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Sensitivity Analysis of Location Specific Constants of IDF Equation for Nanded, Hingoli and Jalna

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ABSTRACT:

Sensitivity analysis of location specific constants of rainfall intensity – duration – frequency (IDF) relationship for Nanded, Hingoli and Jalna locations of Marathwada region was performed under present project. The IDF relationship of locations, Nanded, Hingoli and Jalna were considered for the present study. The location-specific constants of IDF equations considered, were varied within a range of -50% to +50%, with an interval of 5%. Only one constant was varied at a time while keeping the other three constants unchanged, for preparation of data sets. Rainfall intensity was calculated for the different combinations of rainfall duration and return period. The rainfall duration was considered from 0.25h to 3h with an interval of 0.25h. The return period was considered from 5 years to 25 years with an interval of 5 years. Sensitivity analysis was performed by calculating Sensitivity ratio(S) and Relative Sensitivity ratio (S_r) for different combinations of rainfall duration and return period along with the intensity for 3 locations. The values of Sensitivity ratio and Relative Sensitivity ratio for four location specific constants were observed to be equal. Hence, the significant difference was checked between the two ratios using Student t- test. Based on values of S and Sr, location specific constants were classified as Highly Sensitive (HS), Moderately Sensitive (MS), Less Sensitive (LS) and Very Less Sensitive (VLS). The very less sensitivity category was considered as non-sensitivity interval.

Key words: Sensitivity analysis, Location specific constants, non-sensitivity interval, Rainfall intensity, Duration of rainfall, Return period, IDF.

INTRODUCTION:

Water is essential for life on Earth, and its importance stretch across various aspects of our existence. Agriculture is a major consumer of water. With more people to feed, there is an increase in demand for water in the agricultural sector for irrigation, livestock, and crop production. Human actions are impacting the global environment, including the climate. This in turn impacts the amounts and spatial and temporal distributions of precipitation that falls on watersheds and the runoff timings.

Understanding the frequency, intensity, and patterns of hydrological events is crucial for several reasons, infrastructure planning, and environmental management. The intensity-duration-frequency (IDF) relationship is indeed a critical concept in hydrology, particularly in the context of assessing and managing the risks associated with extreme precipitation events. The IDF relationship is a mathematical relationship between the rainfall intensity, duration of rainfall, and return period. The IDF relationship includes location specific constants depending on the geographical location of the area. The relationship helps hydrologists and engineers to understand and quantify the behaviour of extreme rainfall events.

Intensity-duration-frequency (IDF) relationship is one of the most important tools for assessing rainfall events. Updating Intensity-Duration-Frequency (IDF) curves is a critical step in understanding and adapting to the impacts of climate change on hydrological events, specifically rainfall. IDF equation provide valuable information about the relationship between rainfall intensity, duration, and frequency, helping in the assessment of flood risks, landslides, and other weather-related hazards.

Sensitivity analysis is indeed a tool used to assess how variations or changes in the values of independent variables impact a specific dependent variable, while keeping other factors constant. It helps in understanding the robustness and reliability of models or simulations under different scenarios.

There are many approaches to perform a sensitivity analysis. One-at-a-Time (OAT) sensitivity analysis is a straightforward and intuitive method for understanding the impact of individual input factors on the output of a model or system. This approach involves systematically varying one input variable at a time while keeping all other factors constant at their baseline values. OAT sensitivity analysis is particularly useful for providing a quick and easy-to-understand overview of how changes in individual parameters affect the model.

MATERIAL AND METHODS

This chapter deals with data collection and methodology adopted to fulfill the objectives of present study.

Study area

Sensitivity analysis was carried out for location specific constants of IDF relationships for Nanded, Jalna and Hingoli locations of Marathwada region.

