Review of Rainfall Hourly Distributionon the Island of Java

Sri Harto Brotowiryatmo
Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta, INDONESIA
sriharto@tsipil.ugm.ac.id

ABSTRACT

Rainfall hourly distribution is still a very important variable in the computation of the design of some hydraulic works. It has been generally known that this distribution will defer from one to the other region. The distribution defers from that exist in this area may invite additional inaccuracy in further analysis. This review presents some works which have been done in these last years, to fulfill the absence of this distribution on the island of Java region.

Keywords: telemetry system, rainfall intensity, information spreading

1 INTRODUCTION

Computation for preparing hydrologic information for the design of hydraulic works within the acceptable accuracy is needed. This does not mean that the computation should be error free which will never be reached. The simplest scheme for the computation is given in Figure 1.

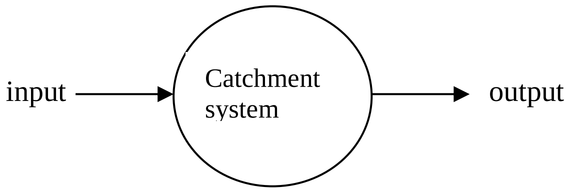

Figure 1. Scheme of the computation.

That figure gives very simplified scheme of computation showing the relationship between input, catchment system, and the produced output. The most important input component is rainfall which will be transformed into the catchment system into output components which may be in the form of some hydrologic information. With that scheme, it is clearly shown that any error contained in the input component will be transformed by the catchment system into the output components. The catchment system as the transforming factor will also contain uncertainties due to the model applied in representing the actual characteristics of the catchment system. The consequences of this procedure that the result of an error contained input which is transformed by an uncertain system will be values of hydrologic information containing unknown error.

Having a look at the rainfall magnitude as the input data, the quite common and easy rainfall data collected from meteorology and geophysics office (BMKG) is daily rainfall data. In the most practice of hydrologic analysis to provide hydrologic information for water works this data is not enough, since mostly for this purpose, an hourly rainfall distribution is needed. The problem is that up to now, no appropriate rainfall hourly distribution available in the area.

2 RAINFALL HOURLY DISTRIBUTION

Referring to the fact that in Java Island, the spatial and temporal variability of rain is very high, this always becomes major questions in estimating the real catchment rainfall and even more in trying to obtain rainfall hourly distribution. That is one reason that hydrologist should be careful right from the beginning of the work, by trying to minimize all possible error encounter in the data and in the method of computations. Then the work should be done according to the scheme as in Figure 2.

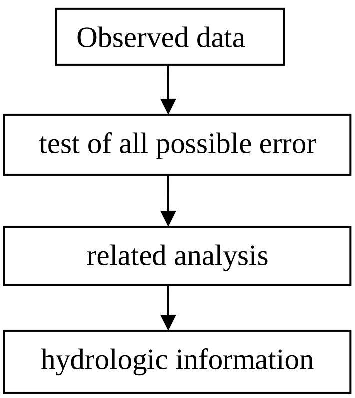

Figure 2. Scheme of the general hydrologic procedure.

No tolerance should be given to the possible presence of an error in the data. All data should be thought to contain error, all possible error should be identified then all of them should be corrected with a relevant method to minimize the magnitude of the error. Having error free data for the computation is impossible. It has been known in practice the presence of a kind of pronouns Garbage in Garbage out (GIGO), means that if the quality of the data is 'Garbage' then the output of the analysis will also be Garbage. But if the quality of the data is good, then the quality of the output will still be depended on three questions:

a) whether the problem is really properly identified,
b) whether the right formulas are selected to solve the identified problem,
c) Whether/how those formulas can be integrated and constructed to be a model suitable for the problem.

One of the possible uncertain variables for the analysis is the rainfall hourly distribution (RHD). Up to the present days, there are no RHD available which gives an estimate of the catchment RHD with relatively high accuracy for this area. Due to the lack of this variable, the common RHD applied by the hydrologists is one contained in the text book such as the Alternating Block Method (ABM) (Chow, et al., 1988) and the Tadashi Tanimoto's method (Mutia (2011) and Erick Lauw (2012)).

