

Regional Flood Frequency Analysis with Respect to Maximum 24 Hours Precipitation (Case Study: Northern Karun Sub Basins)

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Abstract: Maximum moment regional flood frequency estimating has an important role in design of different projects such as water development, road, railway, irrigation and drainage systems, particularly where there is no hydrometrical data in ungauged basins. In this research, maximum moment regional flood frequency analysis was applied for Northern Karun sub basins and in the framework of this research, 18 hydrometric stations were used. Using regression method, missing data of hydrometric stations were estimated maximum 24 hours precipitation and maximum moment regional flood rate for all 18 hydrometric stations for 2, 5, 10, 25, 50 and 100 years return period were calculated. In order to make the isoline of precipitation in the studied area, obtained results showed that the method of minimum curvature was the best method of interpolation. Finally a multiple regression relationship with acceptable correlation was derived. Results showed that maximum moment regional flood frequency can be estimated more accurate with respect to regional maximum 24 hours and long term annually precipitation.

Key words: Flood • Frequency Analysis • Maximum 24 hr Precipitation • Multiple Regressions

INTRODUCTION

Regional flood frequency analysis is a well known technique which, one makes an attempt constructing relations between flood and physiographic information of a basin [1,2]. Regional flood frequency analysis (FFA) is commonly used to estimate flood risk in a particular sites where little or no information is available on peak flows. Regional flood frequency analysis (FFA) is commonly used to estimate flood risk in a particular site where little or no information of peak flow is available [3]. Benson (1962) proposed regional analysis for estimating flow magnitude using ordinary multiple regression (MR) with respect to the basin physiographic and climatic characteristics as independent variables [4]. Regional analysis has been suggested for estimating flood magnitude in a given site when data are not available or data are short [5]. Information of flood magnitudes and their frequencies are required for design of hydraulic structures such as dams, spillways, road and railway bridges, culverts, urban drainage systems, flood plain

zoning, economic evaluation of flood protection projects etc [6]. Regression methods are frequently used to build models that predict flood amounts as a function of site physiographic characteristics [7]. The methods have been widely used to obtain flood magnitude estimates at sites where no historical flood records are available [8]. For estimation of floods for desired return periods of ungauged catchments, regional flood frequency relationship has been developed by coupling the regional flood frequency relationship with the regional relationship between mean annual maximum peak flood and catchment area [6].

Samadi Boroujeni (2008), has performed an equation in which, one can estimate maximum flood frequency[9]. He made correlation through 12 rivers flood information with different frequency and the related basin area in Northern Karun basin of Iran. Ghanipour (2000), used flood index for regional flood frequency analysis in Eastern Azarbayegan of Iran using 79 moment flood discharge of hydrometric stations [10]. Chavoshi and Islamian (1999), used hybrid method for flood frequency

analysis in arid area of Iran. They found out in such area, hybrid method gives better results than multiple regressions for short term regional flood frequency analysis [2]. Shahinejad (2002) applied regional flood modeling in the basin of Dez Dam, using multiple regressions between maximum flood frequency and physiographic characteristics included basin area, length of main River and it's time of concentration [11].

Flood frequency analysis could be conducted by several methods. Maximum flood discharge can be estimated using multiple regressions with respect to physiographic characteristics of basin in form of power relationship as follow:

$$Q_T = \alpha A^b B^C \dots M^n \quad (1)$$

Where:

Q_T is flood discharge in special duration; α is constant coefficient; A, B, C, ..., M are physiographic and climatologic characteristics of basin; and b, c, ..., n are parameters to be regressed from the data, which for each catchment could be estimated. Many researchers have obtained flood regional equation based on the observed floods data. The equations have been mostly based on the watershed physical properties parameters. Some of researchers have introduced flood regional equation included climatology parameters such as precipitation.

