Analysis of Deviations observed in Design Flood of existing River Valley Projects in India and the Causative Factors

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Design Flood

- A design flood is a hypothetical flood (peak discharge or hydrograph) adopted as the basis in engineering design of project components.
- One of the most common purposes is the safety of structures against failure by overtopping during floods.
- Utmost attention has been given world over to select and estimate the design flood that is most appropriate for a given case
- IS 11223-1985: Guidelines for Fixing Spillway Capacity mandate standards for some aspects related to mitigating dam failure hazard, specifically the design of spillways to handle floods.

Methods of Determination of Design Flood

- Flood Formulae & Enveloping Curves
- Flood Frequency Analysis
- Hydro-meteorological approach

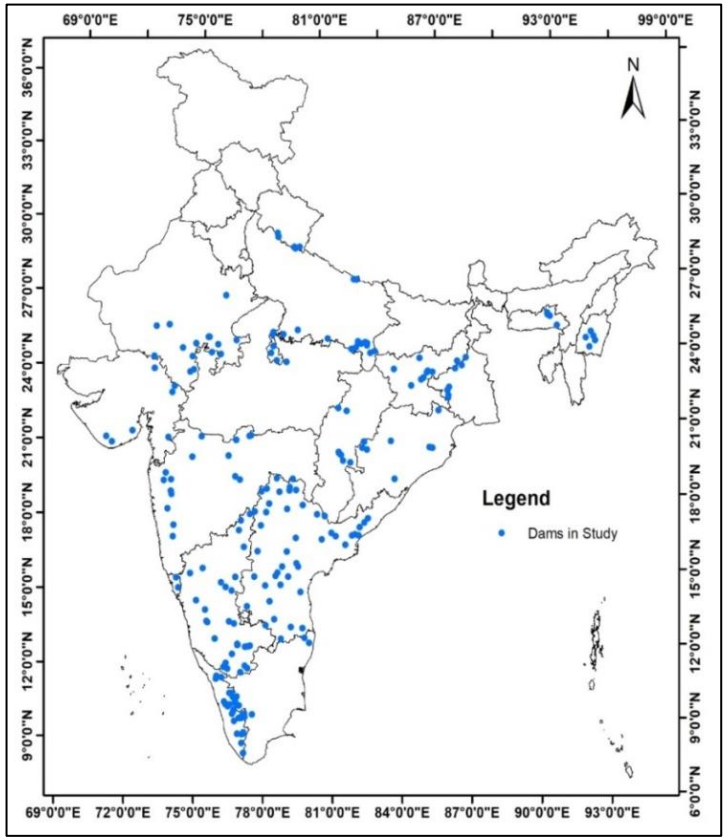
IS 11223:1985 - Criteria For Selection of Design Flood For Dams In India

- Design flood standards are based on the storage capacity and hydraulic head of the dam.

Classification	Gross storage	Hydraulic Head	Inflow design flood for safety of dam
Small	Between 0.5 and 10 MCM	Between 7.5 m and 12 m	100 year flood
Intermediate	Between 10 and 60 MCM	Between 12 m and 30 m	Standard Project Flood
Large	Greater than 60 MCM	Greater than 30 m	Probable Maximum Flood

Study Area

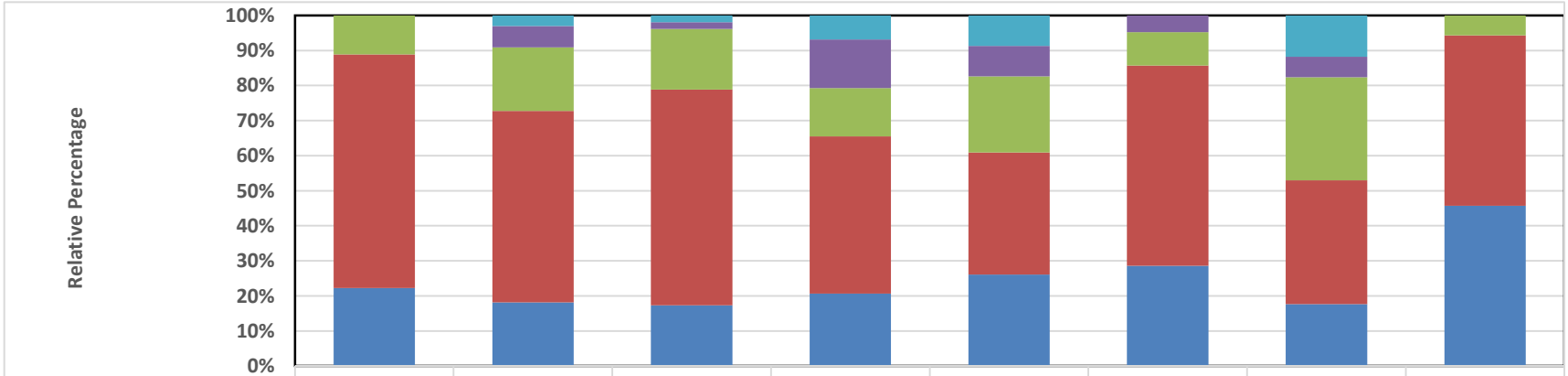
- The dams for design flood review were selected as per their inclusion in Dam Rehabilitation and Improvement Project (DRIP).



