ACCURACY OF INDEX FLOOD METHOD APPLIED IN TWO DIFFERENT REGIONS IN INDONESIA

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ABSTRACT

Problems of having relatively accurate estimates of design discharge values in ungauged catchments remains. There is an empirical equation in the area which gives appropriate estimates, but it needs some efforts in measuring catchment parameters, which is time consuming in line with the catchment area. A relatively simple method in doing so is the known Index Flood Method. The accuracy of this method in its application in Indonesia has never been examined. An understanding of its accuracy will provide the design with more confidence.

Keywords: Index flood method, direct flood method.

1 INTRODUCTION

There are still problems of obtaining design value of a water works in ungauged catchments. Partly this is caused by the number of water works which are imbalance with the development of hydrometric networks. Some empirical equations based on the unit hydrograph theory may partly solve the problems, but their accuracy are considerably low (Sri Harto, 1989). Using storm and models to derive peak discharge will certainly come to another problem that is the relation between the storm return period and the peak discharge return period. So far this relation is not understood yet, therefore, an assumption of equal return period is used in practice, which is certainly not true (Sri Harto, 1985).

A regional analysis is one of solutions to provide means for estimating peak flows with reasonable accuracy, derived from flow records from the same hydrological region. There are some methods available, one of them is Index Flood Method (IFM) (Ponce, 1989).This study is trying to apply IFM in south Sulawesi and on the island of Java. The accuracy of IFM will be compared with the Direct Flood Relationship (DFR), both will be compared with the observed discharge with a certain return period. The DFR has also been applied on the Island of Java (Sri Harto, 2000).

Index Flood Method (Ponce, 1989) in general is prepared by developing two curves. First is the curve relating average flood with catchment area, and second is the relation between the peak flow ratio and the frequency. The peak flow ratio is the ratio of peak flow with certain return period to the mean annual flood.

Other way of obtaining peak discharge (DFR) is proposed by directly relating the peak flow with a certain period with mean annual flood. This is done with the purpose of omitting the possible error when introducing peak flow ratio. This later is obtained from its relation with the catchment area.

2 AREA OF STUDY

This study is done in two different regions. One is in the area of South Sulawesi, and the other is in the island of Java. The latter has been done previously by Sri Harto (2000). The study in South Sulawesi is involving 14 catchments with the average length of record of 20 years. While the one done on the island of Java covers 30 catchments with the same length of flow data. The studied catchment area ranges from 14.2 Km^2 to 2,318.2 Km^2. Ten catchments are used for developing flow relationship while the other four catchments are used for verification. Characteristic of the catchments and their mean annual flood is presented in Table 1, while the result of the frequency analysis is shown in Table 2 (Rita Tahir Lopa, 2001).

In line with that has been indicated by Sri Harto (1985) the frequency distributions of discharge data are mostly in favor of Pearson Type III and Log Normal distribution.

Table 1. Catchments under study, area and the mean annual flood

Catchment	Area (Km^2)	Mean annual flood (m^3/sec)
Kalaena	933.30	217.59
Maloso	1,476.10	288.82
Tomoni	194.00	51.41
Noling	595.50	122.90
Walanae	2,318.20	826.32
Segeri	78.90	61.05
Pangkajene	200.60	359.62
Salomekko	14.20	10.93
Maros	274.20	157.48
Pamukkulu	94.30	49.83
Mare	137.90	50.84
Jenelata	228.10	74.99
Kelara	188.60	78.01

Relating column 3 and 4 for the first ten catchments results in Equation (1) with R^2 value of 0.80, and presented also in Figure 1.

$$Q_{2.33} = 2.1647\ A^{0.7167} \tag{1}$$

where A is the catchment area and $Q_{2.33}$ is the mean annual flood.

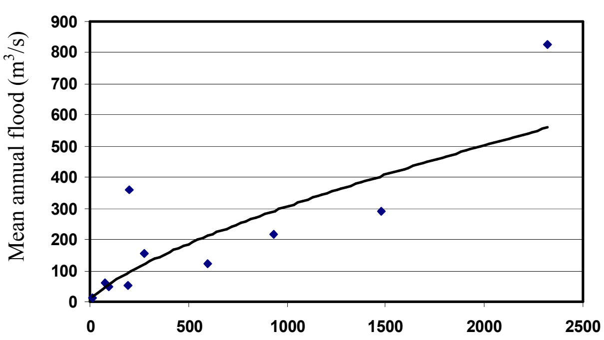

Figure 1. Mean annual flood as function of catchment area.