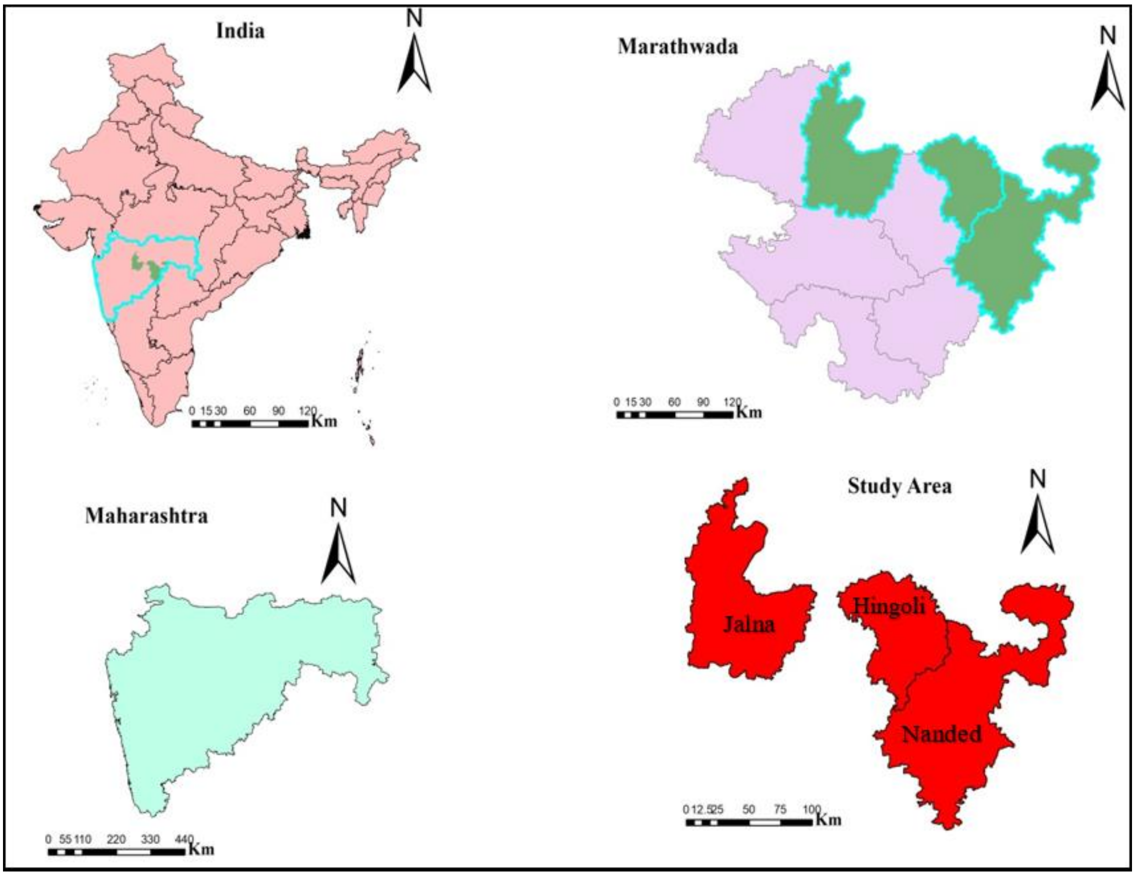

Fig: Location map of study area

Data collection

The general formula of the rainfall intensity-duration-frequency (IDF) equation is (Nemec, 1973)

$$I = \frac{KT^a}{(t+b)^d} \qquad \text{---------(1)}$$

Where, I – Maximum rainfall intensity (cm/h); T – Return period (year); t – Duration (h); K, a, b, and d – Location specific constants, depending on the geographical location of the area.

IDF relationships of locations Nanded, Hingoli and Jalna of Marathwada region were considered and accordingly the sensitivity analysis was performed on constants of these relationships**.**

The IDF relationships of locations Nanded, Hingoli and Jalna are tabulated in the Table 2.1

Table 1: IDF relationships for selected locations of Marathwada region

Sr. No.	Location	IDF relationship	Source
1	Nanded	$I = \frac{9.33T^{0.1770}}{(t+1.0)^{1.090}}$	Kadam, 2015
2	Hingoli	$I = \frac{15.560T^{0.1116}}{(t+1.0)^{1.1476}}$	Jagtap, 2017
3	Jalna	$I = \frac{12.15T^{0.09422}}{(t+1.0)^{1.1762}}$	Jagtap, 2017

The location specific constants of IDF equations considered, were varied within a range of -50% to +50%, with an interval of 5%. Rainfall intensity was determined for the different combinations of rainfall duration and return period. The rainfall duration was considered from 0.25h to 3h with an interval of 0.25h. The return period was considered from 5 years to 25 years with an interval of 5 years. For preparing the data sets, only one constant was changed at a time, while the other three constants were kept unchanged.

Sensitivity analysis

Sensitivity analysis is a technique used to assess how the variation or uncertainty in the input parameters of a model influences the results or outputs of that model. It helps to understand the sensitivity of a model's predictions or outcomes to changes in the values of its input variables. The foundational approach of the sensitivity analysis technique uses Partial differentiation whereas the basic approach is to vary parameter values one at a time by keeping the other parameters fixed to baseline values (Shiradkar, 2017).

