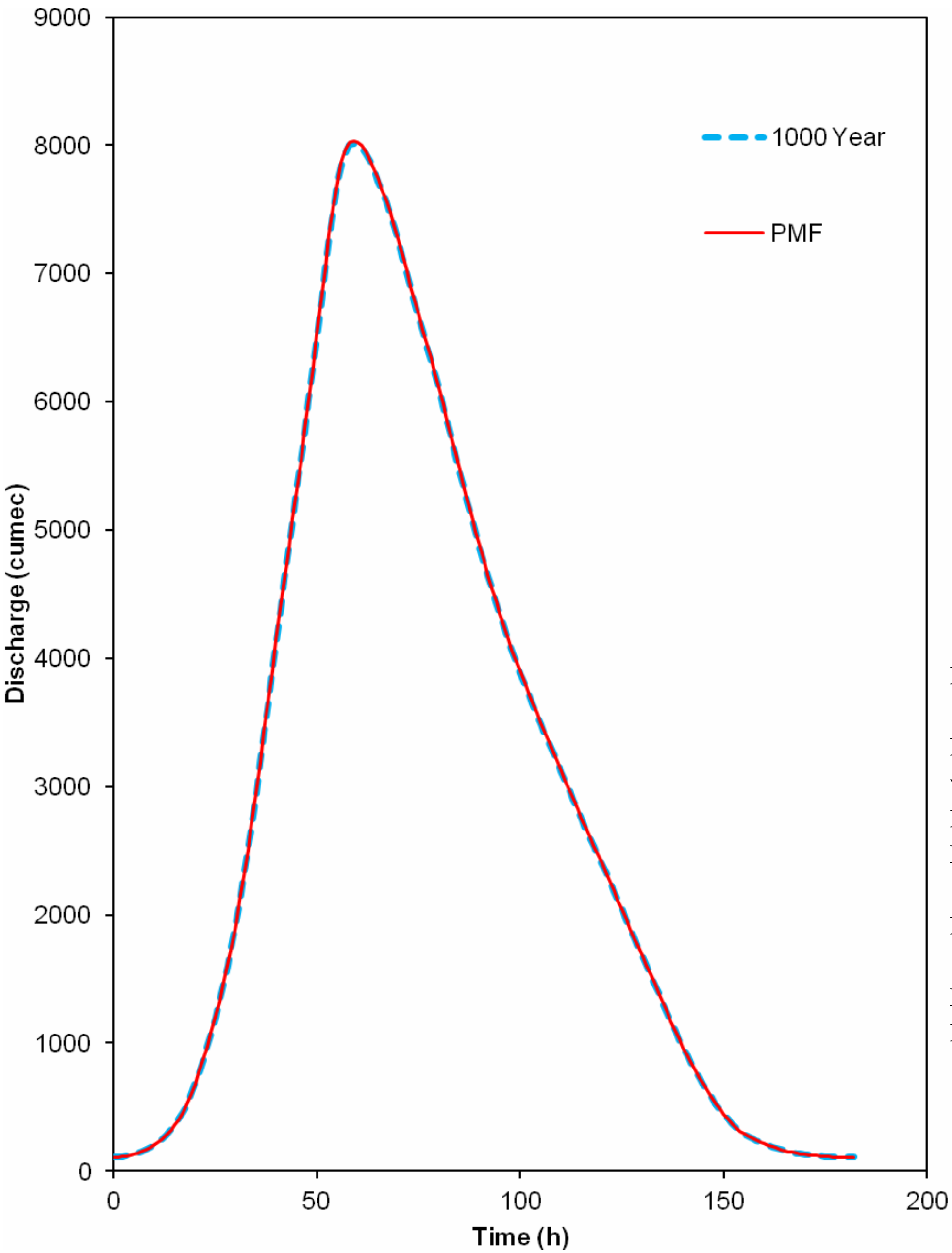
Values of Regional Coefficient “b” and “C_T”

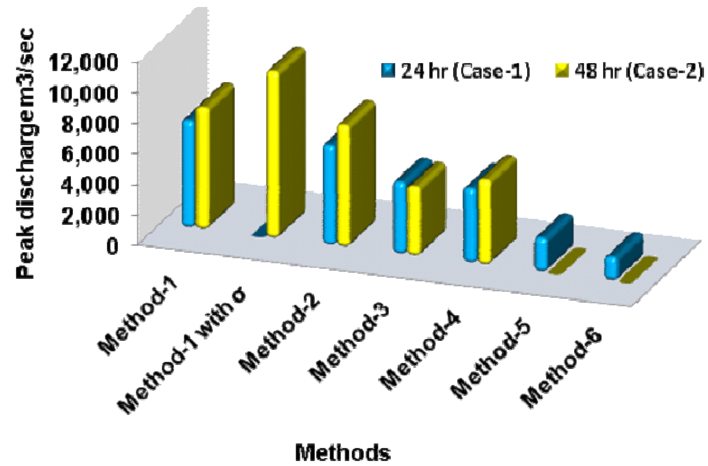
Sub-zone	Coeff. “b”	C_T for various Return Period (Years)			
		100	200	500	1000
3 (d)	0.863	7.871	8.912	10.340	11.465

Variation of floods of various return periods with catchment area based on L-moments for Mahanadi Subzone 3(d)

Catchment Area (km^2)	Return periods (Years)			
	2	10	25	50
	Floods of various return periods (m^3/s)			
10	16	33	43	50
100	117	244	312	365
500	468	979	1253	1464
1000	851	1780	2279	2662
1500	1207	2526	3234	3778
2000	1547	3238	4145	4842
2500	1876	3926	5026	5871
3000	2196	4595	5882	6871
4000	2815	5890	7540	8807
5000	3412	7141	9141	10678

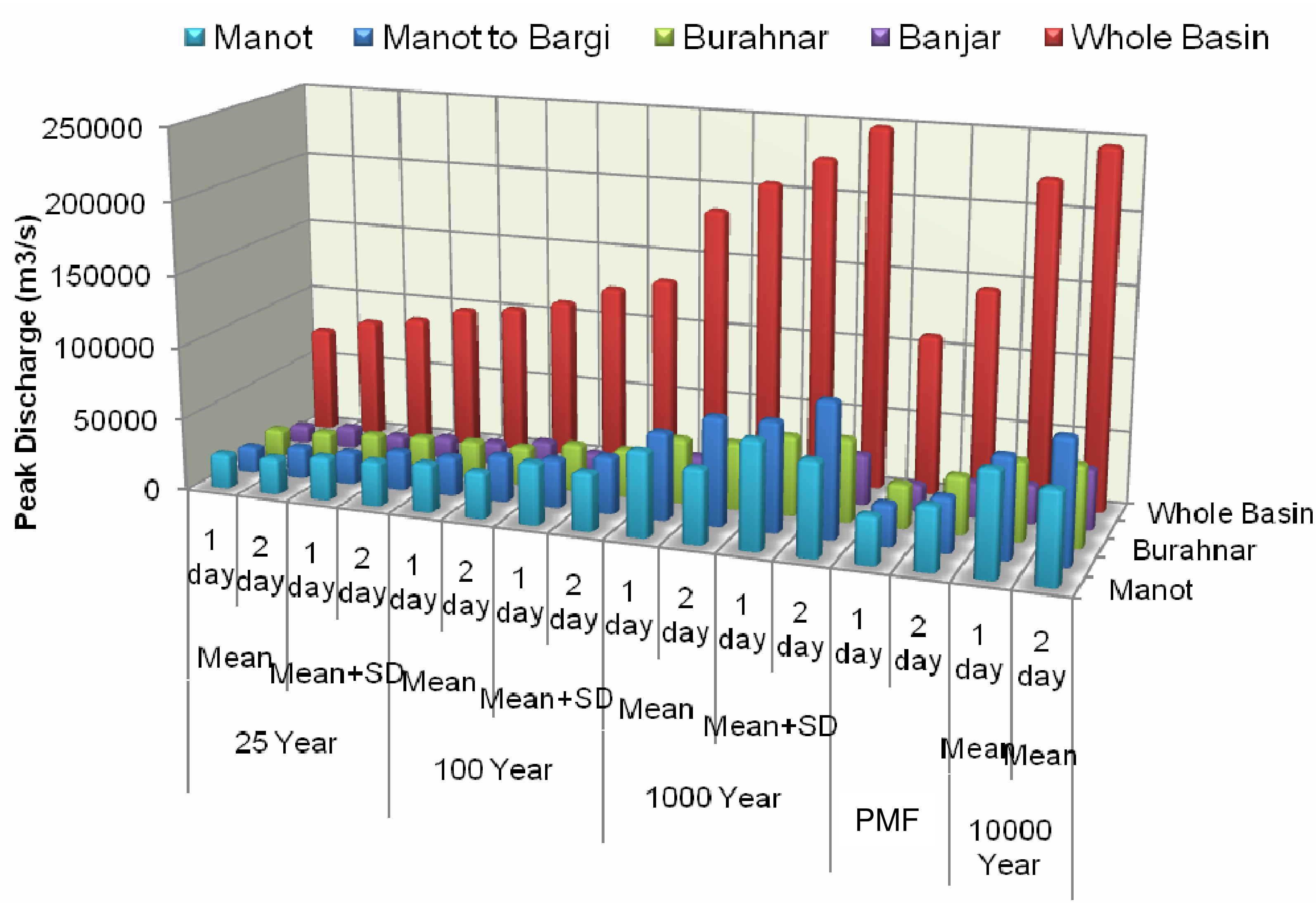
PMF /SPF Estimation



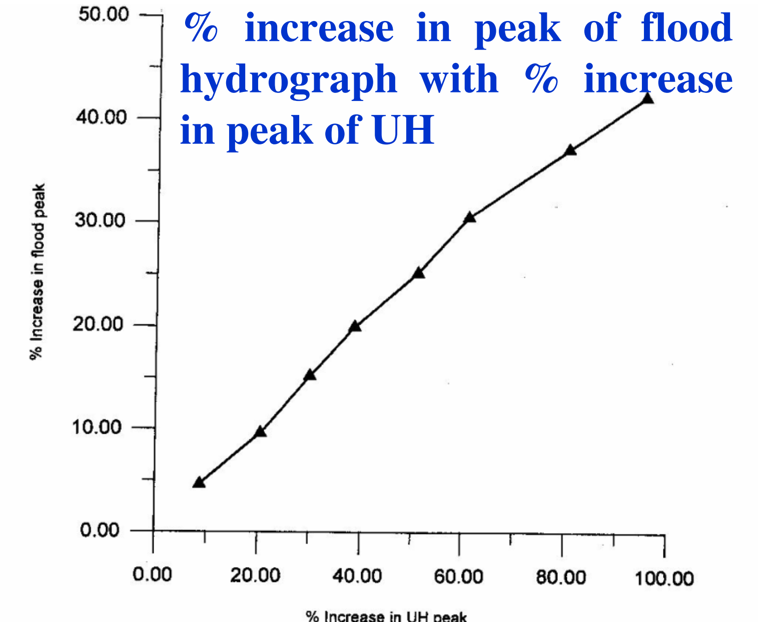


Method-1	**Flood due to rainfall estimated by at site rainfall frequency analysis based on L-moments approach**
Method-1 with σ	**σ is added to mean eastimates in Method-1**
Method-2	**PMF due to PMP**
Method-3	**Flood due to rainfall estimated by regional rainfall frequency analysis based on L-moments approach**
Method-4	**Flood due to rainfall estimated by frequency analysis based on EV1 distribution**
Method-5	**CWC flood estimation approach**
Method-6	**Regional flood frequency analysis based on L-moments approach**