The value of discharge with different return period is presented in Table 2. The value of flow ratio of each catchment is shown in Table 3.

Instead of plotting the above values on probability paper, the above table is presented in Figure 2 on ordinary paper.

The equation representing the line is:

$$Q_t / Q_{2.33} = 0,8671\ T^{0.2442} \tag{2}$$

where T is return period in years; Q_t is discharge with certain return period, and $Q_{2.33}$ is the mean annual flood.

Table 2. Discharge with specified return period for each catchment

Catchment	Return period (years)					
	2.33	5	10	20	50	100
Kalaena	217	288	367	380	434	472
Maloso	288	345	423	505	626	725
Tomoni	51	90	119	146	181	208
Noling	122	155	178	199	226	247
Walanae	826	955	1,026	1,098	1,142	1,181
Segeri	61	84	101	118	141	158
Pangkajene	360	524	634	723	851	936
Salomekko	11	17	21	24	28	30
Maros	157	191	209	221	239	249
Pamukkulu	50	88	117	144	180	206

Table 3 The value of flow ratio of each catchment

Catchment	Return period (years)					
	2	5	10	20	50	100
Kalaena	0.96	1.32	1.55	1.75	2.00	2.17
Maloso	0.98	1.19	1.46	1.75	2.17	2.51
Tomoni	0.91	1.75	2.31	2.84	3.53	4.05
Noling	0.97	1.26	1.45	1.62	1.85	2.01
Walanae	0.98	1.16	1.24	1.33	1.38	1.43
Segeri	0.95	1.37	1.66	1.95	2.32	2.59
Pangkajene	0.94	1.46	1.76	2.04	2.37	2.60
Salomekko	0.93	1.59	1.93	2.24	2.59	2.83
Maros	0.97	1.21	1.33	1.41	1.52	1.58
Pamukkulu	0.90	1.76	2.35	2.91	3.62	4.14
Median Value	0.95	1.35	1.60	1.85	2.25	2.55

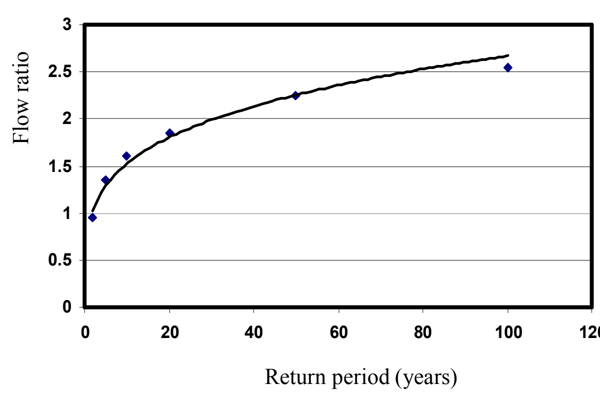

Figure 2. Peak flow ratio as function of return period.

The IFM method is applied using Equation (1) or Figure 2 to obtain annual peak flow ($Q_{2.33}$) from catchment area (A) then the peak discharge is computed from the value of peak flow ratio which corresponds with the assigned return period as represented by Equation (2) of Figure 3. Applying that procedure the computed peak discharge is shown in Table 4.

Table 4. Peak discharge computed with IFM and its relative deviation

Catchment	Return period (years)					
	2	5	10	20	50	100
Mare'	75	95	112	133	167	198
Jenelata	108	136	161	191	239	283
Kelara	95	119	141	167	209	247
Bailo	29	36	43	51	64	76
Average Deviation (%)	18	-2	-6	-7	-6	-4

Having a look at the above result, although the absolute deviations range about 28 %, but their average deviations are relatively small.

Other approach of estimating peak discharge is by directly relate peak discharge with a certain period with the annual peak flood instead of using peak flow ratio as has been described before. Similar to that of the IFM, the annual peak flood is obtained by correlating it as function of catchment area as shown in Equations (3) through (7).

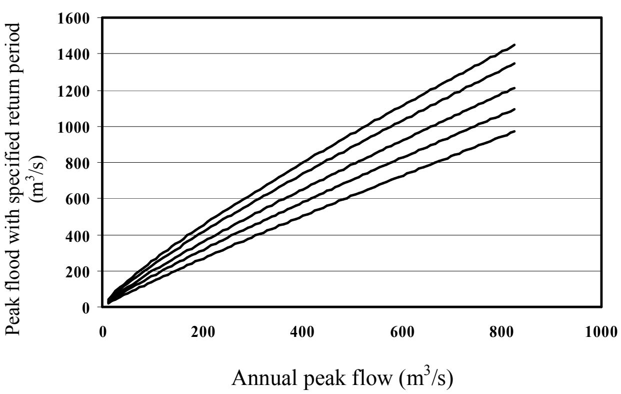

Figure 3. Peak flood with certain period as function of annual peak flow.

