ROYAL OBSERVATORY, HONG KONG

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EXTREME RAINFALL STATISTICS AND DESIGN RAINSTORM PROFILES AT SELECTED LOCATIONS IN HONG KONG

by

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1. INTRODUCTION

Statistical analyses on maximum rainfall are useful to both hydrologists and engineers in their water resources planning and construction works, for example, to calculate the optimum size of the drainage systems (Hung, 1992). One of the methods in designing the size of drains in Hong Kong is the Transport and Road Research Laboratory Hydrograph Method (Road Research Lab. Note 35, 1963). This method requires an estimate of the design rainstorm profiles for various return periods in order to calculate the drainage flow. For engineering purpose, there may be special interest on short-duration rainfall of no more than one day and return period of 50 years for small catchment, but up to 200 years for large catchment.

As an update of deriving design rainstorm profiles in Hong Kong since Peterson and Kwong (1981), extreme rainfall statistics and rainstorm profile analyses were carried out for the Royal Observatory Headquarters (RO). The analyses for three more stations, Yuen Long R.G. Filters (YL), Tai Po Tau Treatment Works (TPT) and Tai Lung Farm (TLF), were also carried out as input to the Drainage Services Department's (DSD's) Land Drainage and Flood Control Strategy Study - Phase II (acronym: TELADFLOCOSS II). Locations of RO, YL, TPT and TLF are shown in Figure 1.

The data used in the analyses will be introduced in Section 2. The procedure of extreme values analysis basically followed that described in Peterson and Kwong (1981). Two methods of statistics of extremes were attempted, namely the Gumbel's and the Jenkinson's methods. Both solutions, viz 1955 solution and maximum likelihood solution, were attempted in the Jenkinson's method. The methods are introduced in Section 3 and the steps of determining the parameters of the distributions are outlined in Appendix 1.

Statistical analyses for RO using data over a 100-year period (1884-1939; 1947-1990) were carried out. For the three outstations, there were only eleven years of data (1980-1990) available. To facilitate inter-station comparisons, the same short period analysis was also done for RO. The annual extreme values of rainfall depth with rainfall durations ranging from 1 hour to 31 days and rainfall intensity 15 minutes to 360 minutes for return period 2 years to 1000 years are presented in Section 4.1. Only the results derived by Gumbel's method are presented in the cases of the three outstations, as the computations following Jenkinson's methods did not converge in these cases. In Section 4.2, the results of using different methods in RO 100-year analysis are compared; while the results of the three outstations compared with that of RO are discussed in Section 4.3. It is also of interest to compare the RO results using 'short-period' data (11 years) with those using 'long-period' data (100 years) to see how much deviation may arise in making estimations based on 'short-period' data. This will be discussed in Section 4.4. Based on the estimates of extreme rainfall intensities, rainstorm profiles are derived in Section 4.5.

Finally, some conclusions will be drawn in Section 5.

2. SOURCES OF RAINFALL DATA

Analysis for RO was based on three sources of data. They were 100 years of hourly readings made on the clock hours (1884-1939; 1947-1990), 44 years of 15-minute data extracted from autographic charts (1947-1990), and 39 years of instantaneous rainfall rate measured by the Jardi's recorder at King's Park (1952-1990). As King's Park is sufficiently close to RO (about 1 km to the north of RO), it is justified to include its data in the RO analysis.

For YL, TPT and TLF, two sources of data were used. They were 11 years of daily rainfall data taken at 3 p.m. each day and 15-minute rainfall data extracted from autographic charts (1980-1990). The types of data used for various rainfall durations are shown in Tables 1 and 2 for RO and the three outstations respectively.

Rainfall depths for durations indicated in integral number of hours and days were derived from data starting and ending on clock hours. Rainfall intensity was calculated by dividing the rainfall depth by the time duration (which did not necessarily start or end on clock hours). The duration of instantaneous rainfall for RO was taken as 15 seconds (Cheng, 1965). It should be noted that no instantaneous rainfall data was available for the outstations YL, TPT and TLF where the shortest duration of data extraction was 15 minutes. For the sake of comparison with the results of RO 100-year study, rainfall depths were extracted on clock hour basis for the outstations. The extracted annual maximum rainfall data for various durations are tabulated in Appendix 2.

3. METHODS FOR EXTREME STATISTICS

The main objectives of the frequency analysis of rainfall data are to determine the return periods of recorded storm events of known magnitude X and then to estimate the magnitude of events for design return periods beyond the recorded range. The average time interval within which the magnitude of the event will be equalled or exceeded once is defined as return period T. Hence, the probability of an annual maximum being equal to or less than X is

$$P = 1 - \frac{1}{T} \tag{3.1}$$

Assuming a double exponential probability distribution function, we can introduce a reduced variate as follows:

$$Y = -\ln(-\ln P) \tag{3.2}$$

The historical data are used to fit a frequency distribution. By estimating the parameters of the frequency distribution, design events can be extrapolated from the recorded events. The true distribution that the events naturally follow is generally not known. The historical events used for analyses usually have relatively low return periods and lie around the centre of the probability distribution. However, it is often the events of large return period that need to be estimated and they lie towards the end of the probability distribution. Many distributions have similar shapes in their centres but differ widely in the tails. It is thus possible to fit several different distributions resulting in different estimates of the design event for the same return period. In the present analyses, Gumbel's and Jenkinson's distributions are attempted. In Jenkinson's distribution, two parameter estimation techniques, namely the method of moments and the method of maximum likelihood, are used.

3.1 Gumbel's method

Extreme depths or intensities of rainfall are linearly related to the reduced variate in the Gumbel's distribution as follows (Gumbel, 1954):

$$X = \mu + \frac{1}{\alpha} Y \tag{3.3}$$

and

$$\frac{1}{\alpha} = \frac{S_X}{\sigma_N} \tag{3.4}$$

$$\mu = \overline{X} - \frac{\overline{Y_N}}{\alpha} \tag{3.5}$$

where μ and $1/\alpha$ are parameters characterized by rainfall duration. They can be determined from the mean of the observed annual extremes $\overline{X}$ and their standard deviation S_X , reduced mean $\overline{Y_N}$, and the standard deviation of the reduced extremes of the population, σ_N , which depends on the sample size N. The steps of determining the two parameters are listed in Appendix 1. The idea of Gumbel's fitting consists of minimizing both the vertical and the horizontal distances from the observed values in a linear plot.

3.2 Jenkinson's method

Jenkinson (1977) developed a more general three-parameter model which includes all the Fisher-Tippette types of distribution as special cases to predict extreme values for various return periods. The formulae used are similar to those of Gumbel's method except for Equation (3.3), replaced by

$$X = X_0 + \alpha\left(\frac{1 - e^{-kY}}{k}\right) \qquad \text{when } k \neq 0 \tag{3.6}$$

X_0 is the value of X at $Y = 0$, α is the slope of the X-Y curve at $X = X_0$, $Y = 0$, and k is the curvature parameter. They are the three parameters that characterized the Jenkinson's distribution.

When $k = 0$, the three-parameter model reduces to a two-parameter model with

$$X = X_0 + \alpha Y \tag{3.7}$$

which is the formula for Fisher-Tippette Type I or Gumbel's distribution.

When $k < 0$, Equation (3.6) describes Fisher-Tippette Type II or Frechet distribution, while it describes Fisher-Tippette Type III or Weibull distribution when $k > 0$.

There are two methods to estimate the three parameters, X_0 , α and k. They are Jenkinson's 1955 solution and the maximum likelihood solution. The former solution employs the method of moments to do distribution fitting, while the latter makes use of a likelihood function and the three parameters are iterated by the initial guess obtained from the two-parameter model with $k = 0$. The computational routines are summarized in Appendix 1.

4. RESULTS AND DISCUSSIONS

4.1 Return period of extreme rainfall

The return period is defined as the average time interval within which the magnitude of a certain event will be equalled or exceeded once. Using the annual extreme values of rainfall depth and rainfall intensity listed in Appendix 2, calculation of return periods was carried out by means of Gumbel's method and Jenkinson's method. Gumbel's method assumes the future extremes lie on the best straight line through the available data and hence is least affected by an unrepresentative sample. Jenkinson's three-parameter distribution assumes some of the curvature will persist and therefore they tend to be more representative of the future when the sample is large.

The two parameters of the Gumbel's distribution and the three parameters of the Jenkinson's distribution for the extreme rainfall depth and rainfall intensity were found (Appendix 3). However, for the three outstations having 11 years of rainfall data, only the results of Gümbel's method are presented. Computations following Jenkinson's methods failed to converge due to the oscillatory behaviour of the least square sum in the best-fit calculation. There is one more degree of freedom in the Jenkinson's distribution compared with Gumbel's which is characterized by only two parameters. Hence, Jenkinson's method is more sensitive to the sample size studied. With a small sample size, non-convergence of the method is not unusual.