Sensitivity ratio was calculated by using the following equation (McCuen and Snyder, 1986),

$$S = \frac{(O_2 - O_1)/O_{12}}{(I_2 - I_1)/I_{12}} \quad \text{----------(2)}$$

Where, O_1 – output for the input I_1; O_2– output for the input I_2; O_{12}– mean of two outputs O_1 and O_2; I_{12}– mean of two inputs I_1 and I_2.

Relative sensitivity ratio was calculated as (White and Chaubey,2005),

$$S_r = \left| \left[\frac{x}{y}\right] * \left[\frac{y_2 - y_1}{x_2 - x_1}\right] \right| \quad \text{----------(3)}$$

Where, S_r = Relative sensitivity ratio; y = predicted output; $x_1 = (x+\Delta x)$ and $x_2 = (x-\Delta x)$; x_1 and x_2 = parameter values that result in output y_1 and y_2, respectively.

Student t-test

The student's t-test is a statistical hypothesis test used to determine if there is a significant difference between the means of two groups.

The t-test was calculated using the following formula, (Patil S.S, 2021)

$$t = \frac{\mu_1 - \mu_2}{\sigma_d} \quad \text{-----------(4)}$$

where,

$$\sigma_d = \sqrt{\left[\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right]}$$

Where, μ_1 and μ_2 are means of sample 1 and 2; σ_d is variance of difference between the means; σ_1 and σ_2 are variances of sample 1 and 2 and; n_1 and n_2 are number of observations of sample 1 and 2.

Student t-test was performed to check the significance difference between sensitivity ratio and relative sensitivity ratio at 5% level of significance.

Classification of location specific constants

Based on values of S and S_r, location specific constants were classified as highly sensitive, moderately sensitive, less sensitive, and very less sensitive. A scale of 0 to 1 was considered and accordingly four groups were formulated (Shiradkar, 2017 and Patil S.S, 2021)

Table 2: Classification criteria for location specific constants

Sr.No.	Range of Sensitivity and Relative Sensitivity ratio	Classification Category
1	<0.25	Very less sensitive (VLS)
2	0.25-0.50	Less sensitive (LS)
3	0.50-0.75	Moderately Sensitive (MS)
4	>0.75	Highly Sensitive (HS)

Based on the classification criteria of sensitivity analysis, non-sensitivity interval was determined. The very less sensitivity category was considered as non- sensitivity interval.

RESULT AND DISCUSSION

Sensitivity ratio and Relative sensitivity ratio values for each location specific constant of IDF equations were calculated and tabulated for Nanded, Hingoli and Jalna locations of Marathwada region.

Table 3: Sensitivity ratio and relative sensitivity ratio for Nanded

Nanded		Sensitivity Ratio(S)				Relative Sensitivity Ratio (Sr)			
t (hr), T (yr)		K	a	b	d	K	a	b	d
0.25,5	Max	1.0000	0.2849	0.8719	0.2432	1.0000	0.2858	1.0521	0.2438
	Min	1.0000	0.2830	0.8631	0.2420	1.0000	0.2849	0.8735	0.2432
0.25,10	Max	1.0000	0.4075	0.8719	0.2432	1.0000	0.4104	1.0521	0.2438
	Min	1.0000	0.4020	0.8631	0.2420	1.0000	0.4076	0.8735	0.2432
0.25,15	Max	1.0000	0.4792	0.8719	0.2432	1.0000	0.4839	1.0521	0.2438
	Min	1.0000	0.4704	0.8631	0.2420	1.0000	0.4794	0.8735	0.2432
0.25,20	Max	1.0000	0.5301	0.8719	0.2432	1.0000	0.5365	1.0521	0.2438
	Min	1.0000	0.5182	0.8631	0.2420	1.0000	0.5303	0.8735	0.2432
0.25,25	Max	1.0000	0.5696	0.8719	0.2432	1.0000	0.5775	1.0521	0.2438
	Min	1.0000	0.5548	0.8631	0.2420	1.0000	0.5698	0.8735	0.2432
0.5,5	Max	1.0000	0.2849	0.7266	0.4419	1.0000	0.2858	0.8249	0.4456
	Min	1.0000	0.2830	0.7215	0.4349	1.0000	0.2849	0.7275	0.4420
0.5,10	Max	1.0000	0.4075	0.7266	0.4419	1.0000	0.4104	0.8249	0.4456
	Min	1.0000	0.4020	0.7215	0.4349	1.0000	0.4076	0.7275	0.4420
0.5,15	Max	1.0000	0.4792	0.7266	0.4419	1.0000	0.4839	0.8249	0.4456
	Min	1.0000	0.4704	0.7215	0.4349	1.0000	0.4794	0.7275	0.4420
0.5,20	Max	1.0000	0.5301	0.7266	0.4419	1.0000	0.5365	0.8249	0.4456
	Min	1.0000	0.5182	0.7215	0.4349	1.0000	0.5303	0.7275	0.4420
0.5,25	Max	1.0000	0.5696	0.7266	0.4419	1.0000	0.5775	0.8249	0.4456
	Min	1.0000	0.5548	0.7215	0.4349	1.0000	0.5698	0.7275	0.4420