The ABM method may be illustrated as follows. This method is considered a bit flexible that can be applied to transform rainfall with short duration as long as the rainfall duration is known or with the availability of Intensity Duration Frequency curve (IDF) (Chow, et al., 1988).

The distribution shows the rainfall depth at any interval Δt for the duration of total T = nΔt. Then the rainfall depth of each interval can be computed for Δ, 2Δ, 3Δ ..... etc and then can be distributed by placing the maximum depth at the center and the rest of them can distribute symmetrically on the left and on the right of the maximum value.

The rainfall duration can be estimated by some known equation such as:

Kirpich's equation (Sri Harto, 2000):

$$t_c = 2.97L^{0,77}\ S^{(-0.385)} \quad (1)$$

Autralian Rainfall-Runoff (Pilgrim, 1987) :

$$t_c=0.76A^{0.38} \quad (2)$$

Williams's equation (Pilgrim, 1987)

$$t_c= 0.243LA^{-0.1}S^{-0.2} \quad (3)$$

where L is length of main stream (km), A is catchment area (km^2), S is stream slope (m/km), and t_c represents time of concentration (hour).

Applying different equation will give a different result, but the problem is that there is no equation available in this area to represent the value of Tc. There are two definitions to represent this value. One says that time of concentration is the time between the end of rainfall until the time of the peak discharge while the other says that this value is the time between the end of rainfall until the time of inflection point in the recession limb. It is quite a subjective decision to decide while waiting for the proper equation for this area. One fact that has to be realized is that most hydrographs on rivers on the island of Java does not have anymore what so called inflection point since the hydrographs mostly with very sharp peak. This then is interpreted that the value of Tc may follow the first definition. The general form RHD in the ABM method is as in Figure 3.

Another method often used by hydrologist in estimating RHD is Tadashi Tanimoto method which gives the value of each consecutive hour for rainfall of 8-hours duration as presented in Table 1. This method gives the general form of RHD is in

Figure 4. On the study made by Sri Harto (1985) and Sri Harto (2000) on 30 catchments, it is found that the general form of RHD on the island of Java shows like the one in Figure 5.

Applying that three different RHD in the transformation of rainfall into hydrograph will obviously result in quite a different hydrograph. Based on that reason, some works have been done with the main purpose to obtain the more suitable RHD for at least to increase the accuracy of the computations.

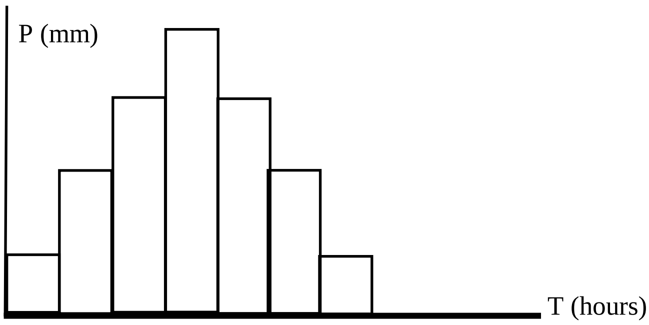

Figure 3. The general form of the ABM method.

Table 1. RHD according to Tadashi Tanimoto

Time (hour)	Percentage distribution	Cumulative percentage
1	26	26
2	24	50
3	17	67
4	13	80
5	7	87
6	5.5	92.5
7	4	96.5
8	3.5	100

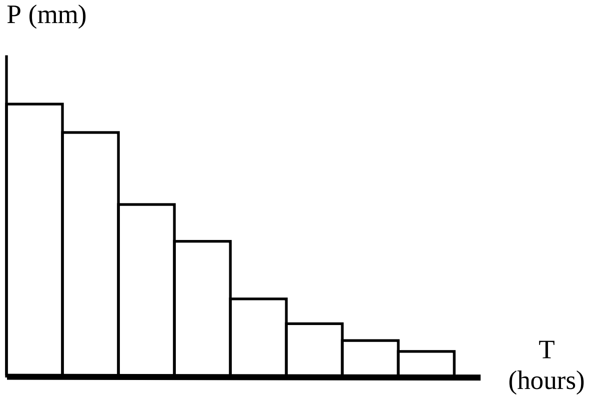

Figure 4. The general form of RHD by Tadashi Tanimoto method.