Table 3 shows the Gumbel estimates of extreme rainfall depth and rainfall intensity corresponding to various return periods after having the parameters smoothed graphically by plotting the calculated parameters against rainfall durations for RO using 100-year rainfall data. The Jenkinson estimates of extremes for RO using 1955 solution (Table 4) and maximum likelihood solution (Table 5) are also tabulated. From Tables 4 and 5, the parameter k in the Jenkinson's distribution varies with the rainfall duration and even changes sign, indicating that extreme rainfall does not always belong to one particular type of distribution. No simple type of frequency distribution gives consistently better results. There are different physical factors controlling each of the annual maximum event. However, for short rainfall durations, say less than 2 hours, the parameter k of the Jenkinson's distribution are all positive. It may indicate that they are of the same population arising from similar physical mechanism.

It should be noted that in Tables 3-5, there are no actual rainfall records for durations of 30 seconds, 60 seconds, 2 minutes, 5 minutes and 10 minutes. The corresponding parameters were found by interpolation of the curves plotting the calculated parameters against the rainfall durations. The interpolated data were included with a view to updating the analysis done by Peterson and Kwong (1981).

In the analyses, smoothing the parameters is necessary even though the graphical means used the purpose is somewhat subjective. Unadjusted parameters may lead to inconsistency in some cases, e.g. rainfall for a shorter duration storm would exceed that for a longer duration storm. In the cases of Jenkinson's fitting, the curvature parameter k was not smoothed, which may lead to inconsistency if the return period is sufficiently large. However, this does not happen even when the return period goes to 1000 years as seen from Tables 4 and 5. Therefore, the necessity of adjusting the parameter k is of no great concern here.

Based on 11-year study, the Gumbel estimates of extremes for YL, TPT, TLF, RO are listed in Tables 6, 7, 8 and 9 respectively. It should be noted that unlike the RO 100-year study, there are no interpolated data for durations 30 seconds, 60 seconds, 2 minutes, 5 minutes and 10 minutes in Tables 6-9.

Figures 2(a), (b), (c), (d) illustrate respectively the fittings of Gumbel and Jenkinson regression lines to the observed annual extreme rainfall intensities for durations of 15, 30, 60 and 120 minutes at RO using 100-year data. Similarly, Gumbel regression lines for YL, TPT and TLF are shown in Figures 3, 4 and 5 respectively. The straight lines come from the Gumbel's results. They are regarded as either the mean or sometimes the mode of the data at a given return period. The distribution of data for a given return period can be described by the confidence limits established on both sides of the fitted line. The "control curves" on the figures show the confidence limits of Gumbel (Chow, 1964) delineating a plus or minus one standard deviation bound from the regression line. The details of deriving the confidence limits are included in Appendix 4. In Figures 3-5, the control curves have been extrapolated by drawing two dashed lines parallel to the extrapolated straight line as originally suggested by Gumbel. It is recognized that this approach will result in "sudden breaks on the control curves and in narrowing down the growing width of the confidence band" (Chow, 1964). The short duration plots for YL, TPT and TLF show that the best fit line for one station generally lies within the control curves of the others. It is attributed to the short length of record analyzed and the resulting large standard deviation of the data. However, all the rainfall data are of the same population from a statistical point of view.

Figures 6(a), (b), (c), (d) illustrate respectively the fitting of Gumbel regression lines to the observed annual extreme rainfall depths for durations 8, 12, 18 and 24 hours at YL. The maximum rainfall value in each case apparently deviates significantly from the rest in the data group. These "outlying" points all came from the heavy rainfall during the passage of Typhoon Brenda in May 1989. It is therefore of some interest to see how the Gumbel estimates will be affected after removing the 1989 data. The revised inferred rainfall amounts for various return periods are given in Table 10(a). When compared with the corresponding Gumbel estimates in Table 6, around 10% - 25% negative adjustments were found for the range of return periods from 10 to 200 years (Table 10(b)). This is an indication of the uncertainties involved in making Gumbel deductions from such a short period of data.

4.2 Comparison of results from RO 100-year analysis using different methods of extreme statistics

For short rainfall durations, say less than 120 minutes, increasing positive deviations were found for Gumbel's estimates compared with Jenkinson's results for larger return periods (Table 11). Gumbel's results tend to over-estimate for short rainfall durations and large return periods.

The Jenkinson's results of using two different parameter estimation techniques are very similar. Table 12 shows that the deviations are in general within 5 %. The choice of a theoretical population distribution has greater impact on the differences between the recorded and the computed events than the parameter estimation techniques of a chosen distribution, especially in the cases of large return periods.

4.3 Comparison of results from YL, TPT, TLF with RO results using 11-year data

Using the 11-year data, the extreme rainfall depths for YL stations as compared with RO had mostly positive deviations (Table 13(a)). But negative deviations were also found, particularly for short durations (1-2 hours). For extreme rainfall intensities with durations of 15-120 minutes, negative deviations within 30% were found. As mentioned in Section 4.1, the Gumbel estimates of rainfall depths were adjusted downwards if the influence of the extreme heavy rainfall in 1989 for durations of 8, 12, 18 and 24 hours was ignored. A comparison of the adjusted statistics of YL (i.e. excluding the 1989 point) with RO for these durations is given in Table 13(b).

For TPT, mostly negative deviations were found when compared with results from the 11-year study of RO (Table 14). They were in general within 10% for durations of 1-12 hours and 20% for durations of 15-120 minutes.

As shown in Table 15, the deviations for TLF were mostly negative in the range of 10% - 20%.

4.4 Comparison between RO results using 11-year data and 100-year data

Comparing the Gumbel estimates of extreme rainfall depths for various return periods using 11-year data (Table 9) with results of the 100-year data analysis (Table 3), the deviations were found to be no more than 10% in most cases (Table 16). Larger deviations were found for short durations like 15-30 minutes and 1-2 hours, which may be partly due to the subjectiveness in the graphical smoothing of parameters in the frequency distribution.

Figures 7, 8, 9, 10 illustrate respectively the fitting of Gumbel regression lines to the observed annual extreme rainfall amounts for durations of 1 hour, 6 hours, 12 hours and 24 hours at RO. In these figures, the data for the 11-year period are shown in (a) and the data for the 100-year period in (b). As in Figures 3-5, the straight solid lines come from the Gumbel's results. The "control curves" are drawn above and below the Gumbel's line and are extrapolated in dashed lines. The error bars are larger for the 11-year study when compared with those for the 100-year analysis. In all cases, the 100-year fitted lines lie within the confidence limits (or very nearly so) of the corresponding 11-year fits.

4.5 Rainstorm profiles

A rainstorm profile is a time series of the rate of rainfall in a storm, usually lasting for a few hours. The profile does not necessarily represent a particular historical storm. It is derived from a design extreme storm event associated with a particular return period.

Using Wisner's formula (1981), the extreme intensity-duration curve can be approximated by fitting the extreme rainfall intensity to the function described by

$$I = \frac{a}{(t+b)^c} \qquad (4.1)$$

where I = extreme rainfall intensity in mm/hr
t = duration in minutes
a, b, c = constants depending on the return period.

The form of Equation (4.1) is shown in Figure 11 (reproduced from Peterson and Kwong, 1981). The method of determining the constants a, b, c is outlined in Appendix 5. Based on the data in Tables 3-9, the profile of extreme intensity for a given return period can be specified by the parameters a, b, c.

In the fittings of the intensity-duration curves for the RO 100-year study, the interpolated data of durations 30 seconds to 10 minutes and the data of duration 4 hours are also included as an update to the work done by Peterson and Kwong (1981).

For the 11-year study, the data are sparse and insufficient, especially for short durations of, say, less than 15 minutes. Apart from TPT, the constraints for the fitted curve are not sufficient to ensure a reasonable interpolation of the peak extreme intensity. As such, steps need to be taken to overcome the problem of non-convergency in the best-fit calculation for YL and TLF.

In the case of YL, 480-minute rainfall intensity data were also utilized in the fitting of the Wisner's formula in Equation (4.1) for the sake of convergence in the best-fit calculation.