Pegram and Parak (2004) introduce a modified rational formula by considering precipitation factor [7]. The formula was expressed in preliminary form as:

$$Q_{MRF} = C \times 0.318 P_{1day,2} [1 + 0.385 y_T] A^{0.558} \quad (2)$$

Where: C is the conventional rational formula; $P_{1day,2}$ is the median 1 day annual maximum rainfall available from maps [12,13]; and y_T is the reduced variate of the GEV Distribution of the rainfall; and A is the catchment area in km^2 .

Regional flood frequency analysis also is required for flood forecasting and warning models[14,15]. This technique also has been applied for selecting design flood in developing hydraulic structure projects and derivation of Unit Hydrograph Model [16, 17].

In this research a flood regional analysis has been done for consider precipitation factor in flood estimation based on the observed data in North-Karun watershed in Iran. Because precipitation has an important role in flood rates of basins.

MATERIALS AND METHODS

The study area is Northern Karun basin in Chaharmahal and Bakhtiary Province, located in south west of Iran. 18 hydrometric stations with the basin area range in 40 to more than 10000 Km^2 are selected. Daily and maximum daily flood discharges of 18 hydrometric stations from first of the data collection (1957) up to 2006-07 (start of analysis) were compiled from the Department of water in Shahrekord - Iran. Then data assessments have been carried out. Armand station was selected with no gap and long term data (1957 to 2007) as a base hydrometric station. Using linear regression, missing data for the maximum daily flood discharge of the rest of hydrometric stations has been conducted (Table 1). As shown in table (1) for all regression equations, values of R^2 is more

Table 1: Regression equation and R^2 among maximum flood discharge of Armand hydrometric station with the other 17 hydrometric stations

| Number | Hydrometric Station Name | Regression equation | R^2 |
|--------|--------------------------|--|-------|
| 1 | Dezak Abad | $Q_p = 0.273 Q_{p,*Armand} - 24.346$ | 0.80 |
| 2 | Taghargh Ab | $Q_p = 0.0055 Q_{p,*Armand}^{-1.3483}$ | 0.93 |
| 3 | Tangh Pordanjan | $Q_p = 0.0164 Q_{p,*Armand}^{-1.0901}$ | 0.86 |
| 4 | Barz | $Q_p = 1.381 Q_{p,*Armand}^{-1.0007}$ | 0.65 |
| 5 | Kaj | $Q_p = 0.4096 Q_{p,*Armand} + 35.4$ | 0.90 |
| 6 | Kooh Sookhteh | $Q_p = 0.0496 Q_{p,*Armand} + 11.58$ | 0.73 |
| 7 | Zarin Derakht | $Q_p = 0.0014 Q_{p,*Armand}^{-1.3905}$ | 0.71 |
| 8 | Pole karehbas | $Q_p = 0.0346 Q_{p,*Armand}^{-1.2573}$ | 0.64 |
| 9 | Soleghan | $Q_p = 0.0011 Q_{p,*Armand}^{-1.7234}$ | 0.81 |
| 10 | Behesht abad | $Q_p = 0.2062 Q_{p,*Armand} - 31.651$ | 0.91 |
| 11 | Tangh Darkesh | $Q_p = 0.0822 Q_{p,*Armand} + 32.618$ | 0.74 |
| 12 | Gerde Bisheh | $Q_p = 0.3646 Q_{p,*Armand}^{0.4867}$ | 0.95 |
| 13 | Pole Kharaji | $Q_p = 0.0497 Q_{p,*Armand}^{0.94}$ | 0.86 |
| 14 | Marghack | $Q_p = 4.01565 Q_{p,*Armand}^{0.8017}$ | 0.94 |
| 15 | Ghoshe Pol | $Q_p = 0.018 Q_{p,*Armand}^{1.0661}$ | 0.89 |
| 16 | Pole kordshami | $Q_p = 9 \times 10^{-10} Q_{p,*Armand}^{2.9964}$ | 0.87 |