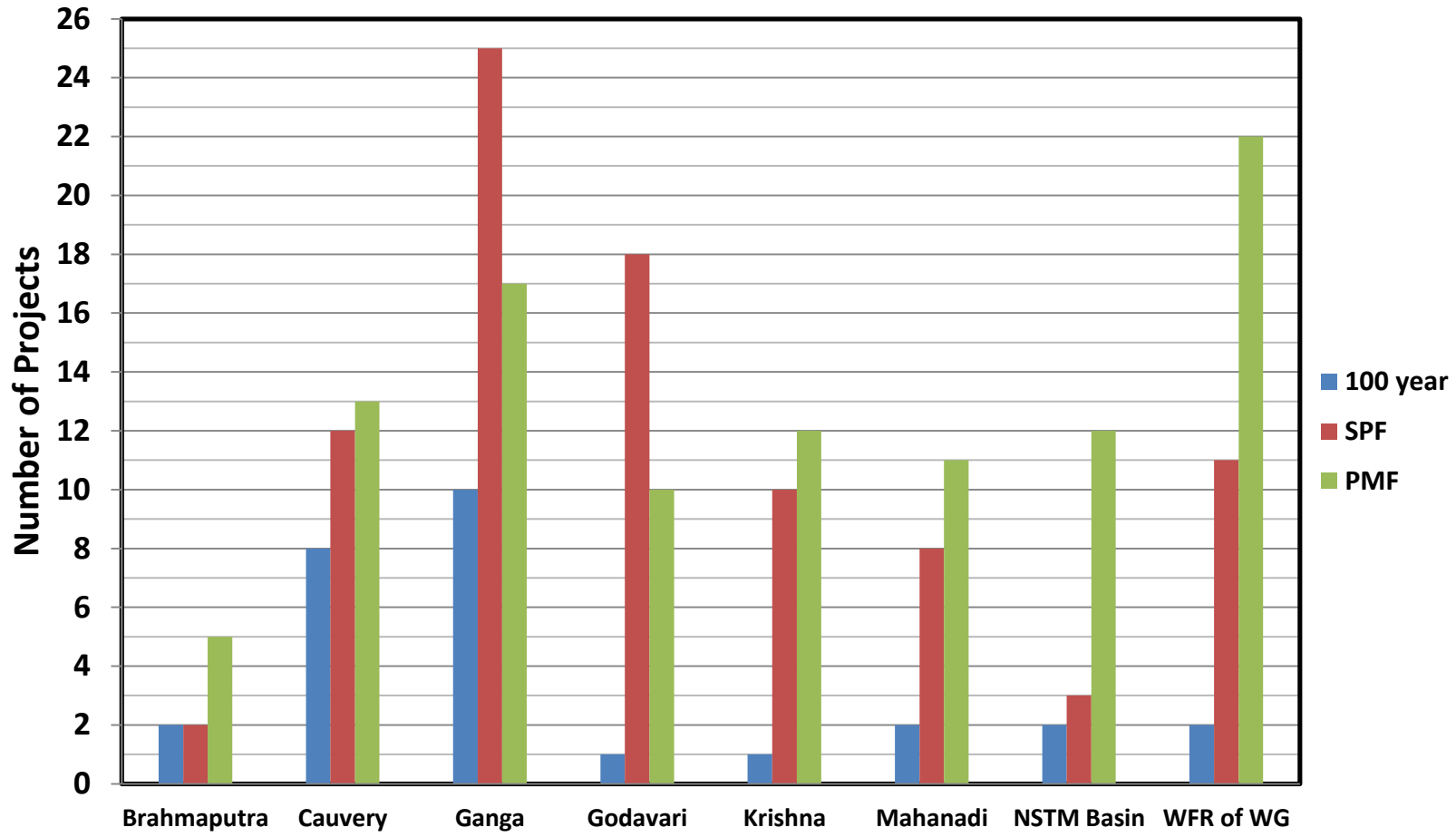
State Wise Distribution of Projects	
State	No. of Projects
Andhra Pradesh	26
Chhattisgarh	7
Goa	2
Gujarat	7
Jharkhand	9
Karnataka	28
Kerala	30
Madhya Pradesh	2
Maharashtra	18
Manipur	5
Meghalaya	4
Odisha	8
Rajasthan	14
Tamil Nadu	4
Telangana	21
Uttar Pradesh	26
West Bengal	8
Total	219