In the case of TLF, however, the best-fit calculation failed to converge despite the additional data. To find a practical solution, the view was taken that the peak rainfall intensity was constrained by physical factors, such as moisture supply, which affected all stations in a similar fundamental way. The first step then was to deduce the peak intensity in order to work out the intensity profile. One would expect the peak intensity to be closely related to the rainfall intensity deduced from the rainfall depth over the shortest available duration. In this study, it was the 15-minute duration. A distance-weighting technique was used for interpolating the spatial field. For simplicity, it assumes the field is univariate and isotropic. A normalized weight, which varies inversely to the square of the distance between TLF and the other station, was given to each of the rainfall data of the respective stations. Based on this empirical method, the 15-minute rainfall intensities were interpolated for TLF using the data of RO, TPT and YL. It was found that they deviated no more than -10% from the Gumbel estimates for various return periods. Employing the same spatial correlation, the peak intensity for a given return period for TLF was then calculated (Table 17b). By re-writing Equation (4.1), the extreme intensity profile can be expressed in terms of the peak extreme intensity I_0 as follows:

$$I = \frac{I_0}{(1+\frac{t}{b})^c} \qquad (4.2)$$

The profile of extreme intensity for a given return period can then be specified by the values of I_0 and the fitted parameters b, c.

The values of parameters after fitting either Equation (4.1) or Equation (4.2) are given in Table 17. Based on the RO 100-year data, the percentage deviations of the fitted rainfall intensities from the Gumbel and the Jenkinson estimates for various durations, as given in Tables 3-5, are around 2-10% (Table 18).

Using Equation (4.1), the percentage deviations of the fitted values from the Gumbel estimates of rainfall intensities for various durations as given in Tables 6, 7, 9 are within 3%, 4%, 2% respectively for YL, TPT and RO (Table 19). Using Equation (4.2), the percentage deviations are within 10% except for the 360-minute duration in the case of TLF. Since the peak intensity was deduced from short-duration rainfall data for TLF, the relatively poor fit at long-duration is not unexpected.

Under the assumption of symmetric profile with maximum at $t = 0$, the rainstorm profile for a specific return period is given by:

$$F(t) = \frac{a[b + 2(1-c)t]}{(2t + b)^{c+1}} \qquad \text{for } t \geq 0 \qquad (4.3)$$

where $F(t)$ = rate of rainfall in mm/hr
t = time in minutes
a, b, c = same constants as in Equation (4.1).

The form of Equation (4.3) is shown in Figure 12 while its derivation is given in Appendix 6. The maximum rainfall amount given by the profile for any duration equals the extreme depth deduced from the intensity-duration curve (multiplying the rainfall rate by the time duration), i.e. the shaded area in Figure 12 is equal to that in Figure 11 for any value of t.

Figures 13(a), (b), (c) show the calculated rainstorm profiles for selected return periods for RO 100-year study using Gumbel's method, Jenkinson's method of the 1955 solution and the maximum likelihood solution respectively. The peak intensity of the profile is largest for the Gumbel's solution, while those derived from the two solutions of the Jenkinson's method are very much similar. Hence Gumbel's method tends to lead to a conservative design. Based on the 11-year data, the calculated rainstorm profiles for selected return periods for YL, TPT, TLF and RO are shown in Figures 14, 15, 16 and 17 respectively. In the case of TLF, the parameter a in Equation (4.3) is given by $a = I_0 b^c$.

Based on RO 100-year study, the corresponding peak intensities of the profiles derived by different methods are compared. For those derived by the Gumbel's method, mostly positive deviations were found when compared with the Jenkinson's results while the deviations between the Jenkinson 1955 solution and the maximum likelihood solution were small (Table 20). If the interpolated data in Tables 3-5 were not used in the intensity-duration curve fitting, the peak intensities of the rainstorm profiles were generally adjusted downwards by 7%. The corresponding peak intensities of the profiles for the 11-year period and the 100-year period were also compared (Table 21).

4.6 Risks involved in choosing return periods

To choose an appropriate return period for a particular hydrological design, evaluating the risks involved is essential. The probability P_r that a particular level with a return period T will be reached or exceeded at least once over a period r is given by the formula (Hershfield, 1973).

$$P_r = 1 - (1 - \frac{1}{T})^r \qquad (4.4)$$

For example, if an extreme event has a return period of 100 years, the probability that the event will occur at least once in the next 10 years is 0.096 and that the chance it will occur within 69 years is about 0.5. Figure 18 shows a plot of T against P_r for some chosen values of r.

5. CONCLUSIONS

Extreme rainfall statistics and symmetric rainstorm profiles derivation were performed for the Royal Observatory Headquarters using 100-year data during the period 1884-1939 and 1947-1990 inclusive. Gumbel's solution, Jenkinson's 1955 solution and Jenkinson's maximum likelihood solution were used for the extreme frequency analyses. Gumbel results of the same analyses were also found for stations at Yuen Long R.G. Filters, Tai Po Tau Treatment Works, Tai Lung Farm and, for comparison, the Royal Observatory Headquarters using 11-year data from 1980 to 1990. It was found that short term rainfall totals for stations in the New Territories were generally less than the corresponding figures for RO.

The reliability of the results depends very much on the length of data used. With 'short-period' data, the effect of outliers can cause significant adjustments in the analysis results. Therefore, careful consideration must be given to the treatment of outliers.

In the extreme annual rainfall analysis, some equally heavy rainstorms occurring in the same year may be neglected, while some relatively insignificant rainstorms for other years may be included. This can also have significant effects on 'short-period' data analysis. In fact, short-period records have low statistical reliability. For large return periods, the standard deviation of the results for one station is larger than the variation of rainfall between stations.

Although the rainfall at RO was found to be representative of Hong Kong's rainfall (Starbuck, 1950; Bell and Chin, 1968), the application of the statistical results and the rainstorm profiles to other locations may not be valid. The point rainfall analysis is considered representative of an area of 25 square kilometres (Mott MacDonald, 1989). A map showing the 30-year mean rainfall distribution in Hong Kong (1961-1990) can be used to illustrate the spatial variation of rainfall (Figure 19). From an engineering point of view, the RO results are often taken to be representative for design purposes for the whole territory. The practice is likely to continue until further analyses using longer periods of data are carried out for other stations. It is considered that the variation of data among the gauges is generally of similar magnitude as the error in rainfall measurement and is no greater than the uncertainty in rainfall runoff and hydrodynamic modelling for drainage design. There is a list of recent rainstorms and their effects on Hong Kong included in Appendix 7 for reference.

The analyses are useful for gaining an insight into the variation of extreme rainfall over the territory. Analysis based on longer period of data is recommended in the future so as to justify or amend the present analysis for the outstations. Moreover, analysis of more stations will benefit the study of areal variability of extreme rainfall over Hong Kong.

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TABLE 1

TYPES OF RAINFALL DATA USED FOR RO HEADQUARTERS
FOR DIFFERENT RAINFALL DURATIONS

Duration	Types of record used
15 seconds	4
15 minutes	3
30 minutes	3
60 minutes	3
120 minutes	3
1 hour	2
2 hours	2
4 hours	2
6 hours	2
8 hours	2
12 hours	2
18 hours	2
24 hours	2
2 days	1
3 days	1
4 days	1
5 days	1
7 days	1
15 days	1
31 days	1

Type 1 : daily readings (midnight to midnight)
(100–year period: 1884–1939; 1947–1990)

Type 2 : hourly readings on clock hours
(100–year period: 1884–1939; 1947–1990)

Type 3 : autographic records (15–minute totals)
(44–year period: 1947–1990)

Type 4 : instantaneous rainfall rate measured
at King's Park
(39–year period: 1952–1990)

TABLE 2

TYPES OF RAINFALL DATA USED FOR THE THREE OUTSTATIONS
(YUEN LONG, TAI PO TAU, TAI LUNG FARM)
FOR DIFFERENT RAINFALL DURATIONS

Duration	Types of record used
15 minutes	3
30 minutes	3
60 minutes	3
120 minutes	3
240 minutes	3
360 minutes	3
480 minutes	3
1 hour	2
2 hours	2
4 hours	2
6 hours	2
8 hours	2
12 hours	2
18 hours	2
24 hours	2
2 days	1
3 days	1
4 days	1
5 days	1
7 days	1
15 days	1
31 days	1

Type 1 : daily records* ending at 3 p.m.