Table 2: Maximum flood discharge with different return period using the best distribution functions for 18 hydrometric stations

| Station | The best distribution function | Return period (Years) | | | | | |
|-----------------|--------------------------------|-----------------------|------|------|------|------|------|
| | | 2 | 5 | 10 | 25 | 50 | 100 |
| Armand | Log normal(2p) | 629 | 1071 | 1415 | 1904 | 2307 | 2741 |
| Marghack | Pearson(3p) | 942 | 1420 | 1716 | 2071 | 2322 | 2563 |
| Koohe Sookhteh | Log normal(3p) | 36 | 78 | 116 | 176 | 230 | 293 |
| Darkesh varkesh | Log pearson(3p) | 77 | 122 | 163 | 229 | 291 | 366 |
| Kaj | Log normal (2p) | 273 | 460 | 605 | 810 | 979 | 1159 |
| Behesht Abad | Log pearson | 87 | 196 | 267 | 343 | 388 | 424 |
| Pol karehbas | Log normal (2p) | 90 | 203 | 311 | 489 | 656 | 854 |
| Soleghan | Log pearson | 56 | 154 | 264 | 471 | 687 | 967 |
| Barz | Log pearson | 795 | 1451 | 1948 | 2628 | 3163 | 3718 |
| Dezak Abad | Log normal (3p) | 131 | 268 | 367 | 499 | 603 | 712 |
| Zarin Derakht | Log normal (3p) | 12 | 29 | 41 | 59 | 73 | 88 |
| Tghargh Ab | Gumbel | 32 | 57 | 73 | 93 | 109 | 124 |
| Kharaji | Log normal (3p) | 19 | 34 | 45 | 60 | 72 | 85 |
| Tange Pordanjan | Log normal (3p) | 19 | 34 | 45 | 60 | 72 | 85 |
| Gerde Bisheh | Pearson | 7 | 10 | 13 | 17 | 21 | 25 |
| Kord Shami | Log pearson | 0.3 | 2 | 4 | 7 | 9 | 11 |
| Hgosheh Pol | Pearson | 15 | 29 | 40 | 56 | 68 | 81 |
| Ghaleh shahrokh | Log pearson | 260 | 450 | 619 | 892 | 1146 | 1449 |

than 0.6 and this is acceptable based on the reference statistical tables. The maximum value of R^2 belongs to the Gerde Bisheh hydrometric station equal to 0.95, while the minimum value belongs to the Pole karehbas hydrometric station equal to 0.65.

Then for all 18 hydrometric stations with using the Easy fit software the best distribution function is recognized and the maximum flood discharge for the return periods of 2, 5, 10, 25, 50 and 100 years were estimated as shown in table (2).

In this research, relations between maximum flood discharge in different return period for 18 hydrometric stations with yearly and 24 hours maximum precipitation in the same basin were compiled.

RESULTS AND DISCUSSION

Isoline Map of Precipitation: In zoning the flood frequency analysis map for a region or an area, more accurate isoline map of precipitation is necessary. There are several methods of interpolation to making the isoline of precipitation in area with rain gauge information. In these methods of interpolation there is not checking method of making peace outcome. In zoning isoline maps making peace interpolation between specified values to estimate non specified values, it needs ranking of the point information by the influence of them. A peace influence ranking of specified points, will gives the best estimated value for non specified point. There are several interpolation methods by different accuracy

distinguishing the weight for each specified point, resulting the best value for non specified point. In this study research, several methods for interpolation are selected using Surfer 8.02 software. In this software there are 12 methods of interpolation including inverse distance to a power, kriging, minimum curvature, local polynomial, moving average, nearest neighbor, polynomial regression and radial basis function. In these techniques after estimation of precipitation values for all non specified points by making interpolation, value of precipitation for all measured points are neglected and estimated again. Then comparison among measured and estimated values for all these points are take place using Root Mean Square Error (RMSE) as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (x_p - x_{exp})^2}{n}} \quad (3)$$

Which:

x_{exp} is measured value; x_p is estimated value and n : is the number of points. The model, which has the lowest RMSE is the best model to making interpolation. The result of RMSE for the yearly precipitation of the study area in 2003, 2004 and 2005 by several methods of interpolation is shown in figure (1). This figure indicate clearly that the method of minimum curvature has the lowest value of RMSE as the best method of interpolation to making the yearly precipitation isolines in the study area.