At least there are five works have been done by Sobriyah (2003), Sukoso (2004), Yudianti (2006), Mutia (2011), and Lauw (2012) which try to develop a suitable equation to relate the cumulative rainfall duration and the cumulative depth of rainfall. Those works give an indication that the RHD derived from the existing rainfall recorder in a catchment mostly have higher accuracy than the other two methods previously mentioned. Those studies were basically based on the belief that the RHD derived from the existing rainfall recorder in a catchment will be more close to the real RHD. Although this thought may still be quite questionable since the representativeness of some number of rainfall gauges exist in a catchment already invited uncertainties especially if the RHD only based on a single rainfall recorder. But the recorded rainfall will at least still bring general characteristic of rainfall in the catchment.

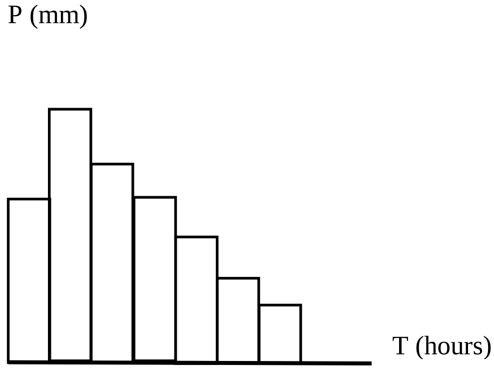

Figure 5. The general form of observed RHD on the island of Java.

Basically, the methods derived from the observation of all recorded data of existing rainfall recorder by grouping the duration of rainfall for certain depth or rainfall. Then a curve can be constructed.

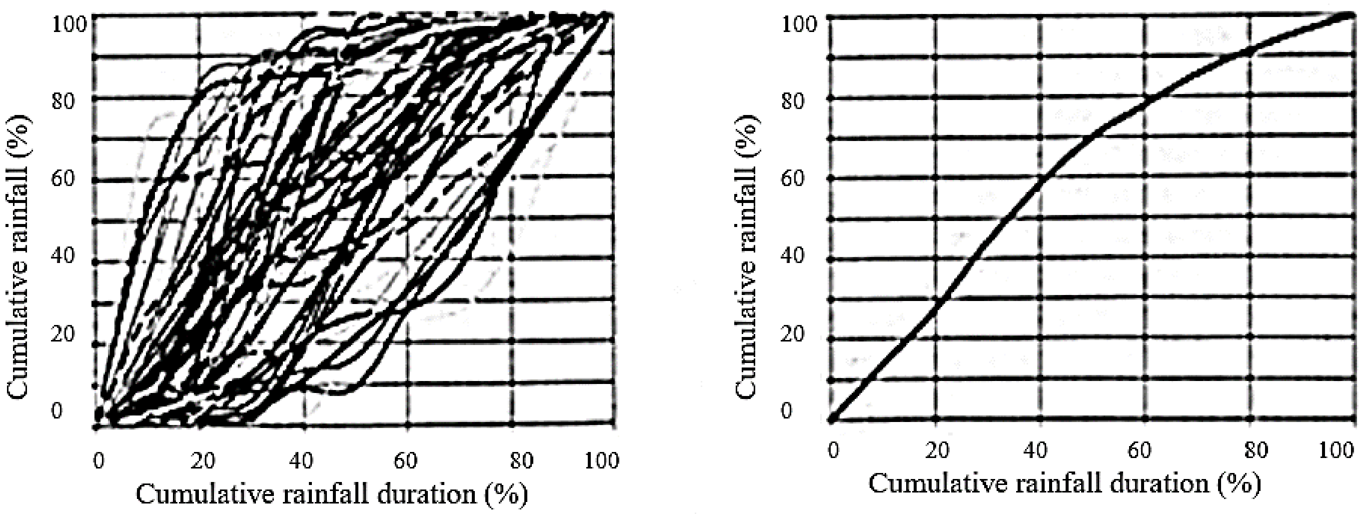

Figure 6. RHD based on Sobriyah (2003) on the case of the large catchment of Bengawan Solo.

