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An Estimation of Probable Maximum Precipitation for Trinidad

Francis Jaggernath, BSc
Civil Engineer, Ministry of Works,
Government of Trinidad & Tobago,
francisjaggernath@hotmail.com

Gyan. S. Shrivastava, PhD
Senior Lecturer, Department of Civil & Environmental Engineering
University of the West Indies, St. Augustine, Trinidad, W. I.,
shriv@eng.uwi.tt

Abstract
Probable Maximum Precipitation (PMP) is the greatest depth of precipitation that is meteorologically possible for a given location, and its estimation is essential for assessing the safety of dams, and for planning flood disaster preparedness and mitigation measures. In this regard, it may be noted that to date, to the best of the authors' knowledge, no estimate of PMP is available for any location in Trinidad. This paper describes an estimation of a 24-hour PMP for Piarco in Trinidad based on a statistics based methodology recommended by the World Meteorological Organization. Additionally, this paper proposes a temporal distribution for the estimated PMP, and highlights the need for further research.

Keywords
Dams, Floods, Mitigation, Natural Hazards, Rainfall

1. Introduction

The estimation of probable maximum precipitation (PMP), together with its spatial and temporal distributions, is essential for calculating probable maximum flood for the safe design of dams, and for planning flood disaster mitigation and preparedness measures. Specifically, its use in the design of spillway of dams will minimize the risk of overtopping of a dam, which generally leads to loss of life and damage to property. Against this background, it may be noted that, to the best of the authors' knowledge, an estimate of PMP for any location in Trinidad is not yet available (Shrivastava 2003), and it is the purpose of this paper to present such an estimate (Jaggernath, 2005).

2. Methodology

Estimation of PMP has a long history, and early methods relied on local knowledge and historical flood marks. Later frequency analysis was used, but it requires a long length of rainfall record. Recently, a number of physics based methods have evolved, and a good introductory account of such methods may be found elsewhere (Wang, 1984, Chow et al., 1988, Wilson, 1990, and Commonwealth Bureau of Meteorology, 2003). This paper, however, uses a statistical method proposed by the World Meteorological Organization (WMO), which is described in one of its operational manuals (WMO, 1986).

The WMO method can be summarized by the following equations and coefficients:

$$X^* = \mu + K.S \qquad (1)$$

Where X^* is the 24-h PMP, μ is the mean of the annual maximum 24-h rainfall values for the period of record X_n, K is a frequency factor, and S is the standard deviation of X_n.

$$\mu = \frac{1}{n}\sum_{i=1}^{n} X_i \qquad (2)$$

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_n - \mu)^2} \qquad (3)$$

The WMO methodology also uses the following correction factors: α for rainfall duration and mean of annual series, β for adjustment of mean annual series for maximum observed rainfall, δ adjustment of standard deviation of annual series for maximum observed rainfall, θ for adjustment of mean and standard deviation of annual series for length of record, and ϕ for adjustment for fixed observational time intervals.

3. Results

Table 1 shows the 20-year record of annual maximum 24-h rainfalls at Piarco in Trinidad. From the data given in this table μ and S were estimated by equations 2 and 3. Further, μ and S were estimated for the data series after excluding the maximum observed value of the annual 24-h rainfall (the exceptional value), and these were given the symbols μ and S_m respectively.

$$\frac{\mu_m}{\mu} = \frac{82.61}{84.5} = 0.98 \qquad (4)$$

$$\frac{S_m}{S} = \frac{21.55}{22.59} = 0.95 \qquad (5)$$

Further, the following values of the previously mentioned correction factors were obtained (WMO, 1986).

$\alpha = 17$ equals K

β = 1.25 thus μ = 1.25x 84.5 = 105.6

δ = 1.1 thus S = 22.59x1.1 = 24.8

θ = 1.02 for μ and 1.07 for S thus μ = 1.02x 105.62 = 107.7
thus S = 24.8x1.07 = 26.6

ϕ = 1.13

With the above correction factors, a point estimate of 24-h PMP was obtained as follows from equation 1 (after incorporating ϕ) :

$$X^* = (107.7 + 17\,x\,26.6)\,x1.13 = 633\ mm$$

A comparative estimate of X^* may be obtained from the following empirical relationship obtained from a record of the world's greatest observed point rainfalls (Chow et al., 1988):