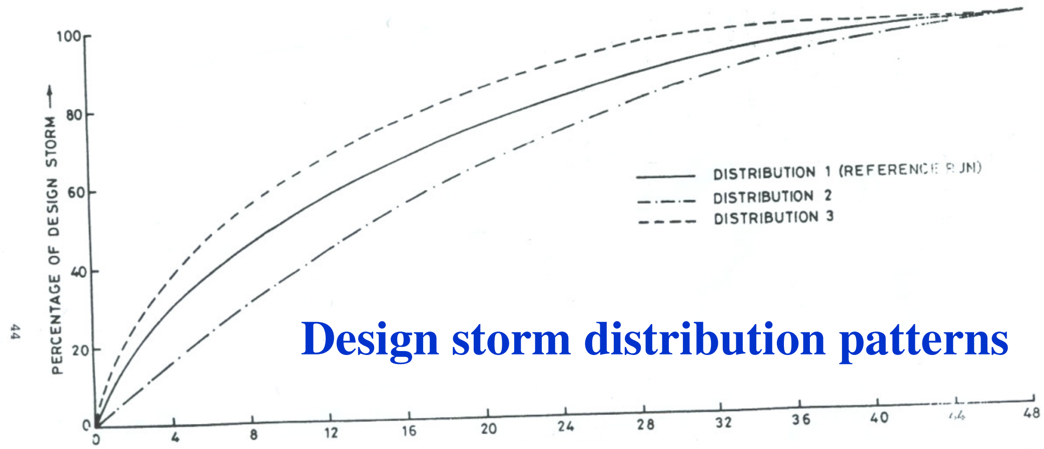
Comparative studies for Design Flood Estimation



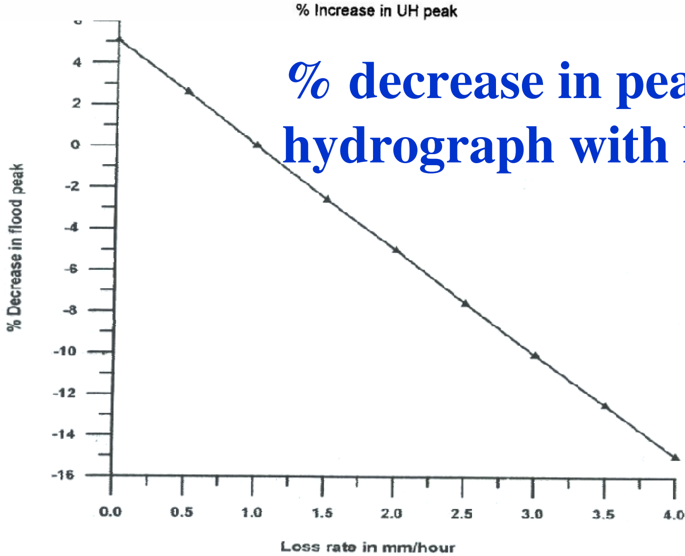
Impact of climate change on design floods under hypothetical scenarios of climate change



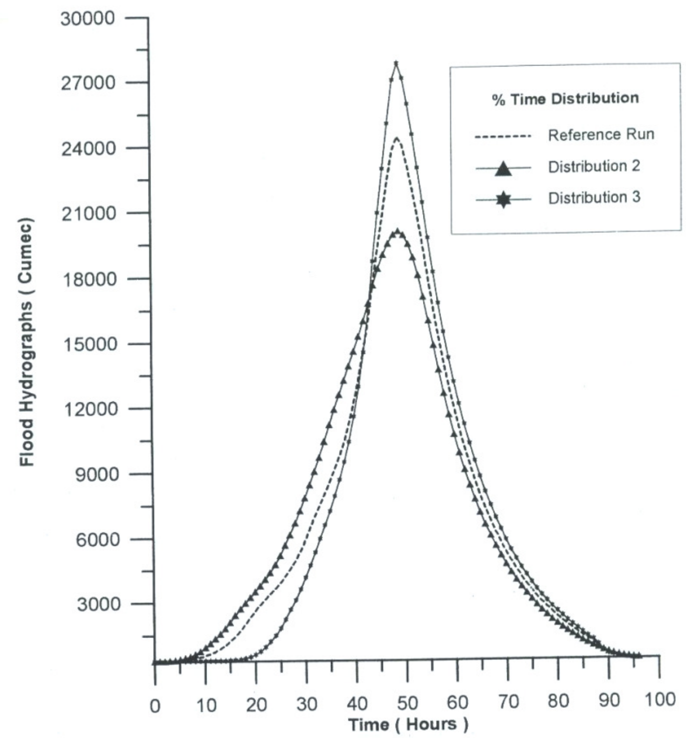
% increase in peak of flood hydrograph with % increase in peak of UH



Design storm distribution patterns

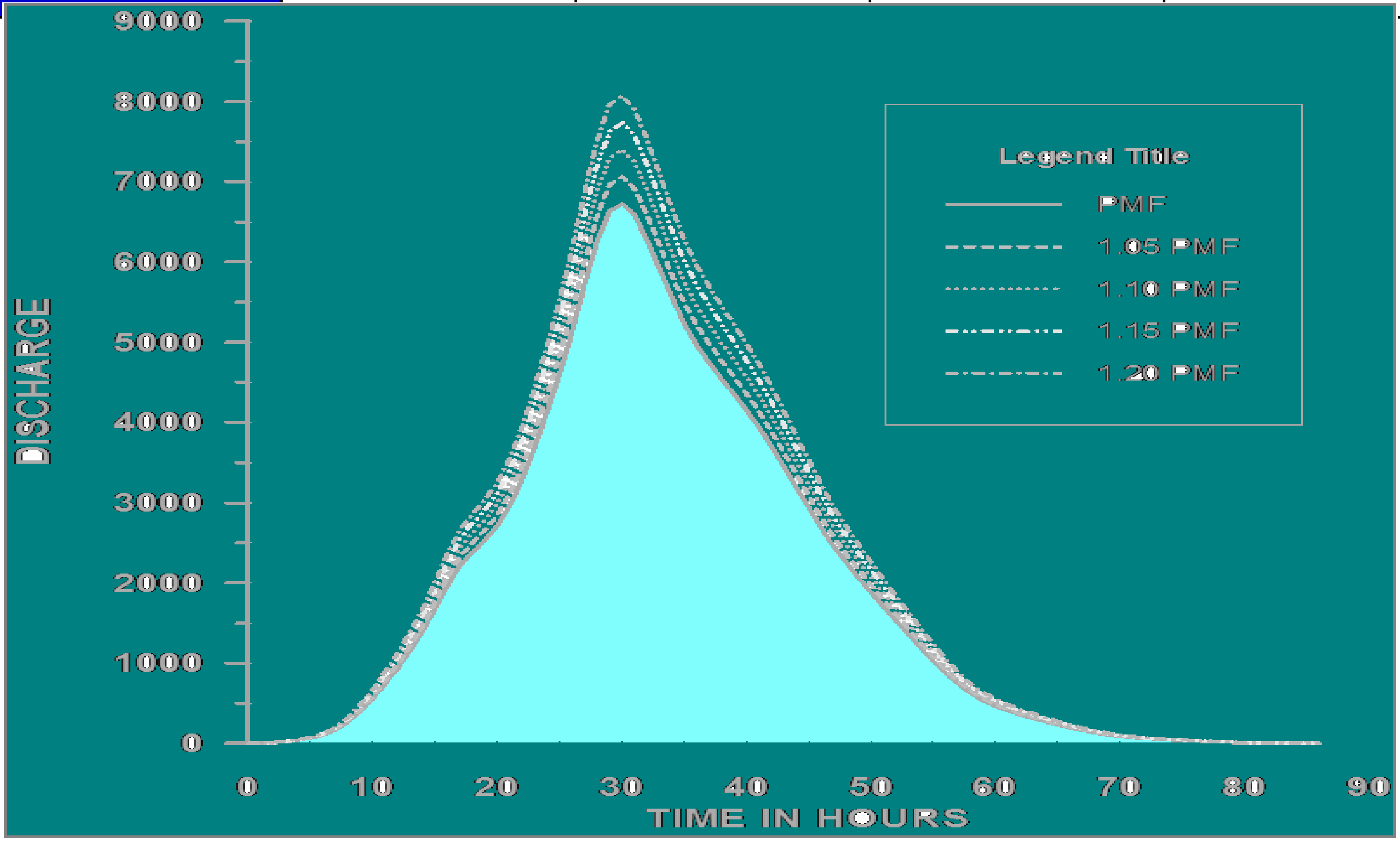


% decrease in peak of flood hydrograph with loss rate



PMF Estimation for Various PMP Scenarios

PMF 6842 m^3/s	1.05 PMP	1.10 PMP	1.15 PMP	1.20 PMP
	Peak of PMF			
	7064	7401	7737	8073
	% Deviation in PMF			
	3	8	13	18



Impact of climate change on design floods under hypothetical scenarios of climate change

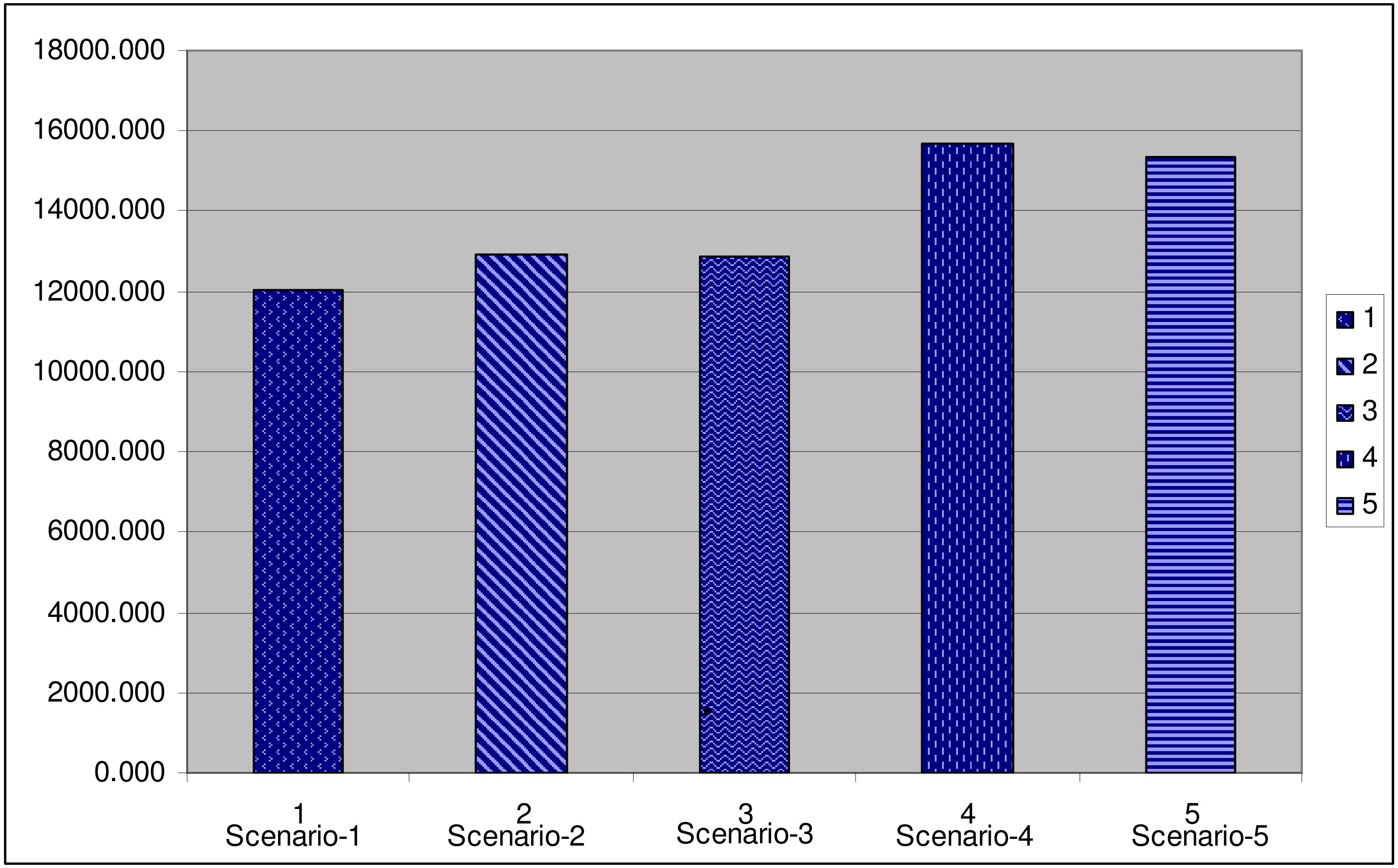
Sensitivity Analysis for Estimation of floods of various return periods using L-moments for different Scenarios (m^3/s)