Nanded		Sensitivity Ratio(S)				Relative Sensitivity Ratio (Sr)			
t (hr), T (yr)		K	a	b	d	K	a	b	d
0.75,5	Max	1.0000	0.2849	0.6228	0.6098	1.0000	0.2858	0.6827	0.6195
	Min	1.0000	0.2830	0.6196	0.5917	1.0000	0.2849	0.6234	0.6101
0.75,10	Max	1.0000	0.4075	0.6228	0.6098	1.0000	0.4104	0.6827	0.6195
	Min	1.0000	0.4020	0.6196	0.5917	1.0000	0.4076	0.6234	0.6101
0.75,15	Max	1.0000	0.4792	0.6228	0.6098	1.0000	0.4839	0.6827	0.6195
	Min	1.0000	0.4704	0.6196	0.5917	1.0000	0.4794	0.6234	0.6101
0.75,20	Max	1.0000	0.5301	0.6228	0.6098	1.0000	0.5365	0.6827	0.6195
	Min	1.0000	0.5182	0.6196	0.5917	1.0000	0.5303	0.6234	0.6101
0.75,25	Max	1.0000	0.5696	0.6228	0.6098	1.0000	0.5775	0.6827	0.6195
	Min	1.0000	0.5548	0.6196	0.5917	1.0000	0.5698	0.6234	0.6101
1,5	Max	1.0000	0.2849	0.5450	0.7552	1.0000	0.2858	0.5842	0.7736
	Min	1.0000	0.2830	0.5428	0.7215	1.0000	0.2849	0.5454	0.7557
1,10	Max	1.0000	0.4075	0.5450	0.7552	1.0000	0.4104	0.5842	0.7736
	Min	1.0000	0.4020	0.5428	0.7215	1.0000	0.4076	0.5454	0.7557
1,15	Max	1.0000	0.4792	0.5450	0.7552	1.0000	0.4839	0.5842	0.7736
	Min	1.0000	0.4704	0.5428	0.7215	1.0000	0.4794	0.5454	0.7557
1,20	Max	1.0000	0.5301	0.5450	0.7552	1.0000	0.5365	0.5842	0.7736
	Min	1.0000	0.5182	0.5428	0.7215	1.0000	0.5303	0.5454	0.7557
1,25	Max	1.0000	0.5696	0.5450	0.7552	1.0000	0.5775	0.5842	0.7736
	Min	1.0000	0.5548	0.5428	0.7215	1.0000	0.5698	0.5454	0.7557
1.25,5	Max	1.0000	0.2849	0.4844	0.8833	1.0000	0.2858	0.5116	0.9130
	Min	1.0000	0.2830	0.4829	0.8305	1.0000	0.2849	0.4847	0.8842
1.25,10	Max	1.0000	0.4075	0.4844	0.8833	1.0000	0.4104	0.5116	0.9130
	Min	1.0000	0.4020	0.4829	0.8305	1.0000	0.4076	0.4847	0.8842
1.25,15	Max	1.0000	0.4792	0.4844	0.8833	1.0000	0.4839	0.5116	0.9130
	Min	1.0000	0.4704	0.4829	0.8305	1.0000	0.4794	0.4847	0.8842
1.25,20	Max	1.0000	0.5301	0.4844	0.8833	1.0000	0.5365	0.5116	0.9130
	Min	1.0000	0.5182	0.4829	0.8305	1.0000	0.5303	0.4847	0.8842
1.25,25	Max	1.0000	0.5696	0.4844	0.8833	1.0000	0.5775	0.5116	0.9130
	Min	1.0000	0.5548	0.4829	0.8305	1.0000	0.5698	0.4847	0.8842
1.5,5	Max	1.0000	0.2849	0.4360	0.9979	1.0000	0.2858	0.4556	1.0408
	Min	1.0000	0.2830	0.4349	0.9233	1.0000	0.2849	0.4362	0.9992
1.5,10	Max	1.0000	0.4075	0.4360	0.9979	1.0000	0.4104	0.4556	1.0408
	Min	1.0000	0.4020	0.4349	0.9233	1.0000	0.4076	0.4362	0.9992
1.5,15	Max	1.0000	0.4792	0.4360	0.9979	1.0000	0.4839	0.4556	1.0408
	Min	1.0000	0.4704	0.4349	0.9233	1.0000	0.4794	0.4362	0.9992