$R = 422\,D^{0.475}$ *(6)* (24-h PMP of 1,900 mm)

Table 1: Annual 24-h maximum precipitation at Piarco, Trinidad

Number	Year	Rainfall (mm)	Comments
1	1984	67.2	
2	1985	88.9	
3	1986	118.4	
4	1987	47.9	
5	1988	87.6	
6	1989	64.1	
7	1990	47.2	
8	1991	76.3	
9	1992	60.4	
10	1993	103.6	
11	1994	109.1	
12	1995	94	
13	1996	92.4	
14	1997	120.1	The highest value
15	1998	104.6	
16	1999	94.9	
17	2000	71.3	
18	2001	78.8	
19	2002	106.9	
20	2003	56	

A temporal distribution of X^* needs to be presented for its application in estimating the corresponding probable maximum flood. For this purpose, the temporal distribution of PMP for nearby Venezuela (Wang, 1984) was used. Figure 1 shows the proposed temporal distribution of 24-h PMP at Piarco.

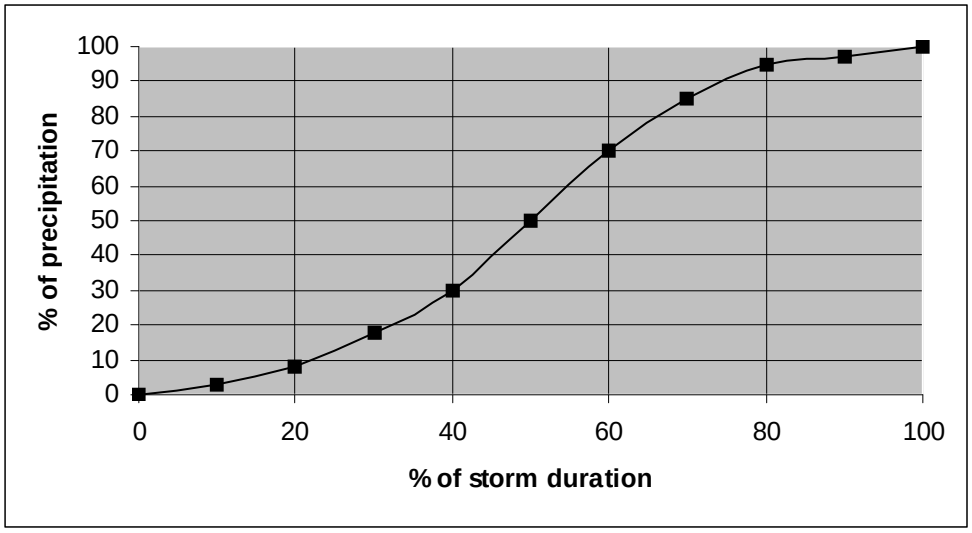

Figure 1: A proposed temporal distribution of PMP at Piarco

4. Conclusion

A comparison of the PMP, estimated by a statistical methodology recommended by WMO Method, with that obtained by a global relationship (Equation 6) shows a wide disparity. Specifically, the statistics based estimate is less than a third of the global maximum. This clearly points to the inadequacy of the length of rainfall record used in this paper. It may be noted that 20 years of rainfall data is, perhaps, the absolute minimum for which a reasonable statistical analysis is feasible. Thus, there is a need for further research on PMP estimation for Trinidad, and in this regard, PMP should be estimated by non-statistical methods as well. Moreover, there is a need to study the spatial distribution of PMP. Finally, it should be noted that the PMP estimate in this paper refers to point rainfall measurements. Therefore, it needs to be corrected for areal reduction.

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Appendix I: References

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Appendix II: Notation

D = Storm duration in hours
K = Frequency factor
R = Maximum recorded precipitation in mm
S = Standard deviation of a series of n annual maxima
S_m = Standard deviation of a series of n annual maxima after excluding X_m
X = The annual maximum 24-h rainfall data series
X_m = The maximum in X series
X^* = The estimated 24-h PMP
α = Correction factor for rainfall duration
β = Adjustment factor for mean annual series for maximum observed rainfall
δ = Adjustment factor for S of annual series for maximum observed rainfall
θ = Adjustment factor for S and μ of annual series for maximum observed rainfall
ϕ = Adjustment factor for fixed observational time intervals
μ = The arithmetic mean of a series of n annual maxima
μ_m = The arithmetic mean of a series of annual maxima excluding X_m

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