Type 2 : autographic records* (clock hour to clock hour)

Type 3 : autographic records* (15–minute totals)

* 11–year period (1980–1990)

TABLE 3

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (USING GUMBEL'S METHOD) $X = \mu + \frac{1}{\alpha} Y$
at Royal Observatory (based on hourly and daily rainfall data, 1884–1939; 1947–1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	609.4	152.7	665	838	953	1063	1205	1312	1418	1558	1664
15 days	427.0	138.7	478	635	739	839	968	1065	1162	1289	1385
7 days	312.6	119.1	356	491	581	666	777	861	943	1053	1135
5 days	284.9	117.7	328	461	550	634	744	826	908	1016	1098
4 days	268.7	113.0	310	438	523	604	710	789	867	971	1049
3 days	249.3	105.0	288	407	486	561	659	732	805	902	974
2 days	217.7	96.6	253	363	435	505	595	662	729	818	885
24 hours	186.2	82.3	216	310	371	431	507	565	622	698	755
18 hours	168.6	72.1	195	277	331	383	450	500	551	617	667
12 hours	146.7	63.0	170	241	288	334	392	436	480	538	582
8 hours	127.7	56.8	149	213	255	296	349	389	428	480	520
6 hours	116.1	50.9	135	192	231	267	315	350	386	432	468
4 hours	101.8	40.3	117	162	193	222	259	287	315	352	380
2 hours	76.1	24.7	85.2	113	132	150	173	190	207	230	247
1 hour	51.0	14.3	56.2	72.5	83.2	93.5	107	117	127	140	150

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES)
at Royal Observatory (based on instantaneous rainfall data, 1952–1990; and autographic rainfall data, 1947–1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
120 minutes	43.3	13.4	48.2	63.4	73.4	83.0	95.5	105	114	126	136
60 minutes	64.4	17.3	70.7	90.4	103	116	132	144	156	172	184
30 minutes	84.8	18.0	91.4	112	125	138	155	168	180	197	209
15 minutes	105.8	20.5	113	137	152	167	186	200	214	233	247
10 minutes	120.0*	23.5*	129	155	173	190	212	228	244	266	282
5 minutes	145.0*	29.0*	156	188	210	231	258	278	299	325	345
2 minutes	173.0*	34.0*	185	224	250	274	306	329	353	384	408
60 seconds	194.0*	36.5*	207	249	276	302	336	362	387	421	446
30 seconds	220.0*	39.0*	234	278	308	336	372	399	427	462	489
15 seconds	232.6	41.4	248	295	326	356	394	423	452	490	519

* Interpolated data

TABLE 4

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (USING JENKINSON'S 1955 SOLUTION) at Royal Observatory (based on hourly and daily rainfall data, 1884–1939; 1947–1990)

$$X = X_0 + \frac{\alpha(1-e^{-kY})}{k}$$

DURATION	PARAMETERS			RETURN PERIOD (YEARS)								
	X_0	α	k	2	5	10	20	50	100	200	500	1000
	mm	mm		mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	619.3	167.3	0.14	679	846	942	1026	1122	1187	1245	1314	1360
15 days	431.8	140.5	0.06	483	633	728	814	921	997	1069	1161	1226
7 days	314.6	111.0	0.00	355	481	564	644	748	825	902	1004	1081
5 days	286.1	105.5	−0.02	325	447	529	609	714	794	875	984	1067
4 days	269.8	100.7	−0.03	307	424	504	583	687	766	848	958	1043
3 days	250.8	96.7	−0.01	286	397	471	542	636	706	777	871	943
2 days	218.9	87.8	−0.02	251	353	421	488	575	642	709	800	869
24 hours	186.8	72.0	−0.05	213	299	358	417	497	559	623	711	780
18 hours	169.3	63.5	−0.05	193	268	320	373	443	498	554	632	693
12 hours	147.1	53.2	−0.10	167	233	281	331	401	458	518	605	676
8 hours	128.0	42.8	−0.14	144	199	241	286	350	404	464	552	626
6 hours	116.4	39.0	−0.13	131	181	218	258	315	362	414	489	553
4 hours	102.2	35.1	−0.05	115	157	186	215	254	284	315	358	392
2 hours	77.1	25.5	0.08	86.3	113	130	145	163	175	187	202	212
1 hour	51.5	14.7	0.07	56.8	72.4	82.0	90.8	102	109	116	125	132

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (USING JENKINSON'S 1955 SOLUTION) at Royal Observatory (based on instantaneous rainfall data, 1952–1990; and autographic rainfall data, 1947–1990)

DURATION	PARAMETERS			RETURN PERIOD (YEARS)								
	X_0	α	k	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr		mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
120 minutes	44.3	13.9	0.14	49.3	63.1	71.1	78.1	86.1	91.4	96.3	102	106
60 minutes	65.9	18.6	0.18	72.5	90.3	100	109	118	124	129	135	139
30 minutes	86.1	19.4	0.13	93.0	113	124	134	145	153	160	169	175
15 minutes	107.4	21.5	0.17	115	136	148	158	169	176	182	190	195
10 minutes	118.0*	24.0*	0.20*	126	149	161	172	183	190	196	203	208
5 minutes	139.0*	30.0*	0.24*	150	177	191	203	215	223	229	236	240
2 minutes	168.0*	39.0*	0.30*	182	215	232	245	258	265	271	278	282
60 seconds	192.0*	43.0*	0.34*	207	243	260	272	285	292	298	303	306
30 seconds	217.0*	46.0*	0.38*	233	270	287	299	311	317	322	327	329
15 seconds	241.7	50.0	0.42	259	297	314	327	338	344	348	352	354

* interpolated data

TABLE 5

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (USING JENKINSON'S MAXIMUM LIKELIHOOD METHOD)

$X = X_0 + \alpha(1 - e^{-ky})/k$ at Royal Observatory (based on hourly and daily rainfall data, 1884–1939; 1947–1990)

DURATION	PARAMETERS			RETURN PERIOD (YEARS)								
	X_0	α	k	2	5	10	20	50	100	200	500	1000
	mm	mm		mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	618.4	168.5	0.13	679	848	947	1034	1134	1202	1263	1337	1387
15 days	432.0	141.5	0.06	483	635	730	817	924	1001	1074	1166	1232
7 days	314.0	110.5	−0.01	355	481	565	647	754	834	915	1022	1104
5 days	285.4	104.8	−0.03	324	446	529	611	719	802	887	1001	1090
4 days	268.9	99.7	−0.04	306	423	504	583	690	772	857	972	1062
3 days	250.8	97.1	−0.01	286	398	472	543	637	708	779	873	945
2 days	218.6	87.2	−0.03	251	352	422	490	580	649	719	814	888
24 hours	186.4	71.2	−0.06	213	298	358	418	499	564	630	723	796
18 hours	167.8	61.2	−0.09	191	266	320	376	454	517	583	677	754
12 hours	146.2	51.8	−0.11	166	231	278	328	399	456	519	608	682
8 hours	127.8	42.6	−0.15	144	199	242	287	354	410	472	565	644
6 hours	116.6	39.5	−0.12	131	181	219	257	313	359	409	481	541
4 hours	102.0	35.2	−0.06	115	157	187	217	257	289	322	367	403
2 hours	76.8	24.9	0.06	85.8	113	129	145	163	177	190	206	218
1 hour	51.4	14.4	0.05	56.6	72.2	82.0	91.0	102	110	118	128	135

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (USING JENKINSON'S MAXIMUM LIKELIHOOD METHOD) at Royal Observatory (based on instantaneous rainfall data, 1952–1990; and autographic rainfall data, 1947–1990)

DURATION	PARAMETERS			RETURN PERIOD (YEARS)								
	X_0	α	k	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr		mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
120 minutes	44.2	13.7	0.12	49.1	62.9	71.1	78.3	86.7	92.5	97.7	104	108
60 minutes	66.1	18.5	0.20	72.6	90.0	99.6	107	116	122	126	132	135
30 minutes	86.4	19.4	0.17	93.3	112	123	132	142	148	154	161	165
15 minutes	107.3	21.5	0.15	115	136	148	159	171	179	186	194	200
10 minutes	118.0*	25.0*	0.17*	127	151	165	176	189	198	205	214	220
5 minutes	140.0*	32.0*	0.22*	151	181	197	210	224	233	240	248	254
2 minutes	171.0*	39.0*	0.28*	185	219	236	250	264	272	279	286	290
60 seconds	195.0*	43.0*	0.34*	210	246	263	275	288	295	301	306	309
30 seconds	218.0*	46.0*	0.41*	234	270	286	297	308	313	317	321	324
15 seconds	242.3	50.0	0.45	259	297	313	324	334	339	343	347	348

* interpolated data

TABLE 6

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES) $X = \mu + \frac{1}{\alpha} Y$
at Yuen Long R.G. Filters (based on hourly and daily rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	483.0	173.0	546	742	872	997	1158	1279	1399	1558	1678
15 days	301.3	166.3	362	551	676	795	950	1066	1182	1335	1450
7 days	230.1	157.0	288	466	583	696	843	952	1062	1206	1315
5 days	212.0	156.6	269	447	564	677	823	932	1041	1185	1294
4 days	200.7	154.0	257	432	547	658	802	909	1016	1158	1264
3 days	190.1	149.7	245	415	527	635	774	879	983	1120	1224
2 days	175.0	144.0	228	391	499	603	737	837	938	1070	1170
24 hours *	145.0	126.0	191	334	429	519	637	725	812	928	1015
18 hours *	134.0	118.5	177	312	401	486	596	679	762	870	953
12 hours *	113.6	102.4	151	267	344	418	513	585	656	750	821
8 hours *	104.2	84.2	135	230	294	354	433	492	550	627	686
6 hours	99.5	71.7	126	207	261	312	379	429	479	545	595
4 hours	88.6	51.0	107	165	203	240	288	323	359	405	441
2 hours	65.2	24.8	74.3	102	121	139	162	179	197	219	237
1 hour	42.2	14.7	47.6	64.2	75.3	85.9	99.6	110	120	134	144