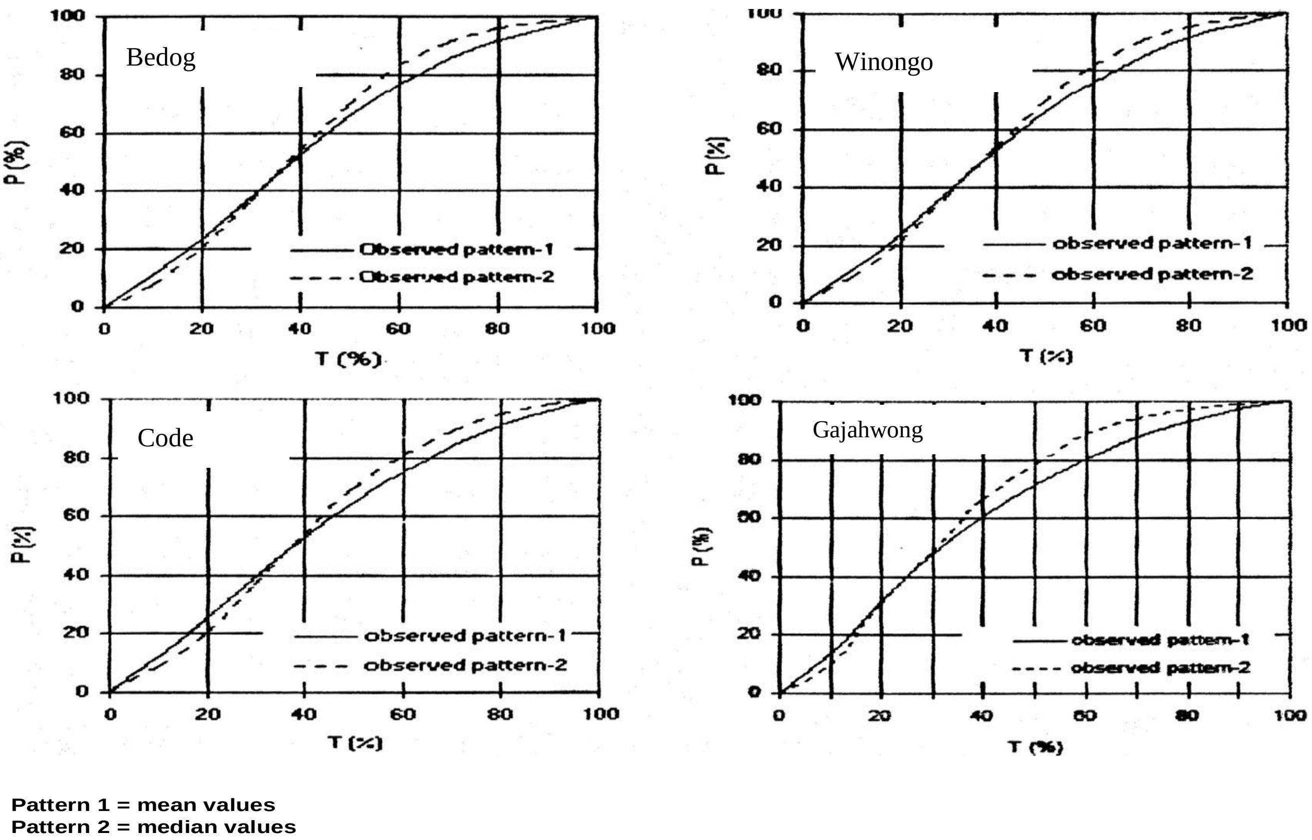

Figure 7. RHD based on Edi Sukoso (2004) in the study of four catchments in volcanic region of Merapi.