1.5,20	Max	1.0000	0.5301	0.4360	0.9979	1.0000	0.5365	0.4556	1.0408
	Min	1.0000	0.5182	0.4349	0.9233	1.0000	0.5303	0.4362	0.9992

Nanded		**Sensitivity Ratio(S)**				**Relative Sensitivity Ratio (Sr)**			
t (hr), T (yr)		**K**	**a**	**b**	**d**	**K**	**a**	**b**	**d**
1.5,25	Max	1.0000	0.5696	0.4360	0.9979	1.0000	0.5775	0.4556	1.0408
	Min	1.0000	0.5548	0.4349	0.9233	1.0000	0.5698	0.4362	0.9992
1.75,5	Max	1.0000	0.2849	0.3964	1.1015	1.0000	0.2858	0.4110	1.1594
	Min	1.0000	0.2830	0.3955	1.0030	1.0000	0.2849	0.3965	1.1032
1.75,10	Max	1.0000	0.4075	0.3964	1.1015	1.0000	0.4104	0.4110	1.1594
	Min	1.0000	0.4020	0.3955	1.0030	1.0000	0.4076	0.3965	1.1032
1.75,15	Max	1.0000	0.4792	0.3964	1.1015	1.0000	0.4839	0.4110	1.1594
	Min	1.0000	0.4704	0.3955	1.0030	1.0000	0.4794	0.3965	1.1032
1.75,20	Max	1.0000	0.5301	0.3964	1.1015	1.0000	0.5365	0.4110	1.1594
	Min	1.0000	0.5182	0.3955	1.0030	1.0000	0.5303	0.3965	1.1032
1.75,25	Max	1.0000	0.5696	0.3964	1.1015	1.0000	0.5775	0.4110	1.1594
	Min	1.0000	0.5548	0.3955	1.0030	1.0000	0.5698	0.3965	1.1032
2,5	Max	1.0000	0.2849	0.3633	1.1961	1.0000	0.2858	0.3745	1.2703
	Min	1.0000	0.2830	0.3627	1.0723	1.0000	0.2849	0.3634	1.1982
2,10	Max	1.0000	0.4075	0.3633	1.1961	1.0000	0.4104	0.3745	1.2703
	Min	1.0000	0.4020	0.3627	1.0723	1.0000	0.4076	0.3634	1.1982
2,15	Max	1.0000	0.4792	0.3633	1.1961	1.0000	0.4839	0.3745	1.2703
	Min	1.0000	0.4704	0.3627	1.0723	1.0000	0.4794	0.3634	1.1982
2,20	Max	1.0000	0.5301	0.3633	1.1961	1.0000	0.5365	0.3745	1.2703
	Min	1.0000	0.5182	0.3627	1.0723	1.0000	0.5303	0.3634	1.1982
2,25	Max	1.0000	0.5696	0.3633	1.1961	1.0000	0.5775	0.3745	1.2703
	Min	1.0000	0.5548	0.3627	1.0723	1.0000	0.5698	0.3634	1.1982
2.25,5	Max	1.0000	0.2849	0.3354	1.2830	1.0000	0.2858	0.3441	1.3749
	Min	1.0000	0.2830	0.3349	1.1330	1.0000	0.2849	0.3355	1.2856
2.25,10	Max	1.0000	0.4075	0.3354	1.2830	1.0000	0.4104	0.3441	1.3749
	Min	1.0000	0.4020	0.3349	1.1330	1.0000	0.4076	0.3355	1.2856
2.25,15	Max	1.0000	0.4792	0.3354	1.2830	1.0000	0.4839	0.3441	1.3749
	Min	1.0000	0.4704	0.3349	1.1330	1.0000	0.4794	0.3355	1.2856
2.25,20	Max	1.0000	0.5301	0.3354	1.2830	1.0000	0.5365	0.3441	1.3749
	Min	1.0000	0.5182	0.3349	1.1330	1.0000	0.5303	0.3355	1.2856
2.25,25	Max	1.0000	0.5696	0.3354	1.2830	1.0000	0.5775	0.3441	1.3749
	Min	1.0000	0.5548	0.3349	1.1330	1.0000	0.5698	0.3355	1.2856