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES)
at Yuen Long R.G. Filters (based on autographic rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
360 minutes	16.8	12.1	21.2	34.9	44.0	52.7	64.0	72.5	80.9	92.0	100
240 minutes	22.5	13.0	27.3	42.0	51.7	61.0	73.1	82.1	91.1	103	112
120 minutes	34.2	13.9	39.3	55.1	65.5	75.5	88.5	98.2	108	121	130
60 minutes	46.7	14.7	52.1	68.7	79.7	90.3	104	114	124	138	148
30 minutes	67.0	15.4	72.6	90.1	102	113	127	138	149	163	174
15 minutes	93.0	16.1	98.9	117	129	141	156	167	178	193	204

*** see text in Section 4.1**

TABLE 7

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES) $X = \mu + \frac{1}{\alpha} Y$
at Tai Po Tau Treatment Works (based on hourly and daily rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	645.3	127.9	692	837	933	1025	1144	1234	1323	1440	1529
15 days	425.4	107.6	465	587	668	745	845	920	995	1094	1169
7 days	329.7	98.4	366	477	551	622	714	782	851	941	1009
5 days	307.3	97.0	343	453	526	595	686	754	821	910	977
4 days	287.3	96.3	323	432	504	573	663	730	797	886	952
3 days	265.0	95.8	300	409	481	550	639	706	772	860	927
2 days	234.0	92.0	268	372	441	507	593	657	721	806	869
24 hours	180.0	85.0	211	307	371	432	512	571	630	708	767
18 hours	160.0	79.0	189	278	338	395	468	523	578	651	706
12 hours	131.3	68.9	157	235	286	336	400	448	496	559	607
8 hours	109.2	61.1	132	201	247	291	348	390	433	489	531
6 hours	99.8	56.1	120	184	226	266	319	358	397	448	487
4 hours	86.2	47.0	103	157	192	226	270	302	335	378	411
2 hours	68.0	30.4	79.1	114	136	158	187	208	229	257	278
1 hour	49.0	16.9	55.2	74.3	87.0	99.2	115	127	138	154	166

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES)
at Tai Po Tau Treatment Works (based on autographic rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
360 minutes	16.6	9.4	20.0	30.7	37.8	44.5	53.3	59.8	66.4	75.0	81.5
240 minutes	21.7	12.1	26.1	39.8	48.9	57.6	68.9	77.4	85.8	96.9	105
120 minutes	35.5	15.2	41.1	58.3	69.7	80.6	94.8	105	116	130	140
60 minutes	54.4	16.9	60.6	79.7	92.4	105	120	132	144	159	171
30 minutes	75.5	19.4	82.6	105	119	133	151	165	178	196	210
15 minutes	99.2	25.8	109	138	157	176	200	218	236	260	277

TABLE 8

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES) $X = \mu + \frac{1}{\alpha} Y$
at Tai Lung Farm (based on hourly and daily rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	574.8	123.6	620	760	853	942	1057	1143	1229	1343	1429
15 days	376.1	114.0	418	547	633	715	821	901	980	1084	1164
7 days	285.2	106.0	324	444	524	600	699	773	847	944	1017
5 days	245.0	102.5	283	399	476	549	645	717	788	882	953
4 days	228.0	100.3	265	378	454	526	619	689	759	851	921
3 days	208.0	97.5	244	354	427	498	588	657	724	814	881
2 days	182.0	93.0	216	321	391	458	545	610	675	760	824
24 hours	139.0	85.0	170	266	330	391	471	530	589	667	726
18 hours	125.6	81.5	155	248	309	368	444	501	557	632	689
12 hours	106.7	73.0	133	216	271	324	392	443	493	560	611
8 hours	92.6	61.4	115	185	231	275	332	375	418	474	517
6 hours	84.9	52.5	104	164	203	241	290	326	363	411	448
4 hours	74.4	42.0	89.8	137	169	199	238	268	297	335	365
2 hours	54.9	24.0	63.7	90.9	109	126	149	165	182	204	221
1 hour	43.0	13.0	47.8	62.5	72.3	81.6	93.7	103	112	124	133

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES)
at Tai Lung Farm (based on autographic rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
360 minutes	14.3	9.3	17.7	28.2	35.2	41.9	50.6	57.1	63.6	72.1	78.5
240 minutes	18.8	10.6	22.7	34.7	42.7	50.3	60.2	67.6	74.9	84.7	92.0
120 minutes	29.3	12.6	33.9	48.2	57.7	66.7	78.5	87.3	96.0	108	116
60 minutes	45.7	16.0	51.6	69.7	81.7	93.2	108	119	130	145	156
30 minutes	70.5	20.4	78.0	103	116	131	150	164	179	197	211
15 minutes	92.8	30.3	104	138	161	183	211	232	253	281	302

TABLE 9

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES) $X = \mu + \frac{1}{\alpha}Y$
at Royal Observatory (based on hourly and daily rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
31 days	573.1	150.0	628	798	911	1019	1158	1263	1367	1505	1609
15 days	366.3	144.0	419	582	690	794	928	1029	1129	1261	1361
7 days	269.9	135.2	319	473	574	671	797	892	986	1110	1204
5 days	244.2	129.0	291	438	535	627	748	838	927	1046	1135
4 days	235.0	124.5	281	422	515	605	721	808	894	1009	1095
3 days	223.0	118.0	266	400	489	573	683	766	848	956	1038
2 days	208.0	108.0	248	370	451	529	629	705	780	879	954
24 hours	183.0	90.0	216	318	386	450	534	597	660	742	805
18 hours	170.0	82.0	200	293	355	414	490	547	604	680	736
12 hours	156.0	70.0	182	261	314	364	429	478	527	591	640
8 hours	139.1	58.0	160	226	270	311	365	406	446	499	540
6 hours	130.7	50.0	149	206	243	279	326	361	395	441	476
4 hours	117.0	40.0	132	177	207	236	273	301	329	366	393
2 hours	89.2	26.0	98.7	128	148	166	191	209	227	251	269
1 hour	57.5	15.7	63.3	81.0	92.8	104	119	130	141	155	166

EXTREME RAINFALL INTENSITIES CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES)
at Royal Observatory (based on instantaneous and autographic rainfall data, 1980 – 1990)

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr	mm/hr
120 minutes	46.7	13.1	51.5	66.3	76.2	85.6	97.8	107	116	128	137
60 minutes	70.1	15.7	75.9	93.6	105	117	131	142	153	168	179
30 minutes	93.0	20.0	100	123	138	152	171	185	199	217	231
15 minutes	114.6	25.0	124	152	171	189	212	230	247	270	287
15 seconds	249.3	35.6	262	303	329	355	388	413	438	471	495

TABLE 10(a)

EXTREME RAINFALL DEPTHS CORRESPONDING TO VARIOUS RETURN PERIODS (GUMBEL ESTIMATES) $X = \mu + \frac{1}{\alpha} Y$
at Yuen Long R.G. Filters (based on hourly rainfall data, 1980 – 1988, 1990) *

DURATION	PARAMETERS		RETURN PERIOD (YEARS)								
	μ	$1/\alpha$	2	5	10	20	50	100	200	500	1000
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
24 hours	153.1	105.3	192	311	390	466	564	637	711	807	880
18 hours	139.4	93.2	174	279	349	416	503	568	633	719	783
12 hours	116.6	71.0	143	223	276	327	394	443	493	558	607
8 hours	105.1	69.8	131	210	262	312	377	426	475	539	587

TABLE 10(b)

PERCENTAGE DEVIATION OF THE GUMBEL ESTIMATES OF EXTREME RAINFALL DEPTHS USING 10–YEAR DATA (1980–1988, 1990) FROM THAT OF USING 11–YEAR DATA (1980–1990) AT YUEN LONG R.G. FILTERS

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
24 hours	0.5	–6.9	–9.1	–10.2	–11.5	–12.1	–12.4	–13.0	–13.3
18 hours	–1.7	–10.6	–13.0	–14.4	–15.6	–16.3	–16.9	–17.4	–17.8
12 hours	–5.3	–16.5	–19.8	–21.8	–23.2	–24.3	–24.8	–25.6	–26.1
8 hours	–3.0	–8.7	–10.9	–11.9	–12.9	–13.4	–13.6	–14.0	–14.4