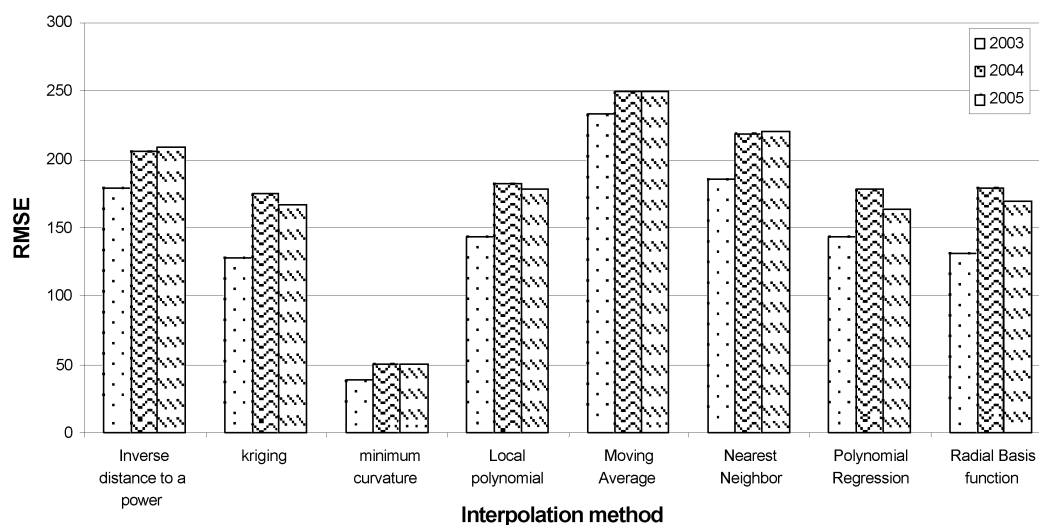


Fig. 1: RMSE value using different methods of interpolation for the precipitation in 2003 to 2005 in the study area