Return Periods	25	50	100	1000
Scenario 1	8978	10418	12042	19208
Scenario 2	9403	11049	12945	21676
Scenario 3	9408	11025	12868	21186
Scenario 4	10603	12896	15657	29802
Scenario 5	10685	12842	15358	27317

% Deviations in floods of various return periods for different Scenarios

Return Periods	25	50	100	1000
Scenario 2	4.73	6.05	7.50	12.85
Scenario 3	4.78	5.83	6.86	10.30
Scenario 4	18.0	23.8	30.0	55.2
Scenario 5	19.0	23.3	27.5	42.2

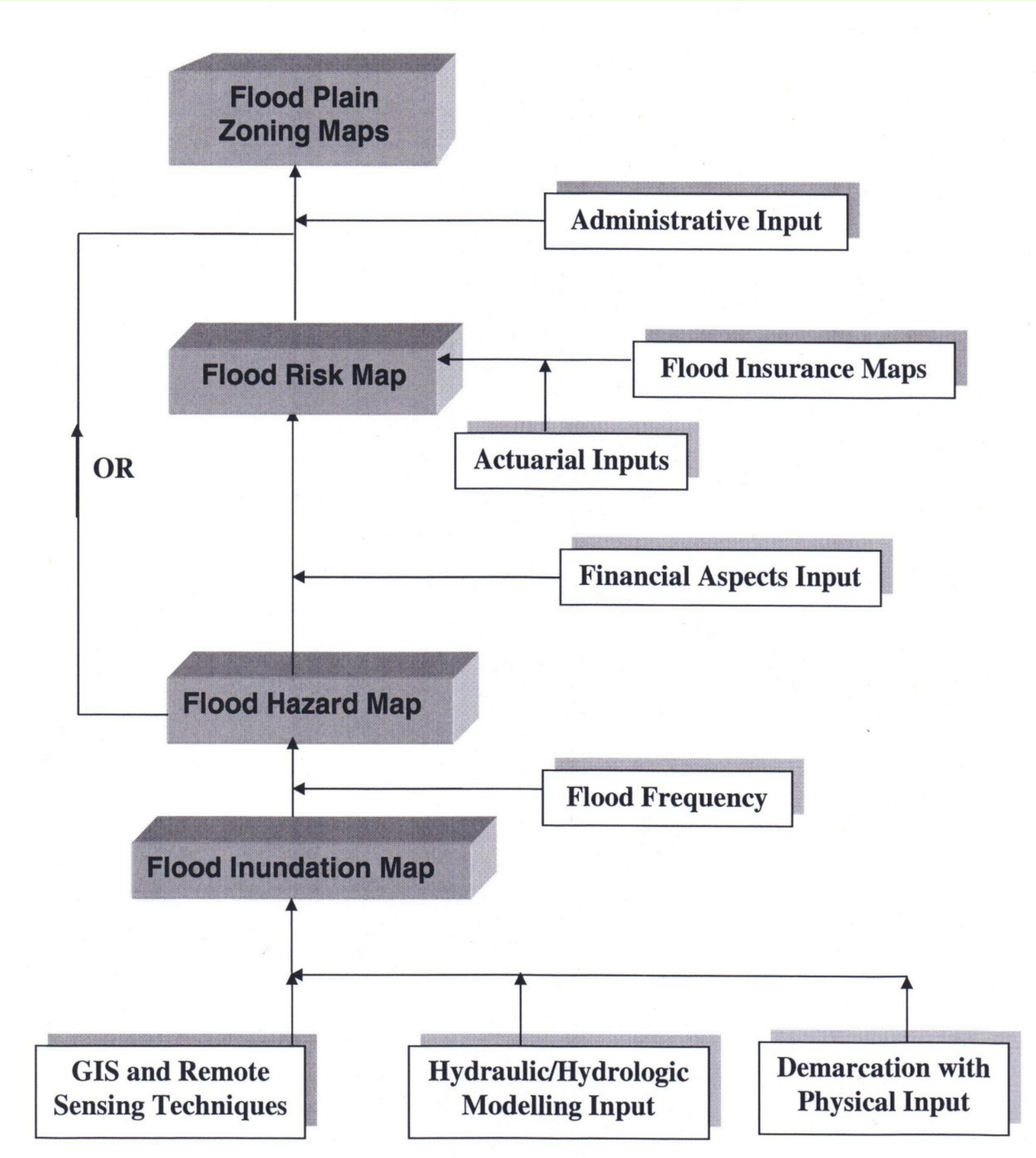
Return Period 100	Scenario-1	Scenario-2	Scenario-3	Scenario-4	Scenario-5
	12042	12946	12868	15657	15359



3. Outputs

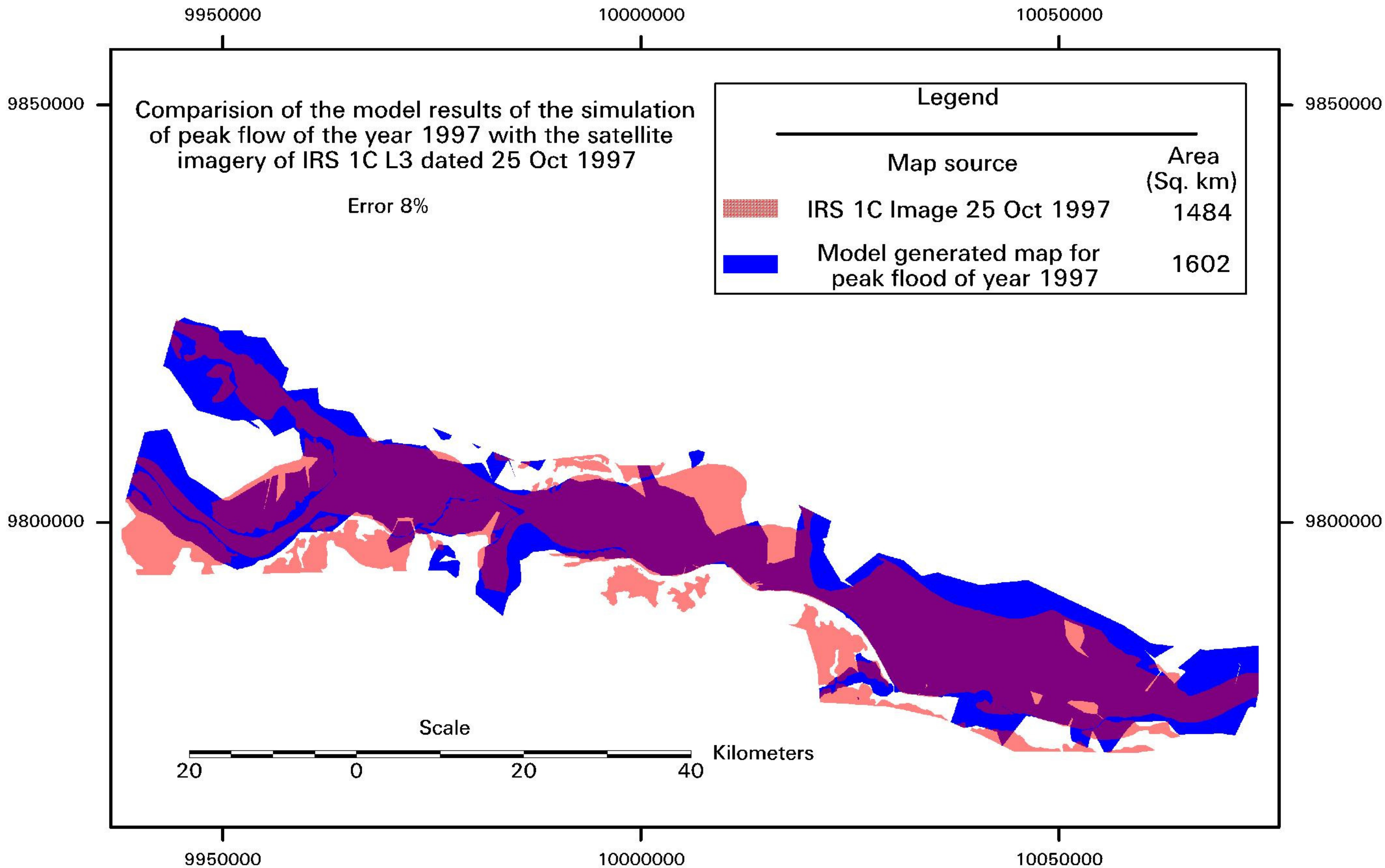
Estimate flood inundation and flood hazard for the present situation and future considering impact of climate change

- Estimate flood inundation due to floods of various return periods for the present.
- Estimate flood inundation due to floods of various return periods in future considering impact of climate change.
- Estimate flood hazard and develop flood hazard classification scheme based on extent, depth, elevation and duration of flooding as well as the maximum flow velocity for various return periods using coupled (1-D & 2-D) hydrodynamic flow modeling for the present.
- Estimate flood hazard and develop flood hazard classification scheme based on extent, depth, elevation and duration of flooding as well as the maximum flow velocity for various return periods using coupled (1-D & 2-D) hydrodynamic flow modelling for the future considering impact of climate change.