The equations representing the above lines are :

$$Q_5 = 2.1239\, Q_{2.33}^{\ 0.911} \quad (3)$$

$$Q_{10} = 2.966\, Q_{2.33}^{\ 0.8798} \quad (4)$$

$$Q_{20} = 3.7599\, Q_{2.33}^{\ 0.8596} \quad (5)$$

$$Q_{50} = 4.8762\, Q_{2.33}^{\ 0.8067} \quad (6)$$

$$Q_{100} = 5.6791\, Q_{2.33}^{\ 0.8249} \quad (7)$$

where Q_T is discharge with a certain period.

Applying those equations in the tested three catchments result in less accurate estimates with average deviation of 22.6 %, 20.10%, 17.43%, 1.11% and 13.18% respectively.

An even more direct relationship between flood with specified return period and the catchment area arrive at the following equation.

$$Q_5 = 4.4941\, A^{0.6454} \quad (8)$$

$$Q_{10} = 6.1006\, A^{0.623} \quad (9)$$

$$Q_{20} = 7.5386\, A^{0.6104} \quad (10)$$

$$Q_{50} = 9.4563\, A^{0.5968} \quad (11)$$

$$Q_{100} = 10.751\, A^{0.5909} \quad (12)$$

Applying these formula in the way as has been previously shown, results in the average deviation of 23.79%, 20,7%, 17.93%, 15.10%, and 13.14% respectively. Comparing this result with the previous one, there is almost no significant different between them.

Other study that has been previously done by Sri Harto (2000) took place on the island of Java. In this study, thirty catchments are used, and a slightly different step is followed by grouping those catchments into two groups. Twenty catchments are used to developed equations while the other 10 catchments are used for verification.

Using 20 catchments equation is obtained as shown in Figure 4 and Equation (13).

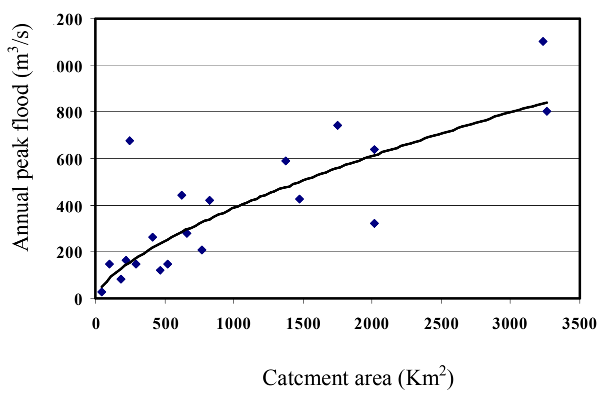

Figure 4. Annual peak flood as function of catchment area.

$$Q_{2.33} = 4.1036\, A^{0.6582} \quad (13)$$

The flow ratio of the 20 catchments is presented in Table 5.

Plotting the above values on plain paper, a relationship between return period and the flow ratio will be obtained, as shown in Figure 5 and Equation (14).

Table 5. Values of flow ratio of each catchment.

Catchment return	Period Number			
	10	25	50	100
1	1.19	1.31	1.41	1.49
2	1.45	1.76	1.96	2.16
3	1.44	1.75	1.96	2.18
4	1.37	1.56	1.72	1.87
5	1.95	2.09	2.09	2.16
6	3.33	3.69	3.91	4.15
7	1.36	1.55	1.69	1.83
8	1.87	4.33	4.70	5.03
9	1.10	1.13	1.13	1.15
10	1.14	1.23	1.23	1.36
11	1.33	1.48	1.56	1.66
12	1.27	1.57	1.80	2.03
13	1.16	1.25	1.27	1.32
14	1.25	1.38	1.44	1.53
15	1.39	1.61	1.70	1.83
16	1.54	1.88	2.17	2.45
17	1.59	2.24	2.33	2.63
18	1.42	2.17	2.21	2.49
19	1.49	1.96	2.10	2.31
20	1.64	2.03	2.39	2.71
Median Value	1.40	1.68	1.88	2.10