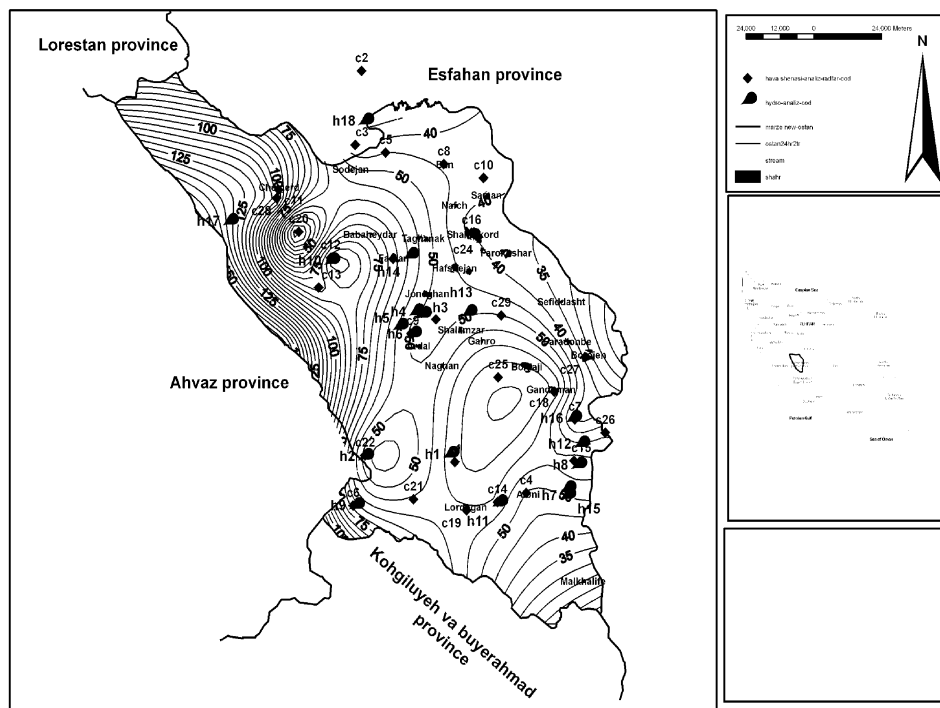


Fig. 2: 2 years return period isoline map of 24 hours maximum precipitation in Chaharmahal and Bakhtiari Province

Maximum Moment Flood: Using geographic information system (GIS), isoline mapping of yearly and the 24 hours maximum precipitation with 2, 5, 10, 25, 50 and 100 years return period in whole Chaharmahal and Bakhtiari Province were conducted as explained in the previous section. Figure (2) shows the 24 hours maximum precipitation for 2 years return period as an example in Chaharmahal and Bakhtiari Province respectively. The yearly and 24 hours maximum precipitation for 2, 5, 10, 25, 50 and 100 years

return period for the whole upper basin of 18 hydrometric stations are extracted from the isoline maps as results is shown in the table (3).

Then several forms of multiple regressions were conducted in order to find the best correlation among area, regional maximum flood discharge and corresponding yearly and maximum 24 hours precipitation in 2, 5, 10, 25, 50 and 100 years return period. Table (4) shows the best correlation equations between maximum

Table 3: Yearly and 24 hours maximum precipitation in different return period in (mm) for the upper basin of 18 hydrometric stations

| Hydrometric station | Basin (km ²) | Yearly precipitation (mm) | 24 hours maximum precipitation (in mm) for different return period (year) | | | | | |
|---------------------|--------------------------|---------------------------|---|-------|-------|-------|-------|-------|
| | | | 2 | 5 | 10 | 25 | 50 | 100 |
| Armand | 10070 | 637.3 | 55.6 | 75.3 | 89.1 | 105.2 | 118.1 | 131.0 |
| Barz | 8255 | 470.0 | 59.4 | 78.6 | 91.2 | 106.9 | 118.7 | 129.0 |
| Behesht Abad | 3820 | 466.5 | 48.1 | 67.1 | 82.1 | 97.5 | 110.2 | 122.5 |
| Koohe Sookhteh | 2900 | 383.6 | 45.0 | 65.2 | 79.1 | 97.3 | 111.1 | 125.4 |
| Pol kareh Bas | 2821 | 513.7 | 56.8 | 78.0 | 92.0 | 100.5 | 123.3 | 136.9 |
| Khraji | 2527 | 348.9 | 43.7 | 63.3 | 77.6 | 96.5 | 109.3 | 121.3 |
| Bazoft | 2355 | 892.5 | 75.7 | 94.1 | 107.3 | 122.8 | 127.9 | 147.5 |
| Soleghan | 2145 | 457.8 | 57.2 | 79.7 | 94.6 | 113.2 | 127.7 | 142.0 |
| Ghaleh shahrokh | 1440 | 720.0 | 64.7 | 85.1 | 99.3 | 117.7 | 131.6 | 145.6 |
| Kaj | 1201 | 1310.0 | 75.2 | 95.9 | 110.0 | 128.1 | 141.5 | 155.3 |
| Taghargh Ab | 950 | 423.1 | 57.9 | 81.1 | 96.2 | 115.4 | 129.9 | 144.3 |
| Darkesh Varkesh | 895 | 569.0 | 58.6 | 77.3 | 90.3 | 101.1 | 110.0 | 118.6 |
| Dezak abad | 563 | 1630.0 | 78.0 | 99.6 | 114.4 | 134.0 | 148.4 | 164.5 |
| Khan Mirza | 397 | 548.1 | 52.8 | 69.2 | 80.6 | 95.8 | 106.7 | 118.1 |
| Tanghe Pordanjan | 368 | 486.5 | 53.0 | 69.1 | 78.5 | 89.3 | 97.2 | 105.0 |
| Gerde Bisheh | 102 | 563.6 | 54.6 | 73.2 | 85.8 | 101.8 | 114.0 | 126.2 |
| Ghosh Pol | 82.5 | 380.0 | 86.6 | 107.7 | 119.2 | 136.2 | 142.1 | 154.6 |
| Kord Shami | 43 | 424.0 | 43.3 | 60.3 | 71.4 | 85.6 | 95.8 | 106.5 |