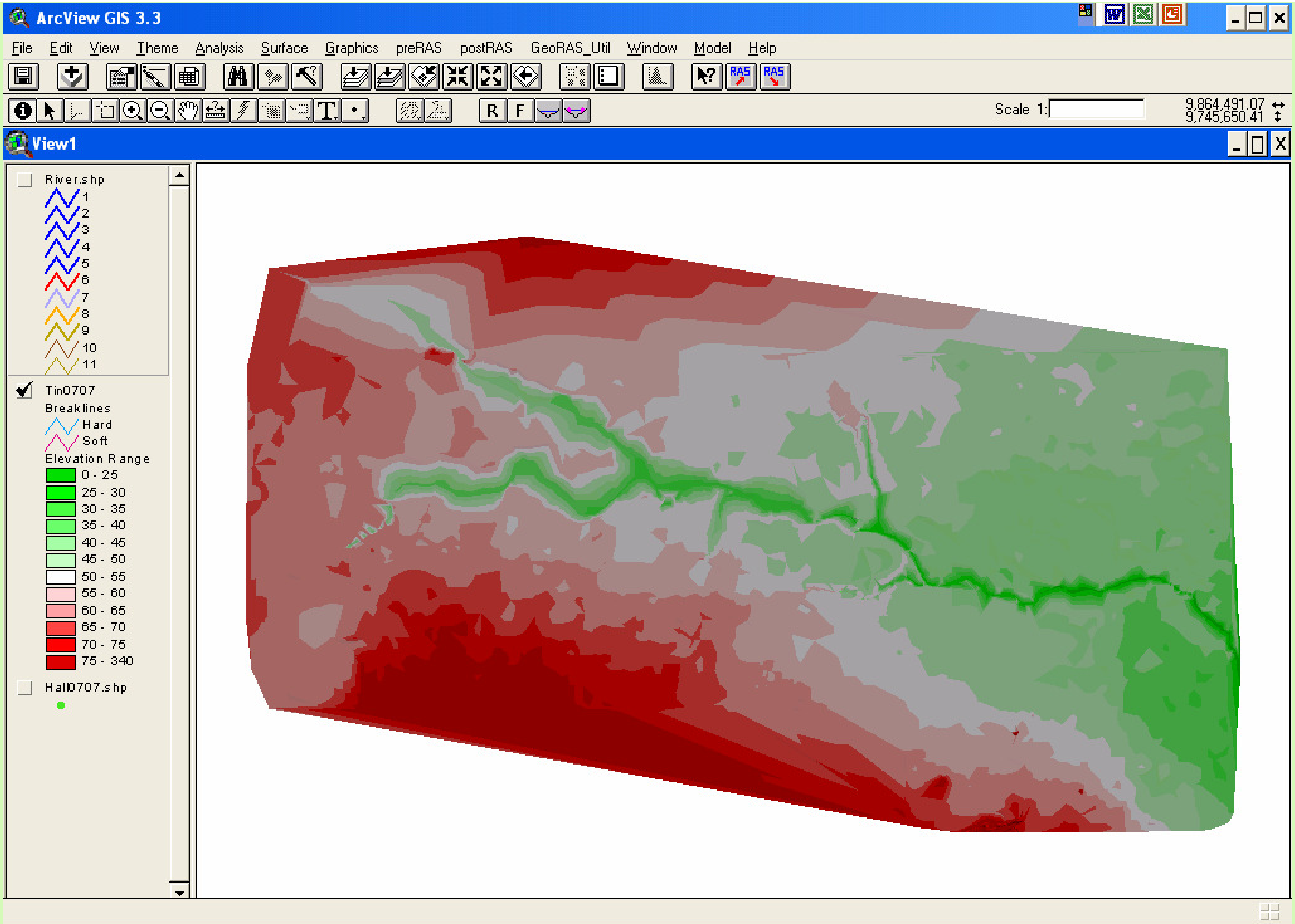


Flow chart illustrating the general terminology of flood inundation mapping flood hazard mapping, flood risk zone mapping and flood plain zoning

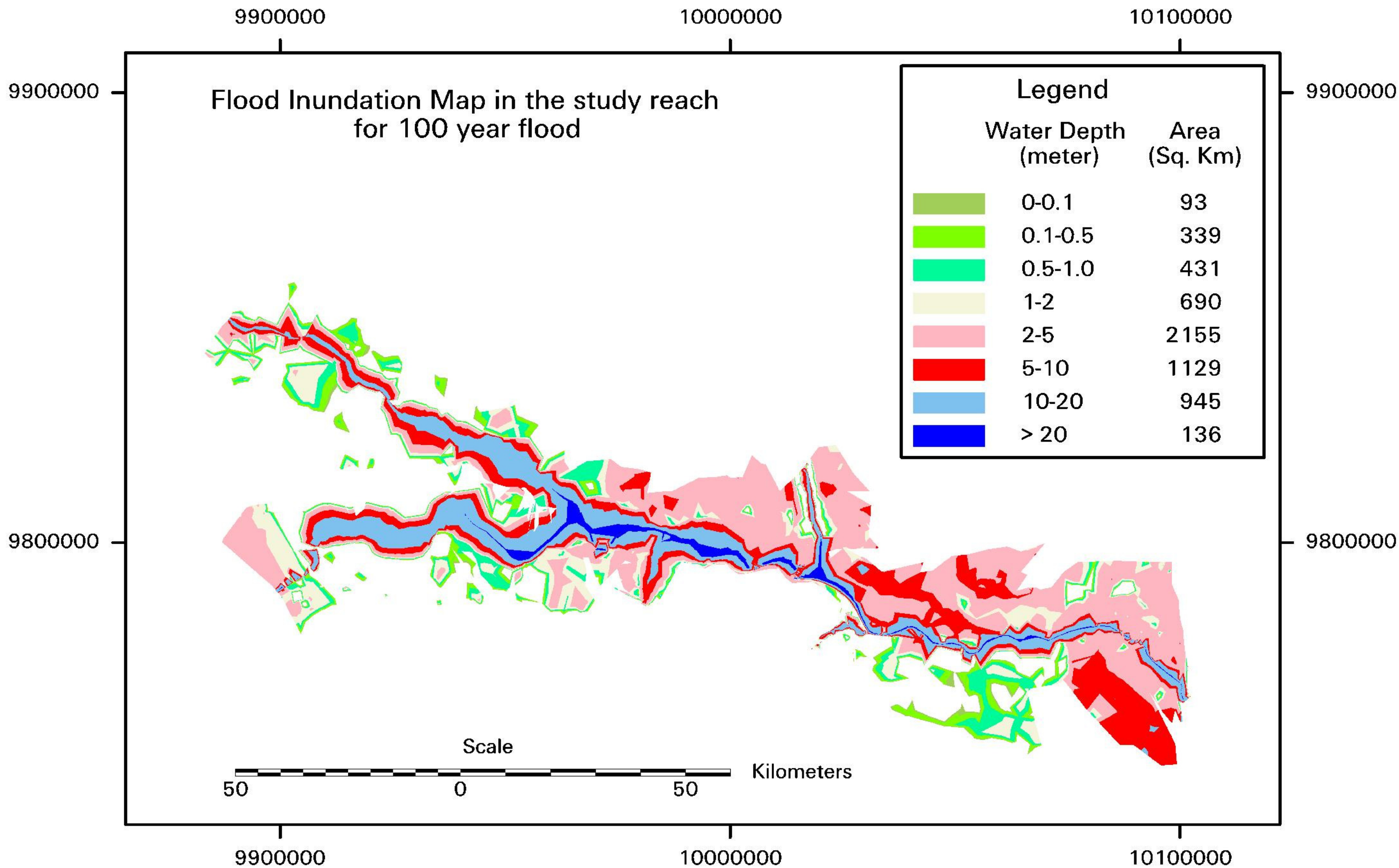
Flood inundation modeling



Comparison of Inundated area computed by hydraulic modeling and Inundated area mapped by satellite data for the year 1997

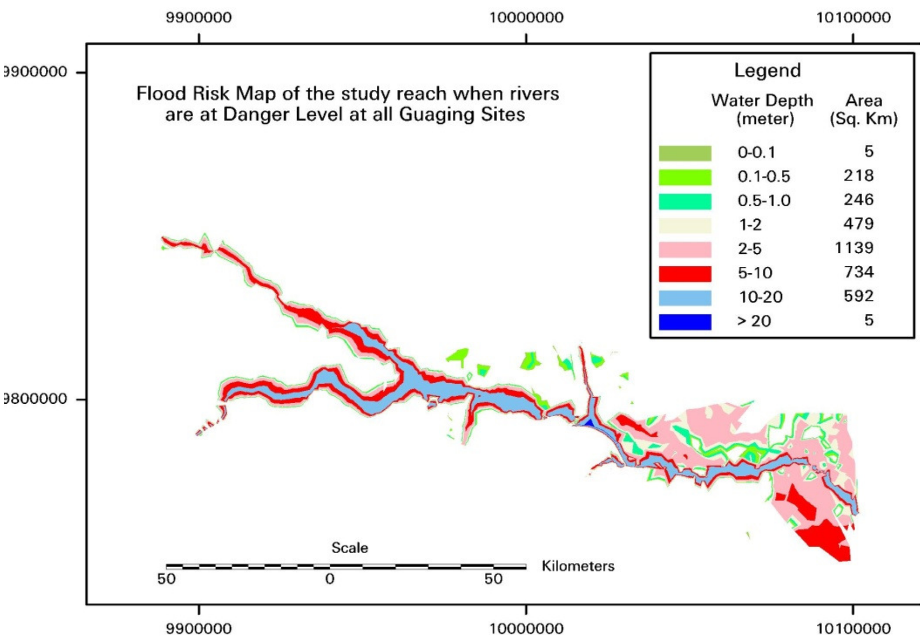


Digital Elevation Model (DEM) of the Study Area

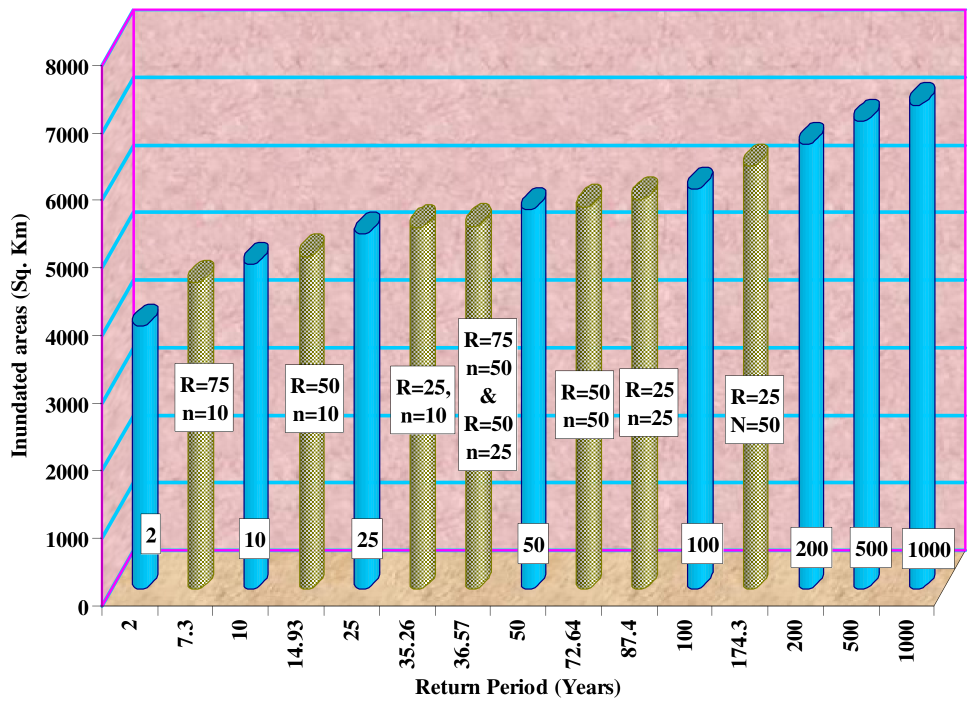


Flood Inundation map for 100 year return period

Flood inundation modeling



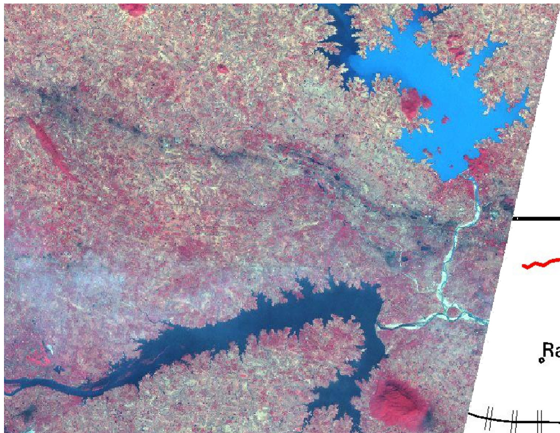
Flood Inundation map when the water level is at danger level at all the gauging sites