% deviation = [YL(10 yrs)–YL(11 yrs)] / YL(11 yrs) x 100%

*** see text in Section 4.1**

TABLE 11

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS AT ROYAL OBSERVATORY USING GUMBEL'S METHOD FROM THOSE OF USING JENKINSON'S MAXIMUM LIKELIHOOD SOLUTION (BASED ON 100–YEAR DATA)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
31 days	−2.1	−1.2	0.6	2.8	6.3	9.2	12.3	16.5	20.0
15 days	−1.0	0.0	1.2	2.7	4.8	6.4	8.2	10.5	12.4
7 days	0.3	2.1	2.8	2.9	3.1	3.2	3.1	3.0	2.8
5 days	1.2	3.4	4.0	3.8	3.5	3.0	2.4	1.5	0.7
4 days	1.3	3.5	3.8	3.6	2.9	2.2	1.2	−0.1	−1.2
3 days	0.7	2.3	3.0	3.3	3.5	3.4	3.3	3.3	3.1
2 days	0.8	3.1	3.1	3.1	2.6	2.0	1.4	0.5	−0.3
24 hours	1.4	4.0	3.6	3.1	1.6	0.2	−1.3	−3.5	−5.2
18 hours	2.1	4.1	3.4	1.9	−0.9	−3.3	−5.5	−8.9	−11.5
12 hours	2.4	4.3	3.6	1.8	−1.8	−4.4	−7.5	−11.5	−14.7
8 hours	3.5	7.0	5.4	3.1	−1.4	−5.1	−9.3	−15.0	−19.3
6 hours	3.1	6.1	5.5	3.9	0.6	−2.5	−5.6	−10.2	−13.5
4 hours	1.7	3.2	3.2	2.3	0.8	−0.7	−2.2	−4.1	−5.7
2 hours	−0.7	0.0	2.3	3.4	6.1	7.3	8.9	11.7	13.3
1 hour	−0.7	0.4	1.5	2.7	4.9	6.4	7.6	9.4	11.1

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL INTENSITIES AT ROYAL OBSERVATORY USING GUMBEL'S METHOI FROM THOSE OF USING JENKINSON'S MAXIMUM LIKELIHOOD SOLUTION (BASED ON 100–YEAR DATA)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
120 minutes	−1.8	0.8	3.2	6.0	10.1	13.5	16.7	21.2	25.9
60 minutes	−2.6	0.4	3.4	8.4	13.8	18.0	23.8	30.3	36.3
30 minutes	−2.0	0.0	1.6	4.5	9.2	13.5	16.9	22.4	26.7
15 minutes	−1.7	0.7	2.7	5.0	8.8	11.7	15.1	20.1	23.5
10 minutes	1.6	2.6	4.8	8.0	12.2	15.2	19.0	24.3	28.2
5 minutes	3.3	3.9	6.6	10.0	15.2	19.3	24.6	31.0	35.8
2 minutes	0.0	2.3	5.9	9.6	15.9	21.0	26.5	34.3	40.7
60 seconds	−1.4	1.2	4.9	9.8	16.7	22.7	28.6	37.6	44.3
30 seconds	0.0	3.0	7.7	13.1	20.8	27.5	34.7	43.9	50.0
15 seconds	−4.2	−0.7	4.2	9.9	18.0	24.8	31.8	41.2	49.1

% deviation = [RO(Gumbel) − RO(Jenkinson's maximum likelihood)] / RO(Jenkinson's maximum likelihood) x 100%

TABLE 12

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS AT ROYAL OBSERVATORY USING JENKINSON'S 1955 SOLUTION FROM THOSE OF USING JENKINSON'S MAXIMUM LIKELIHOOD SOLUTION (BASED ON 100–YEAR DATA)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
31 days	0.0	−0.2	−0.5	−0.8	−1.1	−1.2	−1.4	−1.7	−1.9
15 days	0.0	−0.3	−0.3	−0.4	−0.3	−0.4	−0.5	−0.4	−0.5
7 days	0.0	0.0	−0.2	−0.5	−0.8	−1.1	−1.4	−1.8	−2.1
5 days	0.3	0.2	0.0	−0.3	−0.7	−1.0	−1.4	−1.7	−2.1
4 days	0.3	0.2	0.0	0.0	−0.4	−0.8	−1.1	−1.4	−1.8
3 days	0.0	−0.3	−0.2	−0.2	−0.2	−0.3	−0.3	−0.2	−0.2
2 days	0.0	0.3	−0.2	−0.4	−0.9	−1.1	−1.4	−1.7	−2.1
24 hours	0.0	0.3	0.0	−0.2	−0.4	−0.9	−1.1	−1.7	−2.0
18 hours	1.0	0.8	0.0	−0.8	−2.4	−3.7	−5.0	−6.6	−8.1
12 hours	0.6	0.9	1.1	0.9	0.5	0.4	−0.2	−0.5	−0.9
8 hours	0.0	0.0	−0.4	−0.3	−1.1	−1.5	−1.7	−2.3	−2.8
6 hours	0.0	0.0	−0.5	0.4	0.6	0.8	1.2	1.7	2.2
4 hours	0.0	0.0	−0.5	−0.9	−1.2	−1.7	−2.2	−2.5	−2.7
2 hours	0.6	0.0	0.8	0.0	0.0	−1.1	−1.6	−1.9	−2.8
1 hour	0.4	0.3	0.0	−0.2	0.0	−0.9	−1.7	−2.3	−2.2

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL INTENSITIES AT ROYAL OBSERVATORY USING JENKINSON'S 1955 SOLUTION FROM THOSE OF USING JENKINSON'S MAXIMUM LIKELIHOOD SOLUTION (BASED ON 100–YEAR DATA)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
120 minutes	0.4	0.3	0.0	−0.3	−0.7	−1.2	−1.4	−1.9	−1.9
60 minutes	−0.1	0.3	0.4	1.9	1.7	1.6	2.4	2.3	3.0
30 minutes	−0.3	0.9	0.8	1.5	2.1	3.4	3.9	5.0	6.1
15 minutes	0.0	0.0	0.0	−0.6	−1.2	−1.7	−2.2	−2.1	−2.5
10 minutes	−0.8	−1.3	−2.4	−2.3	−3.2	−4.0	−4.4	−5.1	−5.5
5 minutes	−0.7	−2.2	−3.0	−3.3	−4.0	−4.3	−4.6	−4.8	−5.5
2 minutes	−1.6	−1.8	−1.7	−2.0	−2.3	−2.6	−2.9	−2.8	−2.8
60 seconds	−1.4	−1.2	−1.1	−1.1	−1.0	−1.0	−1.0	−1.0	−1.0
30 seconds	−0.4	0.0	0.3	0.7	1.0	1.3	1.6	1.9	1.5
15 seconds	0.0	0.0	0.3	0.9	1.2	1.5	1.5	1.4	1.7

% deviation = [RO(Jenkinson's 1955 solution) − RO(Jenkinson's maximum likelihood)] / RO(Jenkinson's maximum likelihood) x 100%

TABLE 13(a)

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS AT YUEN LONG (1980-1990) FROM THOSE AT ROYAL OBSERVATORY (1980-1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
31 days	-13.1	-7.0	-4.3	-2.2	0.0	1.3	2.3	3.5	4.3
15 days	-13.6	-5.3	-2.0	0.1	2.4	3.6	4.7	5.9	6.5
7 days	-9.7	-1.5	1.6	3.7	5.8	6.7	7.7	8.6	9.2
5 days	-7.6	2.1	5.4	8.0	10.0	11.2	12.3	13.3	14.0
4 days	-8.5	2.4	6.2	8.8	11.2	12.5	13.6	14.8	15.4
3 days	-7.9	3.8	7.8	10.8	13.3	14.8	15.9	17.2	17.9
2 days	-8.1	5.7	10.6	14.0	17.2	18.7	20.3	21.7	22.6
24 hours *	-11.6	5.0	11.1	15.3	19.3	21.4	23.0	25.1	26.1
18 hours *	-11.5	6.5	13.0	17.4	21.6	24.1	26.2	27.9	29.5
12 hours *	-17.0	2.3	9.6	14.8	19.6	22.4	24.5	26.9	28.3
8 hours *	-15.6	1.8	8.9	13.8	18.6	21.2	23.3	25.7	27.0
6 hours	-15.4	0.5	7.4	11.8	16.3	18.8	21.3	23.6	25.0
4 hours	-18.9	-6.8	-1.9	1.7	5.5	7.3	9.1	10.7	12.2
2 hours	-24.7	-20.3	-18.2	-16.3	-15.2	-14.4	-13.2	-12.7	-11.9
1 hour	-24.8	-20.7	-18.9	-17.4	-16.3	-15.4	-14.9	-13.5	-13.3