Basin Wise Distribution of Projects	
Basin	No. of Projects
Brahmaputra	9
Cauvery	33
Ganga	52
Godavari	29
Krishna	23
Mahanadi	21
Narmada, Tapi, Sabarmati & Mahi	17
West Flowing Rivers of Western Ghats	35
Total	219

Characteristics of Dams chosen - Basin Wise statistics of catchment area of dams studied



	Brahmaputra	Cauvery	Ganga	Godavari	Krishna	Mahanadi	NTSM basin	WFR of Western Ghats
>20000 sq.km	0	1	1	2	2	0	2	0
5000-20000 sq.km	0	2	1	4	2	1	1	0
1000-5000 sq.km	1	6	9	4	5	2	5	2
100-1000 sq.km	6	18	32	13	8	12	6	17
0-100 sq.km	2	6	9	6	6	6	3	16


Number of Projects
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Brahmaputra
Cauvery
Ganga
Godavari
Krishna
Mahanadi
NSTM Basin
WFR of WG
100 year
SPF
PMF

Analysis of Increase in Design Flood

- Using the design flood review data, the increase in design flood over existing spillway capacity were compared and percentage increase in design flood with respect to existing spillway capacity has been computed.

Percentage increase in design flood	Category
0%	No increase
0%-20%	Mild increase
20%-50%	Moderate increase
50%-100%	High increase
>100%	Very high increase

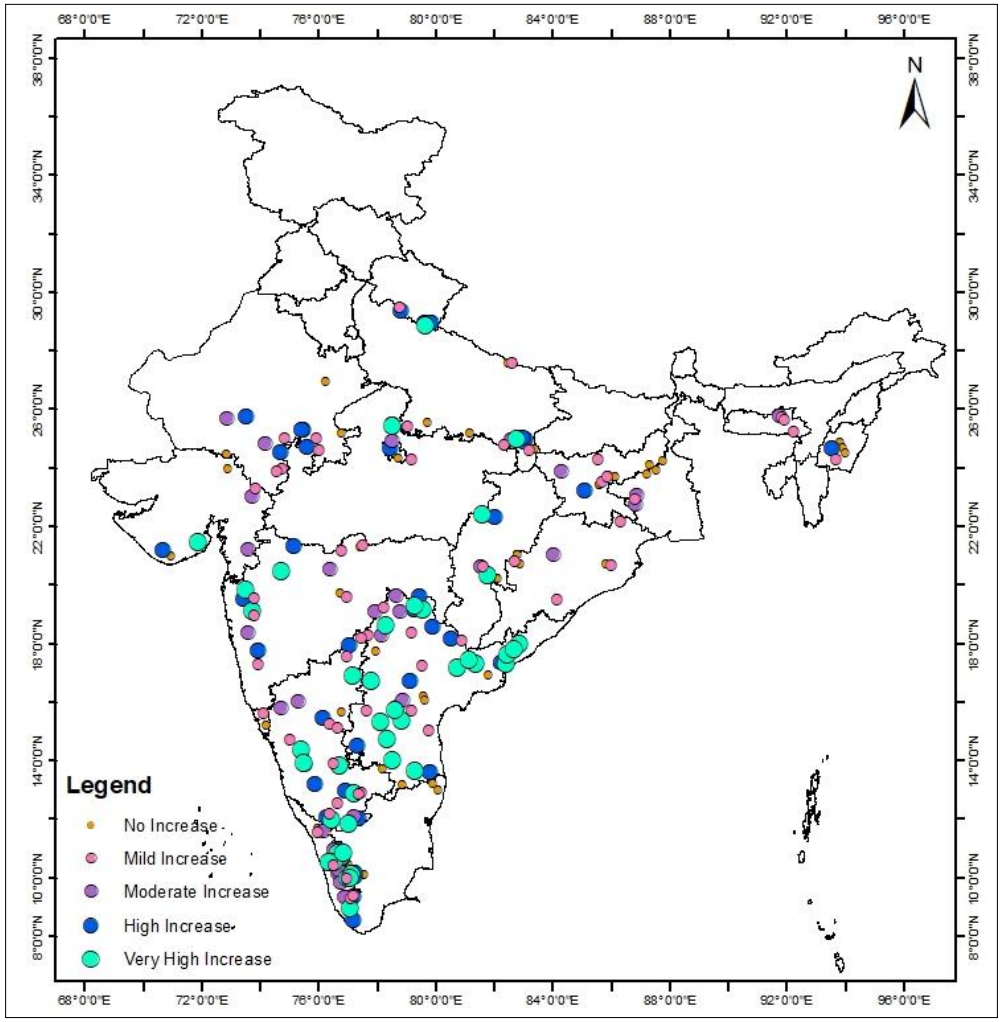
- In order to identify the major causative factors responsible for deviations in design flood, the increase in design flood has further been analysed with respect to followings:

a) Change in design flood selection criteria as per IS 11223:1985

b) Basin-wise analysis to check any uniformity in design flood deviations

c) Updated storm data and PMP Atlases

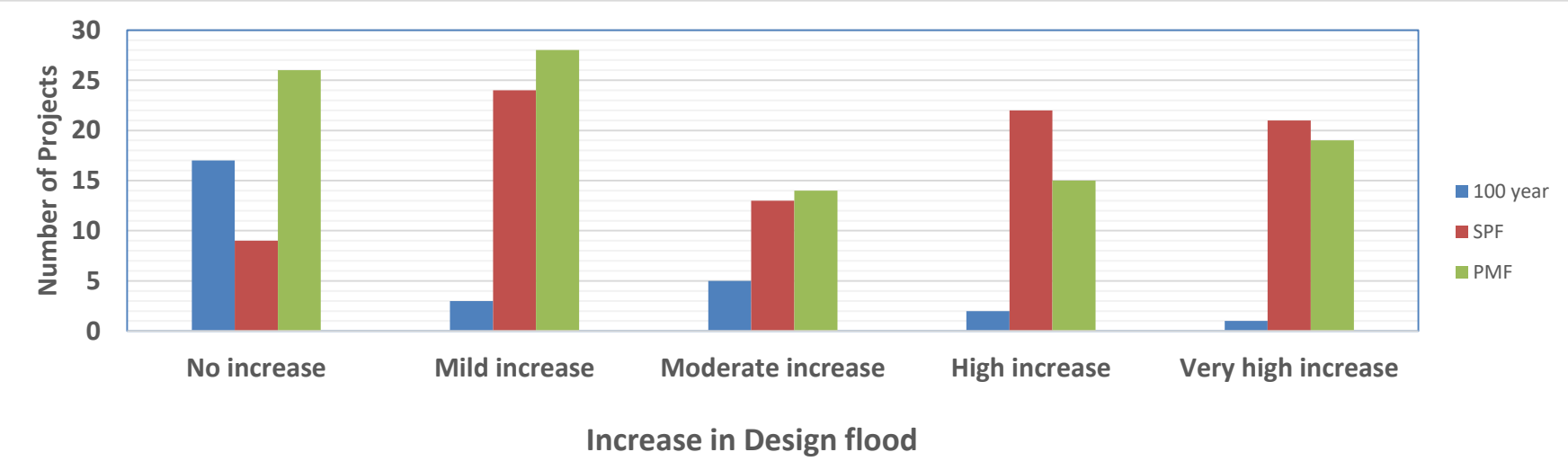
d) Change in design flood with respect to catchment area