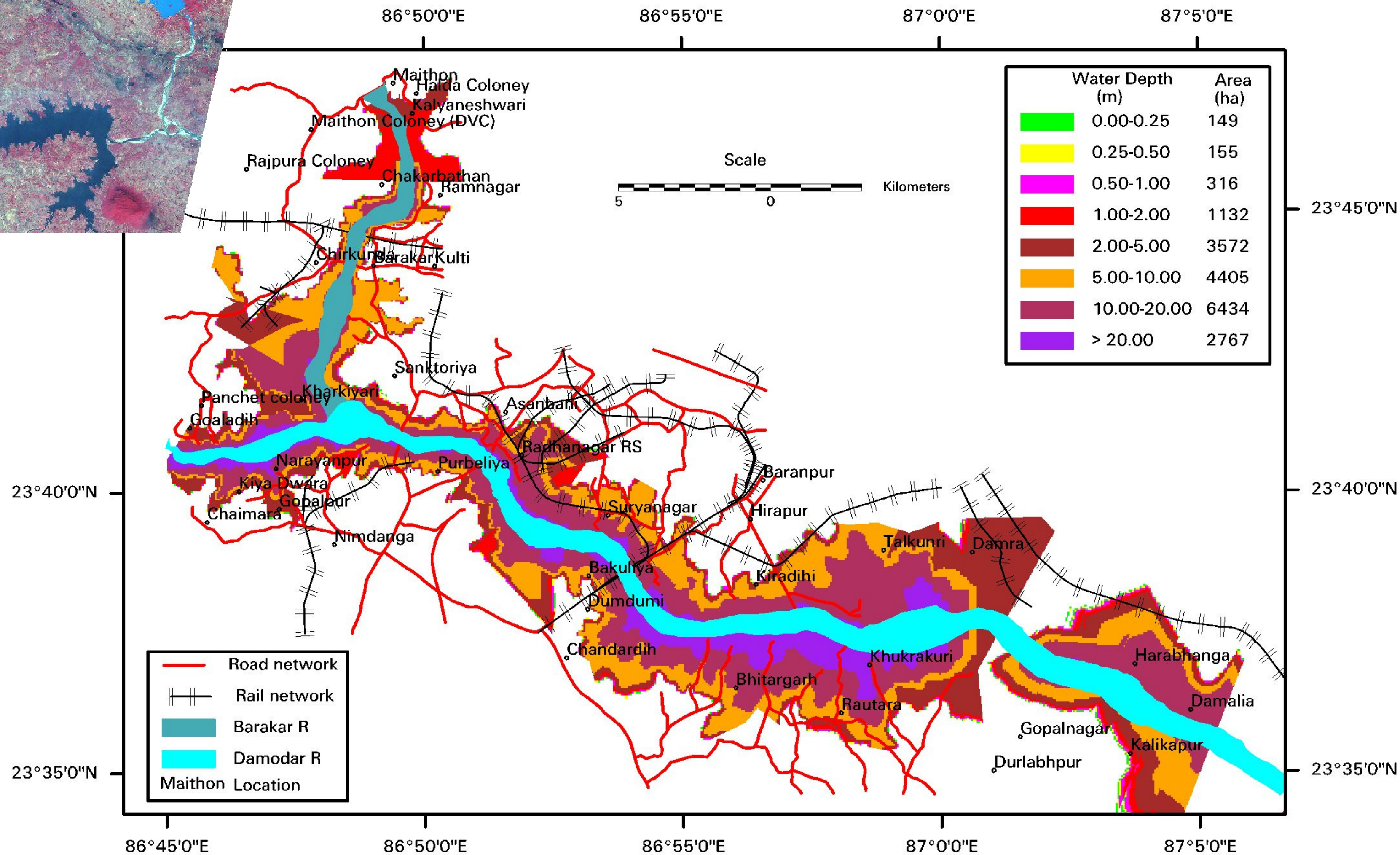


Inundated area for floods of various return periods and hydrological risk

Dam break / Embankment breach flood inundation modeling

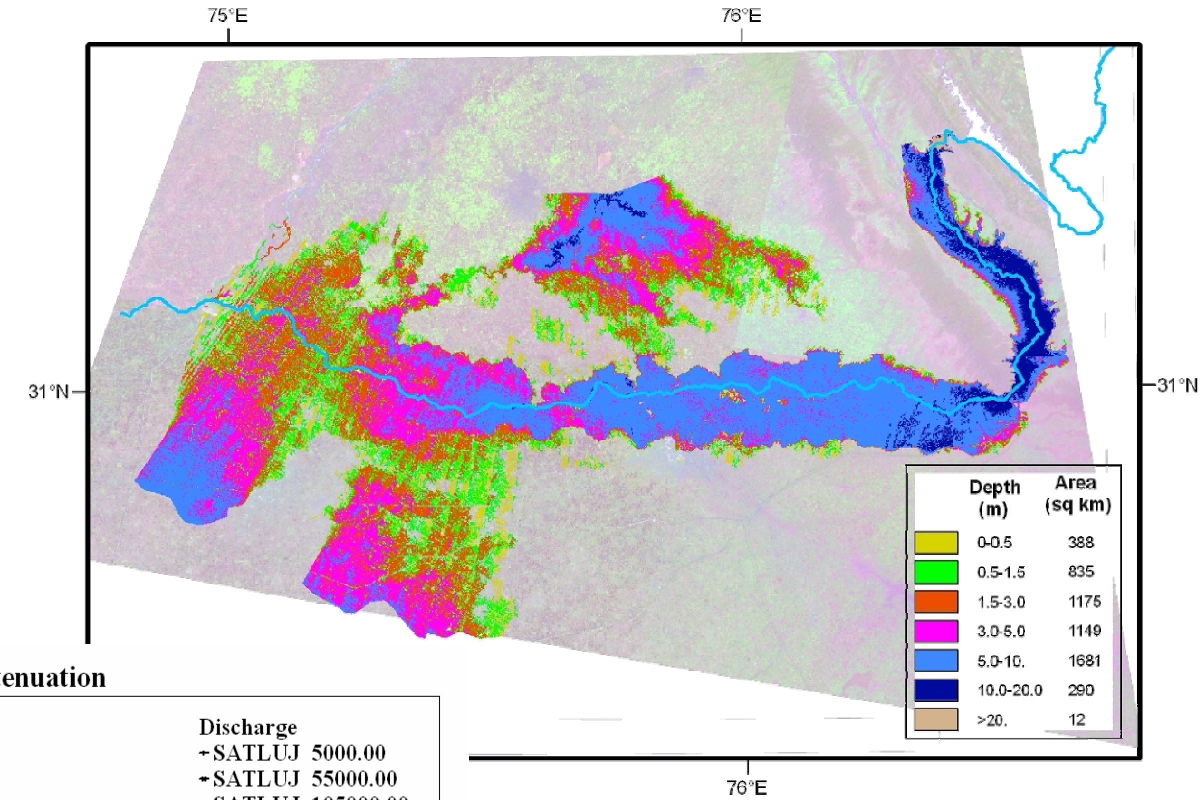
Maithon & Panchet Dam

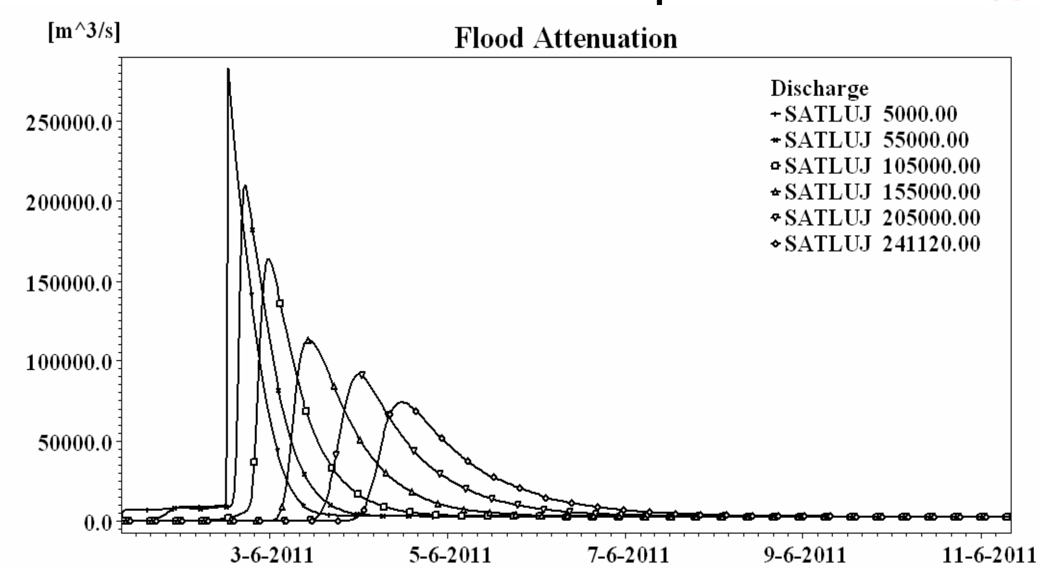




Flood inundation map when both the dams fail under PMF

Dam beak flood inundation modeling



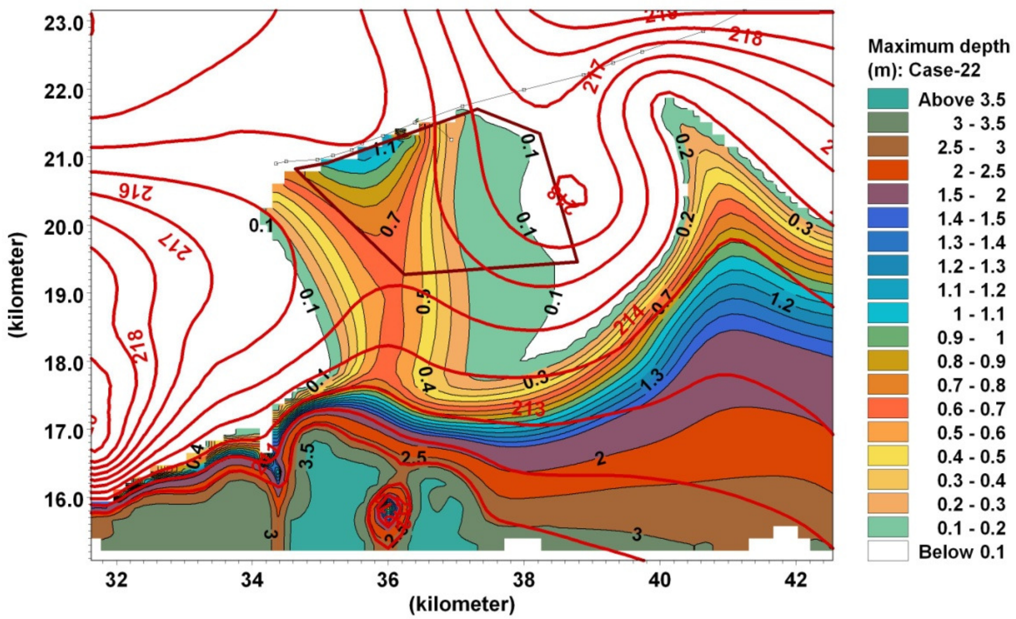


Dam beak flood inundation modeling

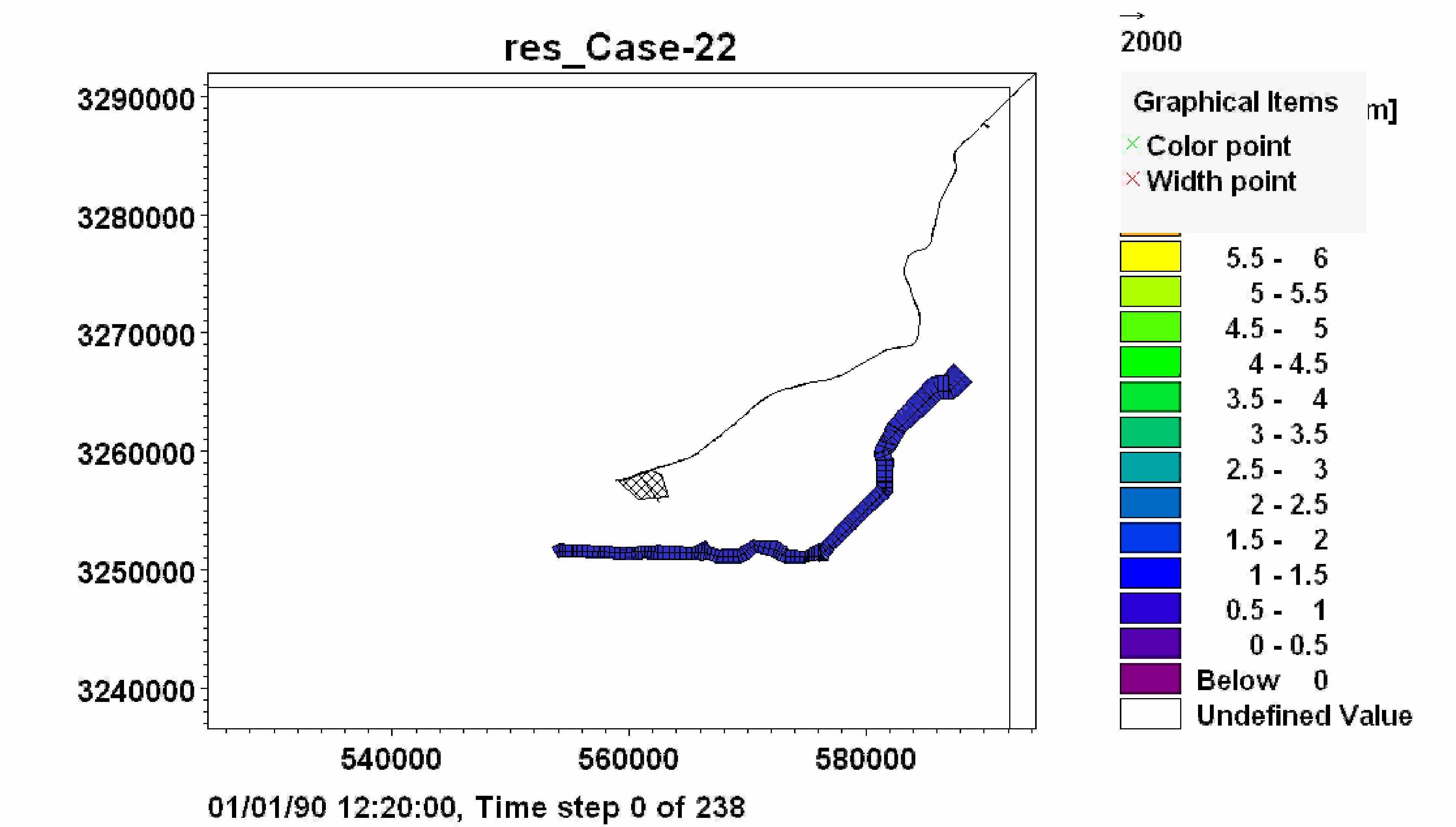
Estimation of Safe Grade Elevation for a Project Site for the Design Flood

Future climate change scenario

- Rainfall estimate is increased by 15% to account for the future climate change