Nanded		Sensitivity Ratio(S)				Relative Sensitivity Ratio (Sr)			
t (hr), T (yr)		K	a	b	d	K	a	b	d
2.5,5	Max	1.0000	0.2849	0.3114	1.3634	1.0000	0.2858	0.3184	1.4741
	Min	1.0000	0.2830	0.3110	1.1866	1.0000	0.2849	0.3115	1.3666
2.5,10	Max	1.0000	0.4075	0.3114	1.3634	1.0000	0.4104	0.3184	1.4741
	Min	1.0000	0.4020	0.3110	1.1866	1.0000	0.4076	0.3115	1.3666
2.5,15	Max	1.0000	0.4792	0.3114	1.3634	1.0000	0.4839	0.3184	1.4741
	Min	1.0000	0.4704	0.3110	1.1866	1.0000	0.4794	0.3115	1.3666
2.5,20	Max	1.0000	0.5301	0.3114	1.3634	1.0000	0.5365	0.3184	1.4741
	Min	1.0000	0.5182	0.3110	1.1866	1.0000	0.5303	0.3115	1.3666
2.5,25	Max	1.0000	0.5696	0.3114	1.3634	1.0000	0.5775	0.3184	1.4741
	Min	1.0000	0.5548	0.3110	1.1866	1.0000	0.5698	0.3115	1.3666
2.75,5	Max	1.0000	0.2849	0.2907	1.4382	1.0000	0.2858	0.2963	1.5686
	Min	1.0000	0.2830	0.2903	1.2343	1.0000	0.2849	0.2907	1.4420
2.75,10	Max	1.0000	0.4075	0.2907	1.4382	1.0000	0.4104	0.2963	1.5686
	Min	1.0000	0.4020	0.2903	1.2343	1.0000	0.4076	0.2907	1.4420
2.75,15	Max	1.0000	0.4792	0.2907	1.4382	1.0000	0.4839	0.2963	1.5686
	Min	1.0000	0.4704	0.2903	1.2343	1.0000	0.4794	0.2907	1.4420
2.75,20	Max	1.0000	0.5301	0.2907	1.4382	1.0000	0.5365	0.2963	1.5686
	Min	1.0000	0.5182	0.2903	1.2343	1.0000	0.5303	0.2907	1.4420
2.75,25	Max	1.0000	0.5696	0.2907	1.4382	1.0000	0.5775	0.2963	1.5686
	Min	1.0000	0.5548	0.2903	1.2343	1.0000	0.5698	0.2907	1.4420
3,5	Max	1.0000	0.2849	0.2725	1.5082	1.0000	0.2858	0.2772	1.6590
	Min	1.0000	0.2830	0.2722	1.2769	1.0000	0.2849	0.2725	1.5125
3,10	Max	1.0000	0.4075	0.2725	1.5082	1.0000	0.4104	0.2772	1.6590
	Min	1.0000	0.4020	0.2722	1.2769	1.0000	0.4076	0.2725	1.5125
3,15	Max	1.0000	0.4792	0.2725	1.5082	1.0000	0.4839	0.2772	1.6590
	Min	1.0000	0.4704	0.2722	1.2769	1.0000	0.4794	0.2725	1.5125
3,20	Max	1.0000	0.5301	0.2725	1.5082	1.0000	0.5365	0.2772	1.6590
	Min	1.0000	0.5182	0.2722	1.2769	1.0000	0.5303	0.2725	1.5125
3,25	Max	1.0000	0.5696	0.2725	1.5082	1.0000	0.5775	0.2772	1.6590
	Min	1.0000	0.5548	0.2722	1.2769	1.0000	0.5698	0.2725	1.5125

Similarly, the sensitivity ratio and relative sensitivity ratio values for Hingoli and Jalna were calculated. The values of S and S_r did not change for K constant.

Student t-test

Sensitivity ratio and Relative Sensitivity Ratio values were observed as approximately same. The values of S and S_r did not change for 'K.' So, there was no necessity to carry out 't' test for 'K.' Student t-test was performed at 5% level of significance and analysed to identify and establish significant difference between S and S_r.