Increase in design flood due Change in design flood selection criteria as per IS 11223:1985

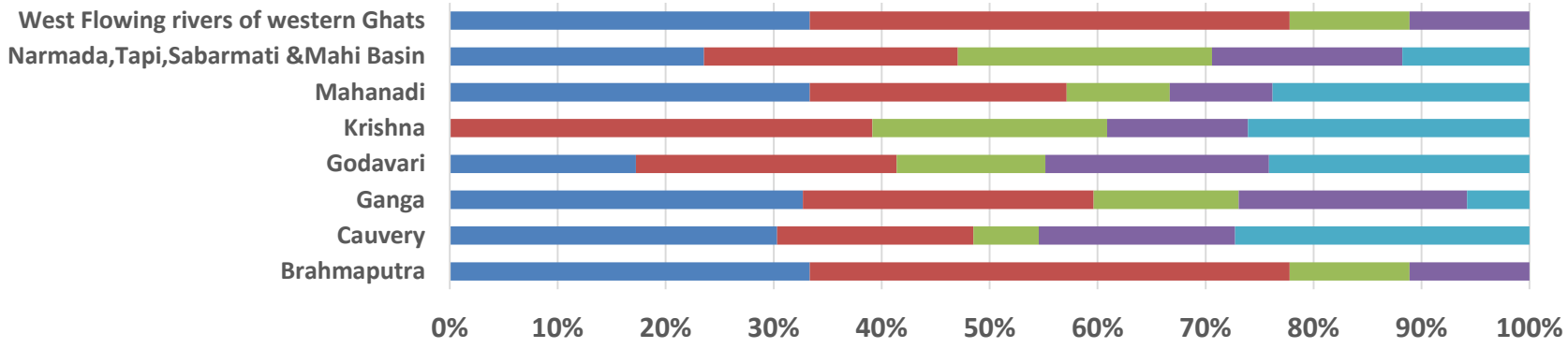
- The dams designed before 1985 were having a different design flood selection criteria in comparison to IS 11223:1985. Hence, out of 219 dams considered in the present study, the revised design flood data of the dams constructed before and after 1985 has been analysed.

Category of Increase in Design Flood	Total dams	Constructed before year 1985	Constructed after year 1985	Percentage of projects constructed before 1985	Percentage of projects constructed after 1985
No increase	52	36	16	69.2	30.8
Mild increase	55	36	19	65.5	34.5
Moderate increase	32	19	13	59.4	40.6
High increase	39	26	13	66.7	33.3
Very high increase	41	34	7	82.9	17.1



- It can be concluded from the above table that the highest percentage of dams constructed before 1985 are lying in very high increase category of design flood. Further, out of the 34 projects constructed before year 1985 and having more than 100% increase in design flood, only 1 project falls under 100 year design flood while rest of 33 projects falls either under SPF or PMF

Basin-wise analysis to check any uniformity in design flood deviations



	Brahmaputra	Cauvery	Ganga	Godavari	Krishna	Mahanadi	Narmada,Tapi, Sabarmati &Mahi Basin	West Flowing rivers of western Ghats
No inc	3	10	17	5	0	7	4	3
Mild inc	4	6	14	7	9	5	4	4
Moderate inc	1	2	7	4	5	2	4	1
High inc	1	6	11	6	3	2	3	1
Very high inc	0	9	3	7	6	5	2	0