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL INTENSITIES AT YUEN LONG (1980-1990) FROM THOSE AT ROYAL OBSERVATORY (1980-1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
120 minutes	-23.7	-16.9	-14.0	-11.8	-9.5	-8.2	-6.9	-5.5	-5.1
60 minutes	-31.4	-26.6	-24.1	-22.8	-20.6	-19.7	-19.0	-17.9	-17.3
30 minutes	-27.4	-26.7	-26.1	-25.7	-25.7	-25.4	-25.1	-24.9	-24.7
15 minutes	-20.2	-23.0	-24.6	-25.4	-26.4	-27.4	-27.9	-28.5	-28.9

% deviation = (YL-RO) / RO x 100%

TABLE 13(b)

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS AT YUEN LONG (1980-1988,1990) FROM THOSE AT ROYAL OBSERVATORY (1980-1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
24 hours *	-11.1	-2.2	1.0	3.6	5.6	6.7	7.7	8.8	9.3
18 hours *	-13.0	-4.8	-1.7	0.5	2.7	3.8	4.8	5.7	6.4
12 hours *	-21.4	-14.6	-12.1	-10.2	-8.2	-7.3	-6.5	-5.6	-5.2
8 hours *	-18.1	-7.1	-3.0	0.3	3.3	4.9	6.5	8.0	8.7

* see text in Section 4.1

TABLE 14

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS AT TAI PO TAU FROM THOSE AT ROYAL OBSERVATORY (1980–1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
31 days	10.2	4.9	2.4	0.6	−1.2	−2.3	−3.2	−4.3	−5.0
15 days	11.0	0.9	−3.2	−6.2	−8.9	−10.6	−11.9	−13.2	−14.1
7 days	14.7	0.8	−4.0	−7.3	−10.4	−12.3	−13.7	−15.2	−16.2
5 days	17.9	3.4	−1.7	−5.1	−8.3	−10.0	−11.4	−13.0	−13.9
4 days	14.9	2.4	−2.1	−5.3	−8.0	−9.7	−10.9	−12.2	−13.1
3 days	12.8	2.3	−1.6	−4.0	−6.4	−7.8	−9.0	−10.0	−10.7
2 days	8.1	0.5	−2.2	−4.2	−5.7	−6.8	−7.6	−8.3	−8.9
24 hours	−2.3	−3.5	−3.9	−4.0	−4.1	−4.4	−4.5	−4.6	−4.7
18 hours	−5.5	−5.1	−4.8	−4.6	−4.5	−4.4	−4.3	−4.3	−4.1
12 hours	−13.7	−10.0	−8.9	−7.7	−6.8	−6.3	−5.9	−5.4	−5.2
8 hours	−17.5	−11.1	−8.5	−6.4	−4.7	−3.9	−2.9	−2.0	−1.7
6 hours	−19.5	−10.7	−7.0	−4.7	−2.1	−0.8	0.5	1.6	2.3
4 hours	−22.0	−11.3	−7.2	−4.2	−1.1	0.3	1.8	3.3	4.6
2 hours	−19.9	−10.9	−8.1	−4.8	−2.1	−0.5	0.9	2.4	3.3
1 hour	−12.8	−8.3	−6.3	−4.6	−3.4	−2.3	−2.1	−0.6	0.0

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL INTENSITIES AT TAI PO TAU FROM THOSE AT ROYAL OBSERVATORY (1980–1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
120 minutes	−20.2	−12.1	−8.5	−5.8	−3.1	−1.9	0.0	1.6	2.2
60 minutes	−20.2	−14.9	−12.0	−10.3	−8.4	−7.0	−5.9	−5.4	−4.5
30 minutes	−17.4	−14.6	−13.8	−12.5	−11.7	−10.8	−10.6	−9.7	−9.1
15 minutes	−12.1	−9.2	−8.2	−6.9	−5.7	−5.2	−4.5	−3.7	−3.5

% deviation = (TPT−RO) / RO x 100%

TABLE 15

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS AT TAI LUNG FARM FROM THOSE AT ROYAL OBSERVATORY (1980−1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
31 days	−1.3	−4.8	−6.4	−7.6	−8.7	−9.5	−10.1	−10.8	−11.2
15 days	−0.2	−6.0	−8.3	−9.9	−11.5	−12.4	−13.2	−14.0	−14.5
7 days	1.6	−6.1	−8.7	−10.6	−12.3	−13.3	−14.1	−15.0	−15.5
5 days	−2.7	−8.9	−11.0	−12.4	−13.8	−14.4	−15.0	−15.7	−16.0
4 days	−5.7	−10.4	−11.8	−13.1	−14.1	−14.7	−15.1	−15.7	−15.9
3 days	−8.3	−11.5	−12.7	−13.1	−13.9	−14.2	−14.6	−14.9	−15.1
2 days	−12.9	−13.2	−13.3	−13.4	−13.4	−13.5	−13.5	−13.5	−13.6
24 hours	−21.3	−16.4	−14.5	−13.1	−11.8	−11.2	−10.8	−10.1	−9.8
18 hours	−22.5	−15.4	−13.0	−11.1	−9.4	−8.4	−7.8	−7.1	−6.4
12 hours	−26.9	−17.2	−13.7	−11.0	−8.6	−7.3	−6.5	−5.2	−4.5
8 hours	−28.1	−18.1	−14.4	−11.6	−9.0	−7.6	−6.3	−5.0	−4.3
6 hours	−30.2	−20.4	−16.5	−13.6	−11.0	−9.7	−8.1	−6.8	−5.9
4 hours	−32.0	−22.6	−18.4	−15.7	−12.8	−11.0	−9.7	−8.5	−7.1
2 hours	−35.5	−29.0	−26.4	−24.1	−22.0	−21.1	−19.8	−18.7	−17.8
1 hour	−24.5	−22.8	−22.1	−21.5	−21.3	−20.8	−20.6	−20.0	−19.9

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL INTENSITIES AT TAI LUNG FARM FROM THOSE AT ROYAL OBSERVATORY (1980−1990)

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
120 minutes	−34.2	−27.3	−24.3	−22.1	−19.7	−18.4	−17.2	−15.6	−15.3
60 minutes	−32.0	−25.5	−22.2	−20.3	−17.6	−16.2	−15.0	−13.7	−12.8
30 minutes	−22.0	−16.3	−15.9	−13.8	−12.3	−11.4	−10.1	−9.2	−8.7
15 minutes	−16.1	−9.2	−5.8	−3.2	−0.5	0.9	2.4	4.1	5.2

% deviation = (TLF−RO) / RO x 100%

TABLE 16

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL DEPTHS USING 11−YEAR DATA FROM THOSE OF USING 100−YEAR DATA FOR VARIOUS RETURN PERIODS AT ROYAL OBSERVATORY

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
31 days	−5.6	−4.8	−4.4	−4.1	−3.9	−3.7	−3.6	−3.4	−3.3
15 days	−12.3	−8.4	−6.6	−5.4	−4.1	−3.4	−2.8	−2.2	−1.7
7 days	−10.4	−3.7	−1.2	0.8	2.6	3.6	4.6	5.4	6.1
5 days	−11.3	−5.0	−2.7	−1.1	0.5	1.5	2.1	3.0	3.4
4 days	−9.4	−3.7	−1.5	0.2	1.6	2.4	3.1	3.9	4.4
3 days	−7.6	−1.7	0.6	2.1	3.6	4.6	5.3	6.0	6.6
2 days	−2.0	1.9	3.7	4.8	5.7	6.5	7.0	7.5	7.8
24 hours	0.0	2.6	4.0	4.4	5.3	5.7	6.1	6.3	6.6
18 hours	2.6	5.8	7.3	8.1	8.9	9.4	9.6	10.2	10.3
12 hours	7.1	8.3	9.0	9.0	9.4	9.6	9.8	9.9	10.0
8 hours	7.4	6.1	5.9	5.1	4.6	4.4	4.2	4.0	3.9
6 hours	10.4	7.3	5.2	4.5	3.5	3.1	2.3	2.1	1.7
4 hours	12.8	9.3	7.3	6.3	5.4	4.9	4.4	4.0	3.4
2 hours	15.9	13.3	12.1	10.7	10.4	10.0	9.7	9.1	8.9
1 hour	12.6	11.7	11.5	11.2	11.2	11.1	11.0	10.7	10.7

PERCENTAGE DEVIATION OF THE EXTREME RAINFALL INTENSITIES USING 11−YEAR DATA FROM THOSE OF USING 100−YEAR DATA FOR VARIOUS RETURN PERIODS AT ROYAL OBSERVATORY