Table 4: Analysis of t-test for location specific constant 'a' for Nanded

S	Sr	t-Test: Two-Sample Assuming Equal Variances		
			Sr	*S*
0.282959551	0.285834721	Mean	0.285241603	0.284132757
0.283320263	0.28565137	Variance	1.08564E-07	4.26779E-07
0.283643943	0.28548738	Observations	10	10
0.283930281	0.285342729	Pooled Variance	2.67671E-07	
0.284179003	0.285217401	Hypothesized Mean Difference	0	
0.284389869	0.28511138	df	18	
0.284562676	0.285024653	t Stat	4.792427896	
0.284697255	0.284957209	P(T<=t) one-tail	0.000072893	
0.284793477	0.284909041			
0.284851247	0.284880143			

The value of P (one-tail) was observed 0.000072893 which is less than 0.05. Hence, the difference in S and Sr was determined to be significant for location specific constant 'a' for Nanded location.

Table 5: Summarized analysis for t-test for Nanded, Hingoli and Jalna

Sr.no	Location	Significant difference between S and Sr							
		K		a		b		d	
		Yes	No	Yes	No	Yes	No	Yes	No
1	Nanded		✓	✓		✓		✓	
2	Hingoli		✓	✓		✓		✓	
3	Jalna		✓	✓		✓		✓	

Classification of location specific constants

Based on values of S and Sr for Nanded, Hingoli and Jalna, location specific constants were classified as highly sensitive, moderately sensitive, less sensitive, and very less sensitive.

Classification of location specific constant 'a' according to sensitivity ratio is presented in Table 6. The constant "a" varies with return period only and not with duration of rainfall. Classification based on sensitivity ratio of location specific constants "K", "b', and 'd' of IDF equations of different locations for combination of duration of rainfall and return period is presented in Table 7.

Table 6: Classification of 'a' according to Sensitivity ratio

Location	Return period, T (yr)	Sensitivity class			
		HS	MS	LS	VLS
Nanded	5			✓	
	10			✓	
	15			✓	
	20		✓		
	25		✓		
Hingoli	5				✓
	10			✓	
	15			✓	
	20			✓	
	25			✓	
Jalna	5				✓
	10				✓
	15				✓
	20			✓	
	25			✓	

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Table 7: Classification of location specific constants K, b, d based on sensitivity ratio

Station	t(h), T(yr) Combination	K				b				d			
		HS	MS	LS	VLS	HS	MS	LS	VLS	HS	MS	LS	VLS
Nanded	(0.25,5) (0.25,10) (0.25,15) (0.25,20) (0.25,25)	✓				✓							✓
	(0.50,5) (0.50,10) (0.50,15) (0.50,20) (0.50,25)	✓					✓					✓	
	(0.75,5) (0.75,10) (0.75,15) (0.75,20) (0.75,25)	✓					✓				✓		
	(1,5) (1,10) (1,15) (1,20) (1,25)	✓					✓			✓			
	(1.25,5) (1.25,10) (1.25,15) (1.25,20) (1.25,25)	✓						✓		✓			
	(2,5) (2,10) (2,15) (2,20) (2,25)	✓						✓		✓			
	(2.5,5) (2.5,10) (2.5,15) (2.5,20) (2.5,25)	✓						✓		✓			
	(3,5) (3,10) (3,15) (3,20) (3,25)	✓						✓		✓			
Hingoli	(0.25,5) (0.25,10) (0.25,15) (0.25,20) (0.25,25)	✓				✓						✓	
	(0.50,5) (0.50,10) (0.50,15) (0.50,20) (0.50,25)	✓				✓						✓	
	(0.75,5) (0.75,10) (0.75,15) (0.75,20) (0.75,25)	✓					✓				✓		
	(1,5) (1,10) (1,15) (1,20) (1,25)	✓					✓			✓			
	(1.25,5) (1.25,10) (1.25,15) (1.25,20) (1.25,25)	✓					✓			✓			
	(1.5,5) (1.5,10) (1.5,15) (1.5,20) (1.5,25)	✓						✓		✓			
	(2.5,5) (2.5,10) (2.5,15) (2.5,20) (2.5,25)	✓						✓		✓			
	(3,5) (3,10) (3,15) (3,20) (3,25)	✓						✓		✓			
Jalna	(0.25,5) (0.25,10) (0.25,15) (0.25,20) (0.25,25)	✓				✓						✓	
	(0.50,5) (0.50,10) (0.50,15) (0.50,20) (0.50,25)	✓				✓						✓	
	(0.75,5) (0.75,10) (0.75,15) (0.75,20) (0.75,25)	✓					✓				✓		
	(1.25,5) (1.25,10) (1.25,15) (1.25,20) (1.25,25)	✓					✓			✓			
	(1.5,5) (1.5,10) (1.5,15) (1.5,20) (1.5,25)	✓						✓		✓			
	(2,5) (2,10) (2,15) (2,20) (2,25)	✓						✓		✓			
	(2.5,5) (2.5,10) (2.5,15) (2.5,20) (2.5,25)	✓						✓		✓			
	(3,5) (3,10) (3,15) (3,20) (3,25)	✓						✓		✓			