- This makes case-22, the flooding scenario when bank full FBC flow is fully diverted towards plant site, local rain is 1000 yr + σ + 15% increase & catchment is flooded with 1000 yr + σ+15% increased rain
- Max flood depth = 1.17 m
- Max flood elevation = 218.25 m, increase of 0.1 m



FLOW MOVEMENT ANIMATION



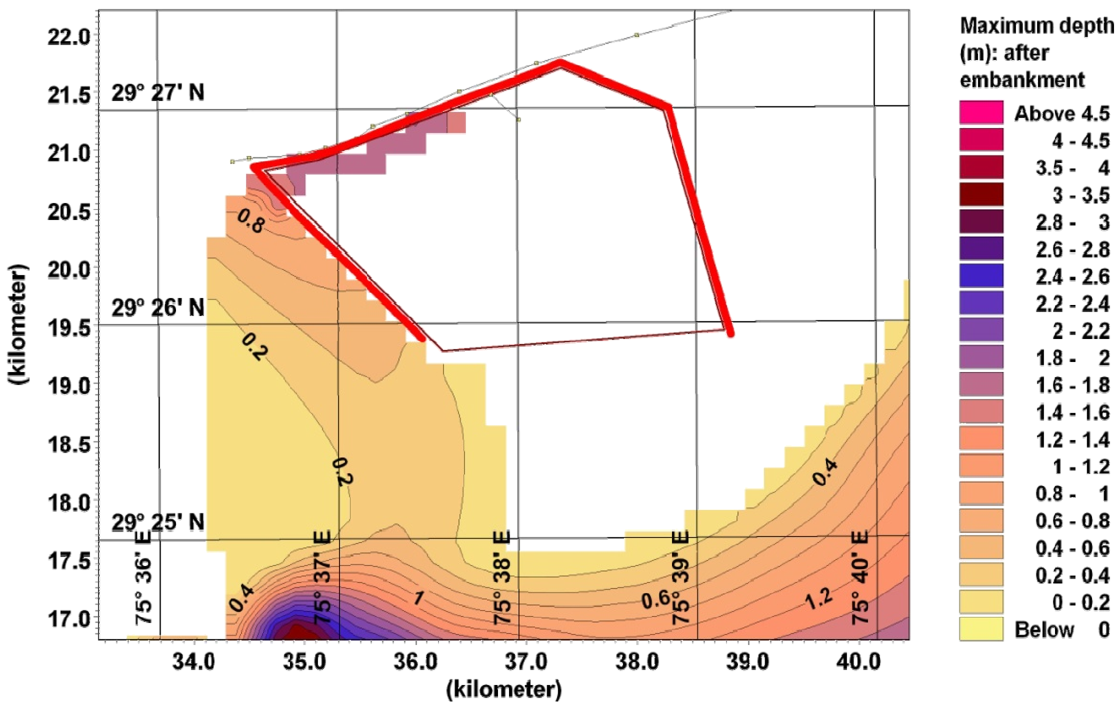
Case-22
Catchment flooding – 1000+σ+15%increase, local site rainfall – 1000+ σ +15%increase, Full flow divert from FBC & BML

FLOOD PROTECTION MEASURE

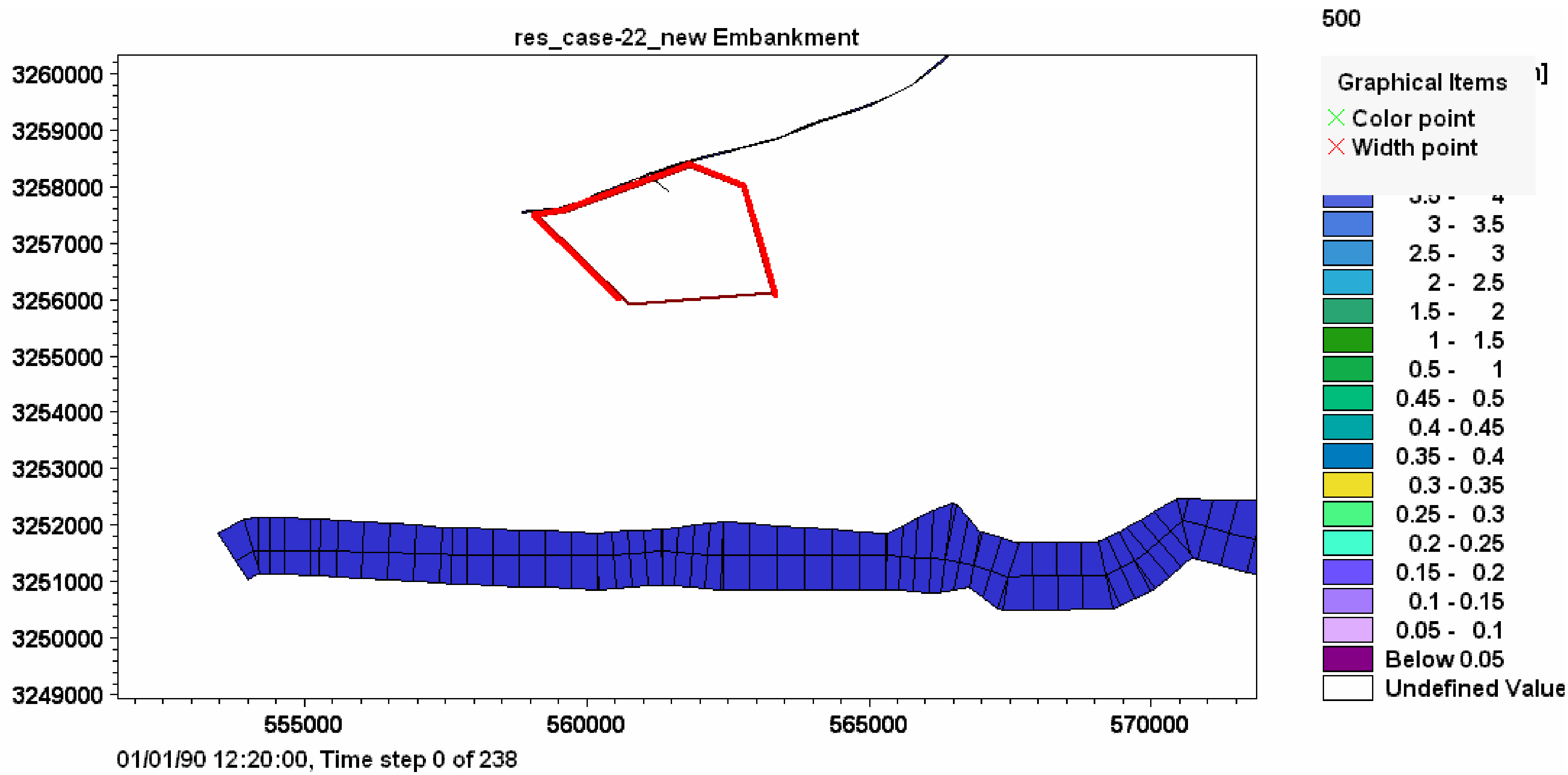
Alternative-I:

A flood protection embankment with top elevation of RL 219.3 m and plinth level of structures at RL 219.1 m