Table 4: Regional equations with ANOVA and percent of mean absolute error

| Analysis ANOVA | | | | | | |
|-----------------|---|----------------|-------------|----------------|-------------------|--------------------------------|
| Equation number | Regional equations | R ² | Mean Square | F ¹ | Sig. ² | Average Error ³ (%) |
| 4 | $Q_p = 0.076 A^{1.09} T_r^{0.426} P_a^{1.969}$ | 0.904 | 10.6 | 242 | 3E-38 | 42 % |
| 5 | $Q_p = 0.077 A^{0.95} T_r^{0.426}$ | 0.683 | 12.1 | 84 | 2E-51 | 80 % |
| 6 | $Q_p = 930252 A^{0.981} T_r^{0.748} P_{24Tr}^{5.666}$ | 0.887 | 10.3 | 185 | 3E-34 | 48 % |
| 7 | $Q_p = 105.16 A^{0.964} P_{24Tr}^{2.618}$ | 0.812 | 14.27 | 167 | 6E-50 | 62 % |
| 8 | $Q_p = 252 T_r^{-0.157} P_{24Tr}^{2.814} P_a^{1.322}$ | 0.928 | 8.1 | 248 | 1E-41 | 37 % |
| 9 | $Q_p = 33.1 A^{1.07} P_{24Tr}^{2.122} P_a^{1.481}$ | 0.927 | 10.8 | 327 | 2E-42 | 37 % |

1: Percentage of the inverted beta (F) distribution

2: Observed Significance Level (or the p value)

$$3: \bar{E} = \frac{1}{n} \sum_{i=1}^n (|Observed - Calculated|_i) / Observed_i$$

flood discharge and corresponding yearly and maximum 24 hours precipitation by considering all the hydrometric stations data. In this table the related ANOVA and the percent of mean error for whole study area was also shown. In these equations Q_p is the maximum flood discharge in (m³/s) for different return period; A is the basin area in square kilometers; P₂₄ is 24 hours maximum precipitation in (m) for different return period; P_a is yearly precipitation of basin in (m) for the same return period. It can be seen because of the maximum power of 24 hours maximum precipitation, it is the most important factor in maximum flood discharge producing in whole basin.

As shown in table (4), equation numbers 8 and 9 have minimum absolute error equal to 37%. Finally equations 9 should be selected, because power in equation 8 is a negative value and it is not acceptable.

CONCLUSION

A piece influence ranking of specified points, will gives the best estimated value for non specified points, resulting in making accurate interpolations.

Equation The best equation for maximum flood discharge estimating in the Charmahal and Bakhtirari Province basins is as:

$$Q_p = 33.1 A^{1.07} \cdot P_{24,Tr}^{2.122} P_a^{1.481} \quad (9)$$

Analysis shows that yearly precipitation is important factor after 24 hours maximum precipitation in maximum flood discharge estimation in the Northern Karun basin in Charmahal and Bakhtiari Province. Basin area has the third ranking of significance in the maximum flood discharge estimation of the Charmahal and Bakhtiari Province basin.

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