After studying five catchments which range from 360 km^2 to 1700 km^2, Mutia (2011) explicitly conclude the following findings.

a) Observed RHD of a catchment differs from that of different catchment not only the magnitude but also the duration for the same magnitude of rainfall depth as well.
b) In general, the performance of the RHD derived from existing rainfall recorder show better accuracy than that performed by methods of ABM or Tadashi Tanimoto.
c) Combining the previous works done by Sobriyah (2003), Sukoso (2004), and Yudianti (2006) and developing the enveloping curve of them, the new equation is proposed.

$$Y = -3{,}8.10^{-5}X^3 - 10^{-3}X^2 + 1{,}48X - 1 \quad (4)$$

Where Y represents percentage of cumulative rainfall, and X represents percentage of cumulative duration.

Lauw (2012) obtained a slightly better result and more simple form of equation after considering the other three previous methods in six catchments differ from those previous catchments. Storms are divided into four categories $50 < P < 75$, $75 < P < 100$, $P > 100$ and $P > 50$. After all, categories were analyzed and compared for all categories then an equation can be obtained Equation 5 for $P > 50$.

$$Y = -0{,}01X^2 + 2{,}14X - 10{,}38 \quad (5)$$

Giving attention to the last two equations those may prove that RHD derived directly from rainfall recorder are more reliable than those based on either ABM or Tadashi Tanimoto equations. That is why although these findings still have to be further verified to increase the performance, for the present those last two equations can be applied in the analysis. Equation (5) gives slightly better result and more simple form. The value of rainfall duration for the same rainfall depth both obtained by Mutia (2011) and Lauw (2012) is about in the same magnitude.

a) $50 \leq P \leq 75$ for 3 hours
b) $75 \leq P \leq 100$ for 5 hours
c) $P \geq 100$ for 7 hours

3 DISCUSSION

Sobriyah (2003) established the relationship between the value of cumulative rainfall duration and the cumulative rainfall depth as shown in Figure 6 based on the average duration of each rainfall depth as in Table 2.

Table 2. Average duration of certain rainfall depth

Rainfall range (mm)	Duration (hour)	Number of cases
0 < i < 10	1.8	976
10 < i < 20	3.5	187
20 < i < 30	3.87	107
30 < i < 40	3.84	63
40 < i < 50	4.5	36
50 < i < 75	5	32
75 < i < 100	5.33	9
100 < i < 150	5.57	7

Although the RHD developed was slightly differ from that of the general pattern of rainfall producing flood on the island of Java, but based on the developed RHD and transformed through the constructed model, the relatively high accuracy can be achieved, such as 98.7% for the peak discharge and 86.8% for the volume although due to very complex system the accuracy of the time to peak was a bit low, 59.9%. From Figure 7 a table can be established Table 3 (Sukoso, 2004).

Table 3. Average rainfall duration for different rainfall depth

Catchment	Rainfall duration			
	50 - 75 (mm)	75 - 100 (mm)	100 - 150 (mm)	> 150 (mm)
1	4	5	5	8
2	4	5	5	7
3	5	6	6	7
4	5	6	6	9
Average	4.5	5.5	5.5	7.8

Illustration of Table 4 shows the accuracies of RHD derived from existing rain recorder compared to the ABM and Tadashi Tanimoto method (Sukoso, 2004), note that the term error is the difference between the magnitude of discharge computed by unit hydrograph and that of obtained by frequency analysis.