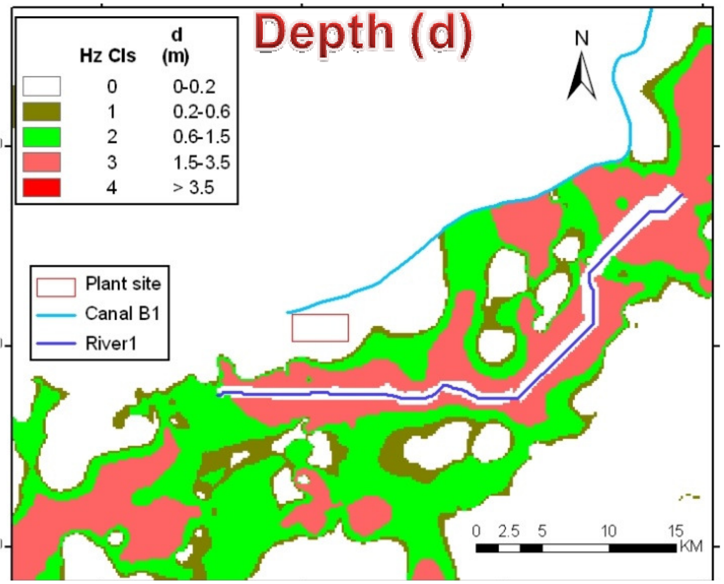
(local 1000 yr rainfall with 15% increase for CC and 1 .0 m free board)

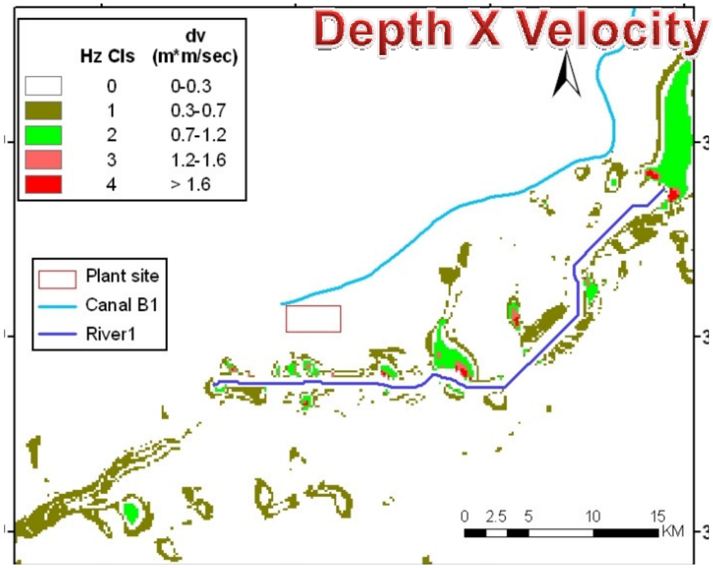


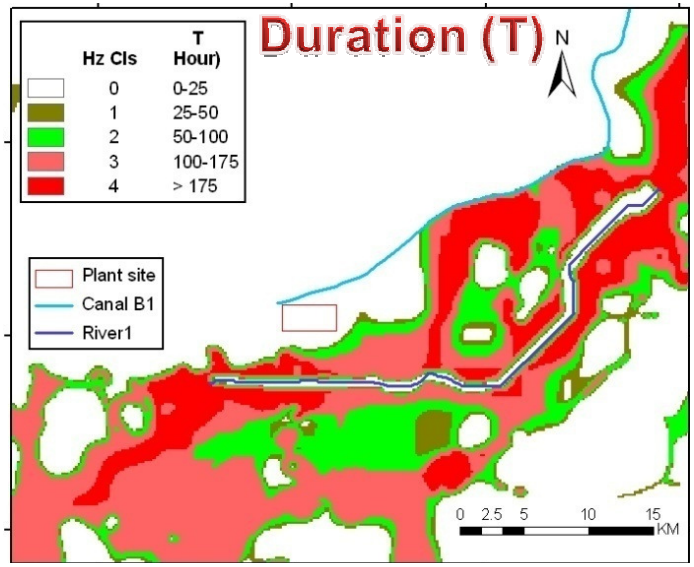
SCENARIO AFTER FLOOD PROTECTION MEASURE



Hazard Category : individual parameters







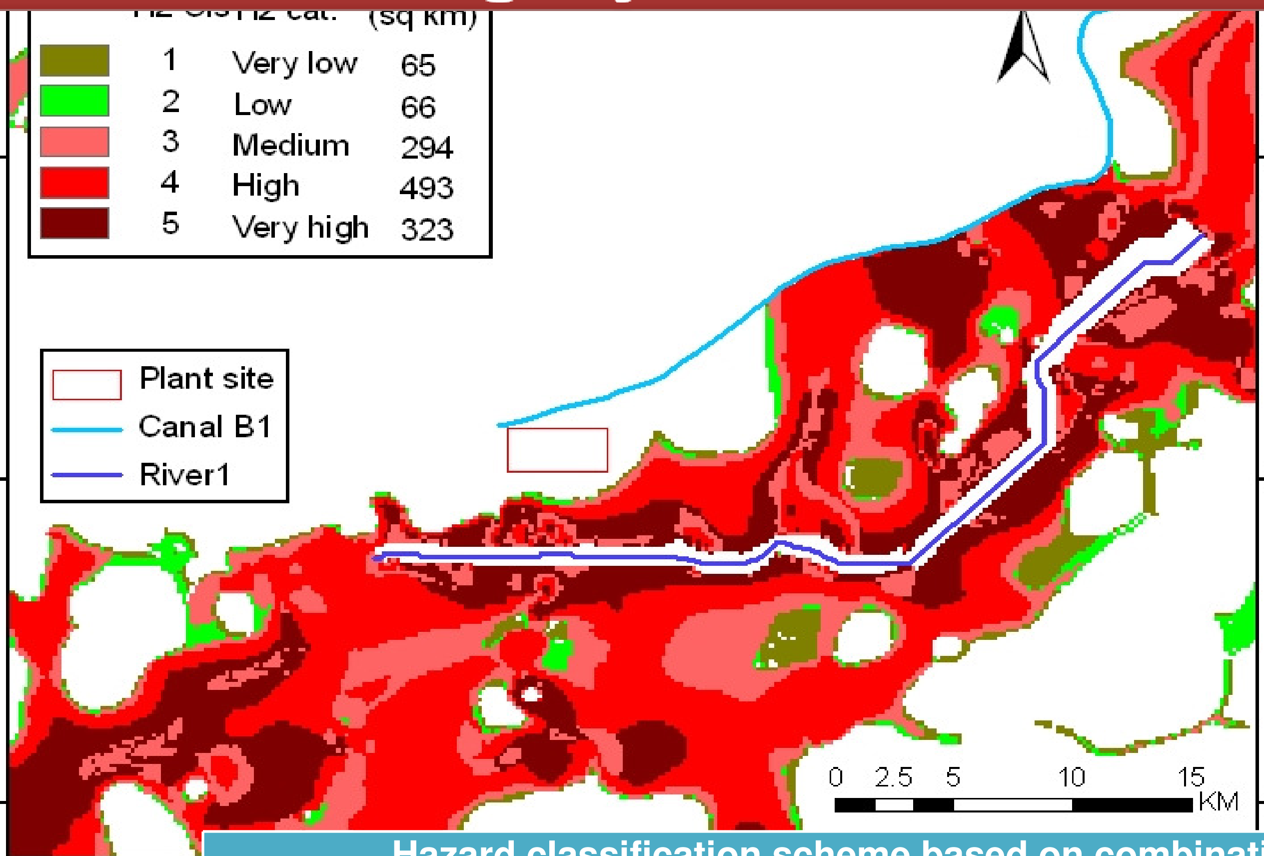
Hazard category for individual flow parameters

Hazard category	Depth of flooding (m)	Depth* flow velocity (m^2/sec)	Flood duration (hour)	Parameter hazard index
Very low	0-0.2	0 -0.3	0-25	0
Low	0.2-0.6	0.3-0.7	25-50	1
Medium	0.6-1.5	0.7-1.2	50-100	2
High	1.5-3.5	1.2-1.6	100-175	3
Very high	>3.5	>1.6	>175	4

Hazard is associated with flood event described by its magnitude and probability of occurrence

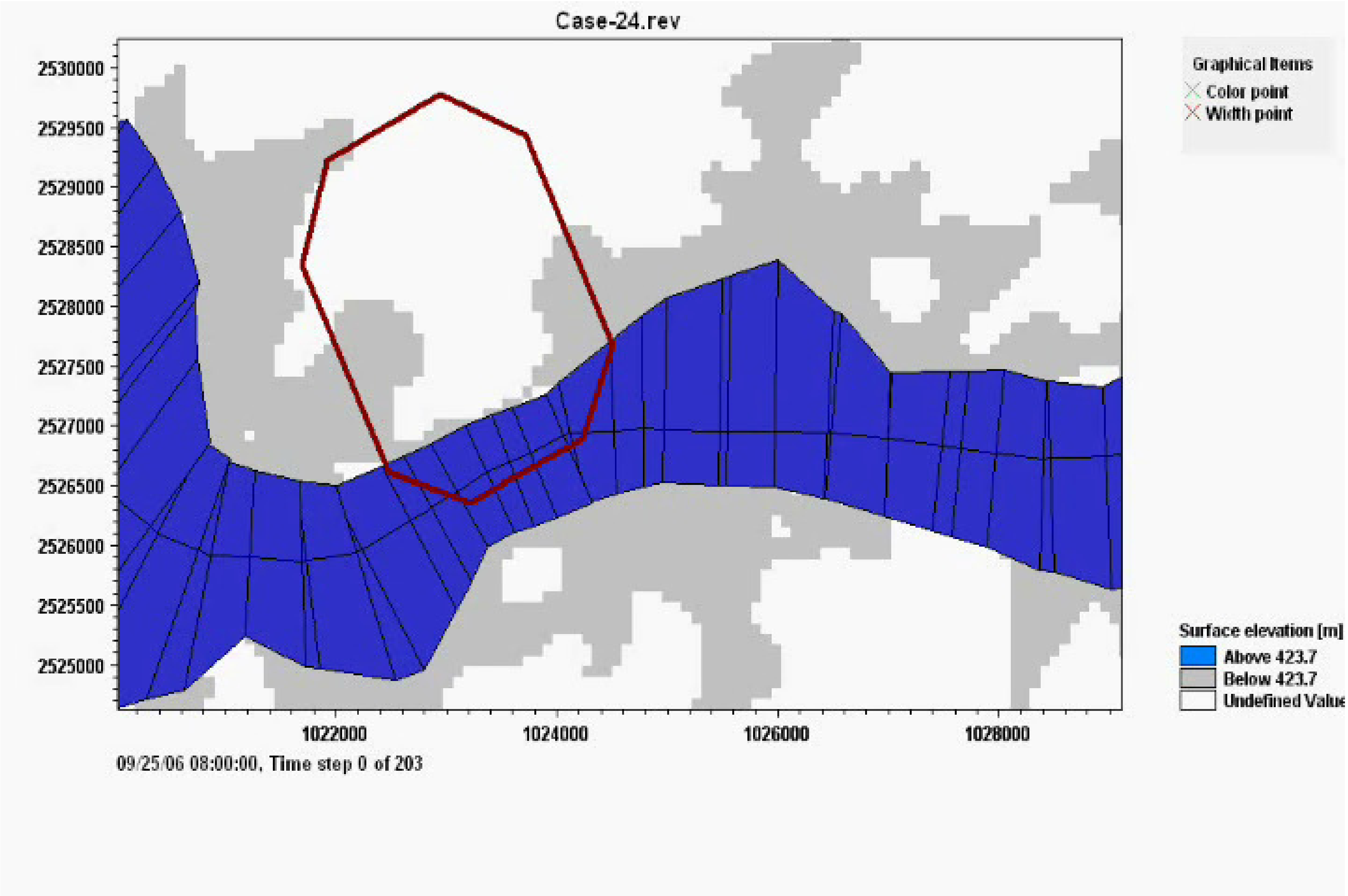
Risk is linked with the exposure of human and its property to the said hazard