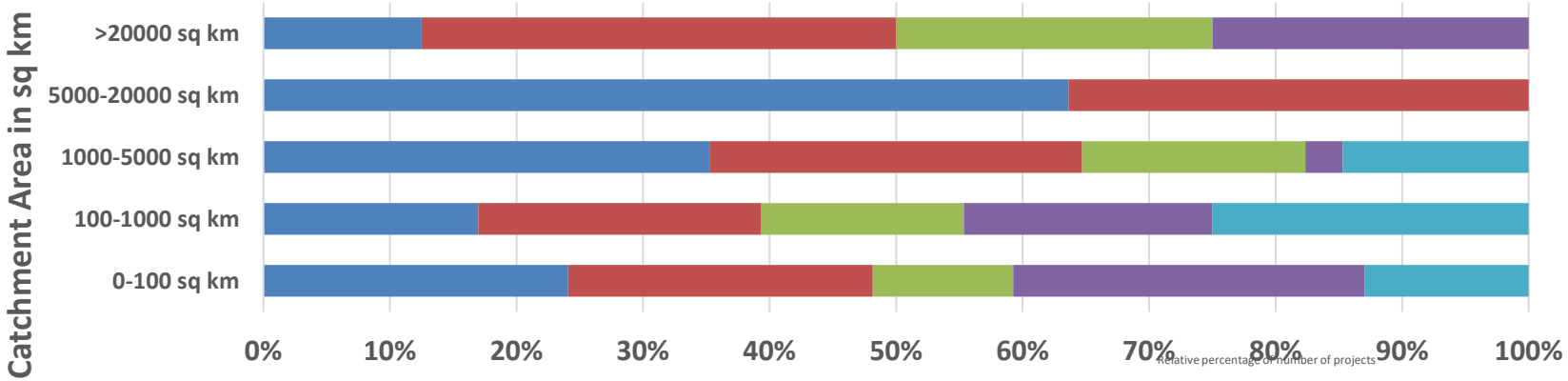
Increase due to updated storm data and PMP Atlas

- Basin wise PMP Atlases were prepared to standardize procedures for estimation of design rainfalls and PMP for various durations at different places in a river basin in order to reduce subjectivity and achieve consistent results. Initially, PMP atlases were prepared for the six river basins (Cauvery, Godavari, Mahanadi, Chambal, Narmada-Tapi and the West flowing rivers of Western Ghats) in 1998. Similar studies for Krishna and Indus River basins were carried out by IITM, Pune.

- Updated PMP Atlases of above six basins and new PMP Atlases for Ganga and Brahmaputra River basins were prepared in 2015 considering the data of new storms which were not available in earlier atlases.

- A case in point is of Dhora dam in Uttar Pradesh which was completed in 1960. The height of dam is 14.6m and gross storage is 45.6 MCM. In Design Flood Study, 2 day Aliganj Storm of 11-12 September 2003 was found to be most critical for computation of SPF. The design flood was revised to 950 cumec, while its spillway capacity was 549 cumec. Hence, updated storm data is one of the reason for increase in design flood.

Analysis of increase in design flood with respect to the catchment area



	0-100 sq km	100-1000 sq km	1000-5000 sq km	5000-20000 sq km	>20000 sq km
No increase	13	19	12	7	1
Mild increase	13	25	10	4	3
Moderate increase	6	18	6	0	2
High increase	15	22	1	0	2
Very high increase	7	28	5	0	0

Accommodating Increased Design Flood Peak in Existing Dams

- The increase in revised design flood due to various causative factors as explained above **does not necessarily mean that the dam has become hydrologically unsafe**.
- In a number of cases it has been found **through reservoir routing studies of revised design flood** hydrograph that the revised flood peak can be safely passed with slight encroachment of available freeboard.
- In cases where the design flood may not be safely passed with available spillway capacity, a combination of **strategies of structural and non-structural measures** need to be adopted.
- Some of the structural measures are construction of additional spillway, fuse plug, raising height of dam etc. In case where sufficient space is available, uncontrolled weir/flush bar may be constructed to release extra discharge.
- With the advancement in rainfall forecast, the non-structural measures like pre-depletion of reservoir on the basis of inflow forecast, implementation of effective inflow forecast, implementation of emergency action plan etc. also provide effective practical solution for ensuring safety of dam and people living downstream of dam

Conclusions

- With the passage of time, new data is added to the records which make the process dynamic.
- Due to dynamicity in Design Flood Estimation, it is essential that design flood of river valley projects should normally be reviewed at an interval of 15 years or occurrence of any extreme event due to which flood has been equalled or exceeded the design flood, whichever is earlier.
- From the above analysis of outputs from the design flood review of 219 projects under DRIP, it has been observed that the major cases of deviations in design flood involve changes in criteria for selecting design flood for e.g. Standardization by IS 11223:1985, consideration of recent storm data in the review, advancements in analysis approaches.
- It has also been observed that such deviations are more common in case of smaller catchments in comparison to larger catchments because of normalisation of flood peaks in large catchments due to routing effects.
- This study provides database in support of the phenomenon of intensification of short-duration rainfall extremes are likely to have more impact on the design flood of smaller catchments in comparison to larger catchments

Thank You