Table 4. Accuracies of RHD with different methods

Catchment	Return period (year)	Error (%)		
		Observed	Tadashi Tanimoto	ABM
Bedog	20	-28	46	119
	50	7	74	134
Winongo	20	-20	18	92
	50	17	49	105
Code	20	1	15	135
	50	27	36	172
Gadjah	20	-28	107	308
Wong	50	9	141	325

Table 5. Average rainfall duration for different rainfall depth

Catchment	Rainfall duration			
	50 – 75 mm	75 – 100 mm	> 100 mm	> 150 mm
1	4	4	7	4
2	5	6	-	5
3	5	6	7	6
4	4	5	4	4
5	6	6	-	6
Average	4.8	5.4	6	5

Pay attention to that table it is clear that the RHD derived from the existing rain recorder is more accurate than those two previously mentioned. Mutia (2011) obtained the average duration of rainfall for different ranges as shown in Table 5. Conclusions by comparing values in Table 2, Table 3, and Table 5 yields good conformity on the values of rainfall duration.

Reviewing previous three results as have been mentioned, Mutia (2011) tried to construct enveloping curve around the three curve established by Sobriyah (2003), Sukoso (2004), and Yudianti (2006) . Applying those all RHD to calculate discharge by the unit hydrograph in several catchments arrived in very large deviation on the accuracy compared to that obtained by frequency analysis, such as between 8 – 179%. There are some important reasons behind that.

a) As the reference value, the value of discharge derived from frequency analysis contains some questionable source of inaccuracies.Different length of discharge record in each catchment for the analysis. Large differences in catchment size and topography which influence the basic nature of transformation process from rainfall into runoff.
b) Rainfall duration plays very important role in the RHD values, that in general, each catchment has its own rainfall basic characteristic.
c) Each pattern of RHD derived for each catchment some what varies due to the difference of the existing length or rainfall record of a catchment.

As has been previously mentioned Lauw (2012) studied 6 catchments. Although each catchment has a different pattern of RHD, in general, an equation can be drawn to represent the whole area of study (Equation 5). Comparing Equation 4 and Equation 5 for 100 mm rainfall with 8 hours duration Figure 8 is presented.

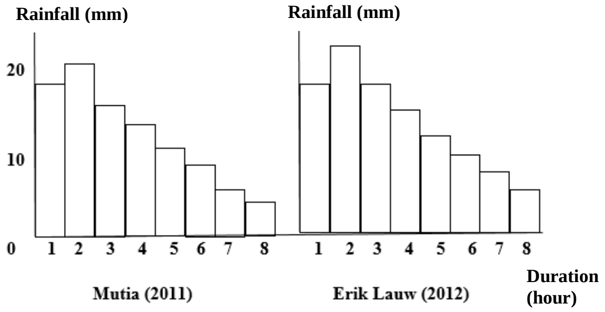

Figure 8. Comparison of RHD Pattern for Equation 4 and Equation 5.

4 CONCLUSIONS

Although those five studies show that at any catchment there will be a special characteristic of RHD but at least a general pattern can be obtained by relatively adequate accuracy. In the case of no RDH data, equation (4) or equation (5) can be used instead.

REFERENCES

Chow, v. T., Maidment, D. R. & Mays, L. W., 1988. *Applied Hydrology*. McGraw Hil.

Lauw, E., 2012. *An explorative study of Rainfall Hourly Distribution on the Island of Java (Indonesian),* Yogyakarta.

Mutia, P., 2011. *Rainfall distribution and its influence on design discharge. (Indonesian)*.

Pilgrim, D., 1987. *Australian rainfall and runoff: a guide to flood estimation.* The institution of Engineers, Australia.

Sobriyah, 2003. *Development of Model for Estimation of Flood in Large Catchment from Synthesis of Selected Equations (Indonesian)*.

Sri Harto, B., 1985. *Study of Unit Hydrograph Basic Characteristics of Rivers on the Island of Java for Flood*.

Sri Harto, B., 2000. *Hydrology, Theory, Problem, and Solution.* Yogyakarta: Nafiri Offset.

Sukoso, E., 2004. *Comparison of the accuracy of rainfall hourly distribution on the design hydrograph (Indonesian)*.

Yudiyanti, I. T., 2006. *Relationship Between Observed and Computed Design Discharge fo certain Return Period (Indonesian),* Yogyakarta.