Hazard Category : combination of parameters

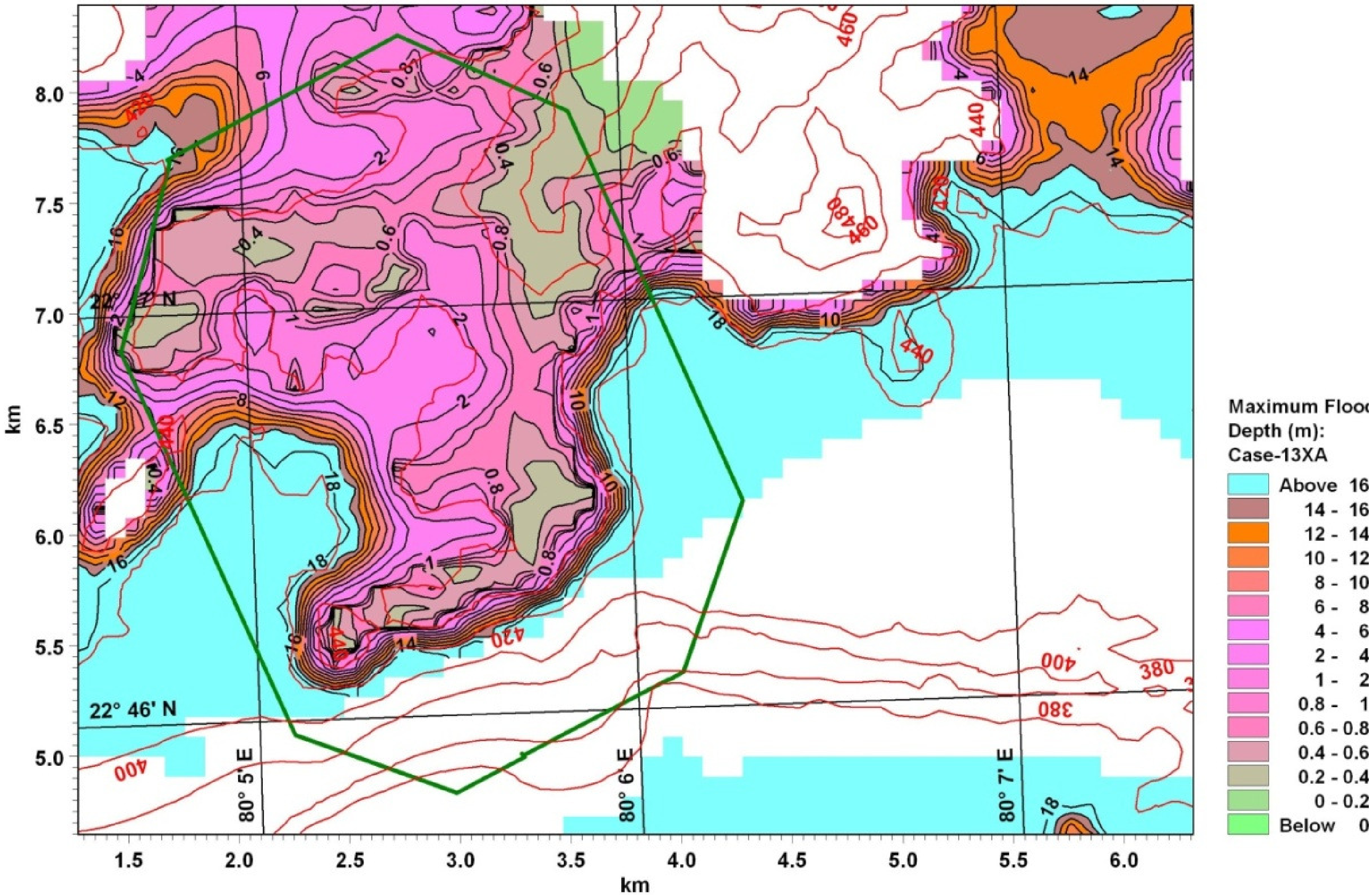


Hazard classification scheme based on combination of flow parameters			
SN	Function of depth, depth x velocity and duration	Hazard index	Hazard category
1	$0<d<0.2$ and $0<dv<0.3$ and $0<T<50$	1	Very low
2	$0<d<0.2$ and $0<dv<0.3$ and $T>50$	2	Low
3	$0.2<d<0.6$ or $0.3<dv<0.7$ and $0<T<25$	2	Low
4	$0.2<d<0.6$ or $0.3<dv<0.7$ and $T>25$	3	Medium
5	$0.6<d<1.5$ or $0.7<dv<1.2$ and $0<T<25$	3	Medium
6	$0.6<d<1.5$ or $0.7<dv<1.2$ and >25	4	High
7	$1.5<d<3.5$ or $1.2<dv<1.6$ and $0<T<25$	4	High
8	$1.5<d<3.5$ or $1.2<dv<1.6$ and $T>25$	5	Very high
9	$d>3.5$ or $dv>1.2$ and $T>0$	5	Very high

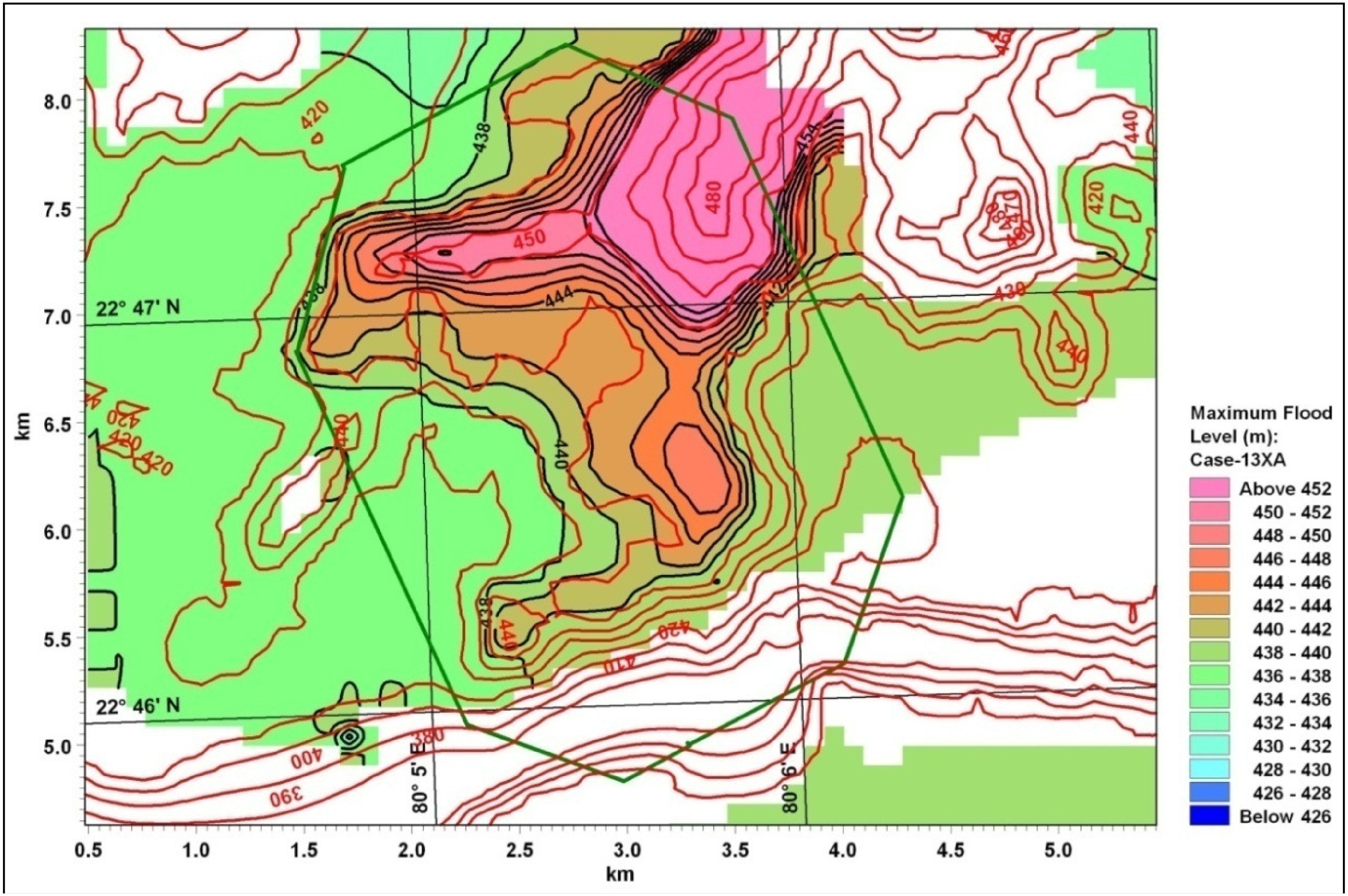
2-D Flood Inundation Modeling for a Project Site



2-D Flood Inundation Modeling (Max. Flood Depth)



2-D Flood Inundation Modeling (Max. Flood Level)



3. Outputs

Assess water availability and demands under the present and changed climatic scenarios and update water allocation policies and operation rules for the reservoirs of the study area

- **Estimate water demands of various sectors under the present and changed climatic scenarios.**
- **Analyze the simulated water availability for hydrologic extremes, inter annual and inter decadal variations to meet the water demands from various sectors.**
- **Propose adaptation practices considering major social, economic, and institutional factors under the changed climatic scenarios.**

3. Outputs

Promote implementation of the advanced technologies and IWRM approaches in field applications and decision-making process

Organization of training programs and workshops for promotion and dissemination of the downscaling techniques, assessment of water availability, hydrologic design practices, development of flood hazard maps and operation polices for reservoirs and IWRM approaches considering the climate change scenarios.

4. Activities and Key Leaders and Contributors

Lead Organizations:

- National Institute of Hydrology, Roorkee, India.
- Water Resources Department , Govt. of Maharastra, India (subject to consent)
- Indian Institute of Technology, Kharaghpur, India

4. Activities and Key Leaders and Contributors

Improve observational, modeling and application capacity

- Develop training modules and design and implement training courses
  - UNU, UN-CECAR, Univ. of Tokyo, AIT, JAXA, NIH, Roorkee.
- Promote secondary educational program in collaboration with universities
  - UNU, UN-CECAR, UT Tokyo, NIH, Roorkee.

Demonstrate improved capacity in modeling techniques for climate change impact studies

- Improve techniques for GCM output bias correction and downscaling.
  - AWCI, DIAS, Science communities, NIH, Roorkee.
- Apply distributed hydrological model(s) (DHM) for converting meteorological data to hydrological information and capable of coupling with GCM outputs
  - AWCI, DIAS, Science communities, NIH, Roorkee.

4. Activities and Key Leaders and Contributors

Assess climate change impacts on extreme events for some regions of India.

- Selection of GCMs which can express the regional climate, bias correction, downscaling.
  - AWCI, DIAS, Science communities, NIH, Roorkee.
- Carry out DHM(s) simulations using the corrected and downscaled GCM outputs for some regions of India.
  - AWCI, DIAS, Science communities, NIH, Roorkee.
- Compare changes of frequency and intensity of rainfall, flood, drought and water-nexus in between present and future.
  - AWCI, DIAS, Science communities, NIH, Roorkee.
- Assessment of the changes of flood, drought and water-nexus.
  - AWCI, DIAS, Science communities, NIH, Roorkee.

Promote implementation of the advanced technologies and IWRM approaches in field applications and decision-making process

- AWCI, National Institute of Hydrology, Roorkee.


THANKS !