Non-sensitive interval

For Nanded location, very less sensitive (VLS) range for determining the non – sensitive interval, pertaining to location specific constant ‘a’ could not be established. Hence, sensitivity analysis was performed for extra range of return period viz. 1 yr, 2 yr, 3 yr, 4 yr for ‘a’ constant. For Nanded location, pertaining to location specific constant ‘b’ also, very less sensitive (VLS) range for determining the non – sensitive interval, could not be established. Hence, sensitivity analysis was performed for extra range of rainfall duration viz. 3.25 h and 3.5 h for b constant.

For Hingoli location, very less sensitive (VLS) range for determining the non – sensitive interval, pertaining to location specific constant ‘b’ and ‘d’ could not be established. Hence, sensitivity analysis was performed with minimum range of rainfall duration viz. 3.25 h ,3.5 h and 3.75 h for b constant and 0.23 hr and 0.24 hr for ‘d’ constant. To determine the exact non – sensitive interval for Hingoli location, pertaining to ‘a’ constant, sensitivity analysis was performed for extra range of return period viz. 6 yr, 7 yr, 8 yr, 9 yr.

For Jalna location, very less sensitive (VLS) range for determining the non – sensitive interval, pertaining to location specific constant ‘b’ and ‘d’ could not be established. Hence, sensitivity analysis was performed with minimum range of rainfall duration viz. 3.25 h ,3.5 h and 3.75 h for b constant and 0.23 hr and 0.24 hr for ‘d’ constant.

The results of the above changes made by considering the extra range of return period and duration of rainfall were tabulated in the table 8.

Table 8: Non-sensitive interval for location specific constants ‘a’ ‘b’ and ‘d’

Sr. no	Location	‘a’ (non-sensitive interval of return period, yr)	‘b’ (non-sensitive interval, h)	‘d’ (non-sensitive interval, h)
1	Nanded	Up to 4 yrV LS hence considered as non-sensitive interval	1.25 h to 3.25 h LS Above 3.5 VLS. Hence considered as non-sensitive interval	Up to 0.25 h VLS hence considered as non-sensitive interval
2	Hingoli	Up to 9 yr VLS, hence considered as non-sensitive interval	1.5 h to 3.5 h LS Above 3.75 VLS. Hence considered as non-sensitive interval	Up to 0.24 h non – sensitive
3	Jalna	Up to 15 yr VLS, hence considered as non-sensitive interval	1.25 h to 3.5 h LS Above that VLS. Hence considered as non-sensitive interval	Up to 0.23 h non – sensitive

CONCLUSION

Non-sensitive interval of sensitive analysis is as under,

K constant – Location specific constant ‘K’ is highly sensitive for each location with change in either duration of rainfall or return period. Hence it is not possible to fix any non-sensitive interval.

a constant – Location specific constant ‘a’ value needs to be updated after 4 years for Nanded location and for Hingoli and Jalna locations ‘a’ constant value should be updated after 9 years and 15 years respectively.

b constant – Location specific constant ‘b’ value depends on rainfall duration. The non-sensitive interval for ‘b’ constant for Nanded, Hingoli and Jalna locations were above 3.5 h, 3.75 h and 3.75 h respectively, which means the changes in b constant above the rainfall duration of 3.5 h, 3.75 h and 3.75 h for Nanded, Hingoli and Jalna respectively, do not account to response.

d constant – Location specific constant ‘d’ value depends on rainfall duration. The non-sensitive interval for ‘b’ constant for Nanded, Hingoli and Jalna locations were up to 0.25 h, 0.24 h and 0.23 h respectively, which means the changes in d constant up to the rainfall duration of 0.25 h, 0.24 h and 0.23 h for Nanded, Hingoli and Jalna respectively, do not account to response.

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