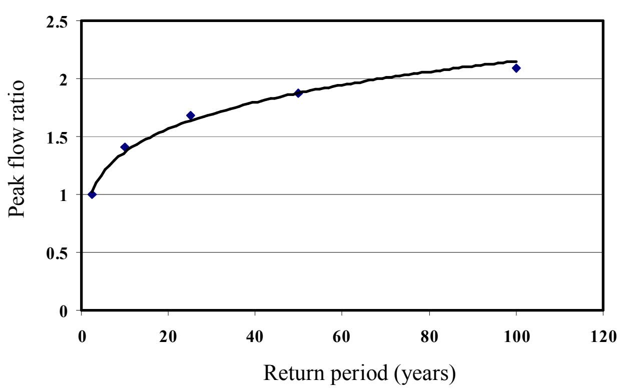

Figure 5. Flow ratio as function of return period.

$$Q_T/Q_{2.33} = 0.8686\, T^{0.197} \quad (14)$$

Applying these two curves in the other 10 catchments does not show any good result, since the deviation ranges from – 70% to +70% although their average values are only around 5 %.

Instead of using flow ratio, another approach is used by directly relate discharge with certain return period with the annual peak discharge. The equations (15), (16), (17), and (18) is for 10, 25, 50 and 100 year return period respectively.

$$Q_{20} = 1.2288\, Q_{2.33}^{1.0375} \quad (15)$$

$$Q_{25} = 1.516\, Q_{2.33}^{1.027} \quad (16)$$

$$Q_{50} = 1.7526\, Q_{2.33}^{1.0152} \quad (17)$$

$$Q_{100} = 1.9264\, Q_{2.33}^{1.0129} \quad (18)$$

Applying those equations does not show any improvement in the accuracy of estimates, since the range of the deviation is still that large, $\pm$ 70% with the average deviation of 4 %.

For the sake of comparison, direct relationship between floods with certain return period directly with catchment area is also derived.

$$Q_{10} = 4.6684\, A^{0.7032} \quad (19)$$

$$Q_{25} = 5.5436\, A^{0.7014} \quad (20)$$

$$Q_{50} = 6.5095\, A^{0.6871} \quad (21)$$

$$Q_{100} = 7.1792\, A^{0.6846} \quad (22)$$

Applying those equations results in similarly large deviation that is around the value of $\pm$ 70 % with the average deviation about 4 %.

3 DISCUSSION

Having a look at the equations as the bases of the Index Flood Method, one may understand that the method was developed and is applicable in areas with low spatial variability of flow. In those areas estimating discharge with a certain return period at an ungaged site with the above method may be expected to obtain relatively high accuracy.

Looking at the above results, either the study done by Sri Harto (2000) or one studied by Rita (2001) shows quite similar result with low accuracy. Indeed that the average deviation is relatively small, but the range of those deviation is significantly large. It does mean that either IFM or those proposed DFR equations are not properly representing a real flow characteristic in both areas of studies. In other words, the flow characteristics are not that homogeneous that can be represented by some equations.

As it has been generally known, the rainfall is transformed into flow by the catchment. It means that the flow characteristics are dictated by two major factors, which are rainfall and catchment characteristics. The latter is further composed of two factors, which are natural factors and anthropogenic factors. In both areas of studies both natural factors and land use factors are similar, with high anthropogenic influence. Since the catchment condition is similar then the way the catchments transform rainfall into flow is considered also similar. It may be also considered that the different in flow characteristics is more influenced by the flow producing storm. Muhamoud (2008) mentioned that rainfall is more of forcing factor to influence the catchment response. Further Littlewood and Croke (2008) mentioned that the more the distance between catchment, the higher the possibly of different characteristics of rainfall.

It has been generally known that there is very high spatial variability of rainfall as has been shown by Sri Harto (1985, 2007, 2009), and Puspa (2006). Considering those reasons it is too difficult to expect the similarity in rainfall behavior and further in flow characteristics in the study areas. It does mean that a flow characteristic in either region is highly inhomogeneous.

Realizing the above facts the similarity in flow characteristics is hardly possible to obtain. The efforts to represent the areal/spatial similarity of flow by introducing some equations will arrive at unsatisfactory results.

The inclusion of rainfall network density in the equations may bring to slightly better result, as this latter may represent the areal variability of rainfall. This one still should be further studied.

4 CONCLUSSION

Those results may suggest that applying those methods is not recommended for important water works, since the risk of having overestimate or underestimate values of the design is quite high.

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