DURATION	RETURN PERIOD (YEARS)								
	2	5	10	20	50	100	200	500	1000
120 minutes	6.8	4.6	3.8	3.1	2.4	1.9	1.8	1.7	0.9
60 minutes	7.4	3.5	2.3	0.6	−0.5	−1.2	−1.8	−2.5	−3.0
30 minutes	9.4	9.8	10.4	10.1	10.3	10.1	10.6	10.2	10.5
15 minutes	9.7	10.9	12.5	13.2	14.0	15.0	15.4	15.9	16.2
15 seconds	5.8	2.6	1.0	−0.3	−1.5	−2.3	−3.1	−4.0	−4.6

% deviation = [RO(11 yrs)−RO(100 yrs)] / RO(100 yrs) x 100%

TABLE 17(a)

CALCULATED VALUES OF PARAMETERS a, b, c AS A FUNCTION OF RETURN PERIOD USING 100-YEAR DATA AT ROYAL OBSERVATORY UNDER DIFFERENT EXTREME DISTRIBUTIONS

Return period	Gumbel			Jenkinson's 1955 solution			Jenkinson's maximum solution		
	a	b	c	a	b	c	a	b	c
2 years	521	4.8	0.50	500	4.5	0.49	507	4.5	0.50
5 years	510	3.7	0.44	482	3.5	0.43	502	3.7	0.44
10 years	518	3.2	0.41	473	3.1	0.40	498	3.4	0.41
20 years	535	2.9	0.40	464	2.8	0.37	492	3.2	0.39
50 years	569	2.7	0.38	446	2.4	0.34	479	2.9	0.36
100 years	590	2.5	0.37	436	2.2	0.32	472	2.8	0.34
200 years	618	2.4	0.36	425	2.0	0.30	455	2.5	0.32
500 years	657	2.3	0.35	408	1.7	0.28	436	2.2	0.29
1000 years	674	2.1	0.34	396	1.5	0.26	429	2.1	0.27

TABLE 17(b)

PEAK INTENSITY I_0 AND CALCULATED VALUES OF PARAMETERS a, b, c AS A FUNCTION OF RETURN PERIOD UNDER GUMBEL DISTRIBUTION

Return period	Yuen Long R.G. Filters *			Tai Po Tau Treatment Works			Tai Lung Farm *			Royal Observatory Headquarters		
	a	b	c	a	b	c	I_0	b	c	a	b	c
2 years	599	9.8	0.57	1383	20.9	0.71	164	17.6	0.75	517	4.0	0.47
5 years	383	3.7	0.41	1034	16.3	0.59	206	17.2	0.68	590	4.2	0.45
10 years	355	2.5	0.36	969	14.5	0.54	234	16.3	0.64	637	4.3	0.44
20 years	348	2.0	0.32	958	13.5	0.51	259	16.7	0.63	685	4.4	0.43
50 years	352	1.8	0.29	957	12.2	0.48	293	16.6	0.60	754	4.6	0.42
100 years	359	1.8	0.27	979	11.7	0.47	316	17.0	0.60	803	4.7	0.42
200 years	370	2.0	0.26	998	11.1	0.45	339	17.6	0.59	853	4.8	0.41
500 years	387	2.5	0.25	1032	10.4	0.44	372	17.5	0.58	917	4.9	0.41
1000 years	402	2.9	0.24	1065	10.1	0.43	395	17.9	0.58	969	5.0	0.41

* see text in Section 4.5

TABLE 18

PERCENTAGE DEVIATION OF THE FITTED RAINFALL INTENSITY (WISNER'S FORMULA) FROM THE GUMBEL AND THE JENKINSON ESTIMATES
(based on 1947–1990 rainfall data at Royal Observatory)

METHOD	DURATION	RETURN PERIOD (YEARS)									MEAN
		2	5	10	20	50	100	200	500	1000	% DEVIATION
Gumbel	4 hours	13.8	12.2	12.9	7.1	9.0	7.8	8.7	9.3	9.7	10.1
	120 minutes	−3.2	−3.4	−1.9	−5.9	−4.2	−5.1	−4.0	−3.0	−3.3	−3.8
	60 minutes	−8.5	−9.3	−8.1	−12.0	−10.6	−11.3	−10.5	−10.1	−10.0	−10.0
	30 minutes	−3.4	−3.1	−1.4	−4.1	−2.4	−3.1	−1.8	−1.2	−0.8	−2.4
	15 minutes	3.6	2.6	3.7	1.0	2.7	2.3	3.3	4.0	3.9	3.0
	10 minutes	5.0	4.0	4.0	1.2	2.2	1.6	2.3	2.6	2.4	2.8
	5 minutes	6.7	4.7	4.1	1.3	1.5	0.7	0.6	0.8	0.3	2.3
	2 minutes	8.0	5.9	5.4	3.4	3.3	2.8	2.7	2.7	2.2	4.0
	60 seconds	4.5	3.7	4.2	2.8	3.0	2.5	2.8	2.8	2.9	3.2
	30 seconds	−3.3	−2.4	−1.6	−2.4	−1.7	−1.5	−0.8	−0.8	−0.4	−1.7
	15 seconds	−6.5	−5.5	−4.4	−5.0	−4.3	−4.1	−3.7	−3.4	−2.9	−4.4
Jenkinson's 1955 solution	4 hours	17.5	15.6	13.0	13.1	8.6	6.0	4.0	−1.9	−3.0	8.1
	120 minutes	−4.6	−3.7	−3.0	0.2	1.0	2.5	4.4	4.3	7.3	0.9
	60 minutes	−10.5	−10.4	−9.9	−8.0	−7.3	−6.2	−4.5	−4.7	−2.4	−7.1
	30 minutes	−5.2	−5.8	−5.9	−4.8	−5.7	−6.2	−6.1	−8.3	−7.7	−6.2
	15 minutes	1.4	1.1	0.4	1.2	−0.1	−0.3	−0.2	−2.4	−2.0	−0.1
	10 minutes	7.0	5.6	5.0	5.0	3.5	3.1	2.9	0.9	0.9	3.8
	5 minutes	10.6	8.5	7.3	6.9	5.0	4.0	3.5	1.5	1.4	5.4
	2 minutes	9.8	7.7	6.3	6.0	4.5	3.9	3.5	1.7	1.4	5.0
	60 seconds	4.8	3.9	3.5	4.1	3.2	2.9	2.6	2.0	2.0	3.2
	30 seconds	−2.5	−1.6	−1.3	−0.2	−0.1	0.1	0.3	0.1	0.5	−0.5
	15 seconds	−10.0	−8.1	−7.1	−6.1	−5.3	−4.9	−4.2	−3.9	−3.3	−5.9
Jenkinson's maximum likelihood solution	4 hours	12.8	13.9	12.0	6.4	3.2	1.0	−2.5	−3.3	−3.3	4.5
	120 minutes	−7.5	−4.2	−2.7	−3.9	−2.3	−0.6	−0.0	4.0	8.5	−0.9
	60 minutes	−13.0	−10.3	−8.8	−8.7	−7.0	−5.3	−3.8	−0.3	4.2	−5.9
	30 minutes	−7.5	−4.6	−3.9	−4.9	−4.1	−2.7	−3.0	−1.1	1.9	−3.3
	15 minutes	−0.2	1.8	2.0	−0.2	−0.8	−0.9	−2.1	−1.5	−0.3	−0.3
	10 minutes	4.8	5.1	4.1	2.2	0.9	0.2	−1.1	−1.4	−0.5	1.6
	5 minutes	8.9	7.1	5.6	3.1	1.6	0.8	−0.5	−0.8	−0.5	2.8
	2 minutes	7.5	6.6	5.7	3.5	2.4	1.8	0.8	0.5	1.1	3.3
	60 seconds	2.9	3.3	3.1	2.2	1.9	1.6	1.2	1.7	2.3	2.3
	30 seconds	−3.1	−1.1	−0.3	−0.5	0.1	0.5	1.0	1.8	2.3	0.1
	15 seconds	−10.2	−7.6	−6.4	−6.3	−5.1	−4.7	−4.0	−3.1	−2.1	−5.5

TABLE 19

PERCENTAGE DEVIATION OF THE FITTED RAINFALL INTENSITY (WISNER'S FORMULA) FROM THE GUMBEL ESTIMATES
(based on 1980 – 1990 rainfall data)

STATION	DURATION	RETURN PERIOD (YEARS)									MEAN % DEVIATION
		2	5	10	20	50	100	200	500	1000	
Yuen Long R.G. Filters	360 minutes	−0.6	−0.6	−1.0	−0.9	−1.1	−0.9	−1.3	−1.2	−1.0	−0.9
	240 minutes	−3.6	−2.7	−2.8	−2.5	−2.6	−2.3	−2.7	−2.6	−2.4	−2.7
	120 minutes	−3.0	−2.3	−2.1	−1.8	−1.8	−1.5	−1.8	−1.6	−1.4	−1.9
	60 minutes	3.9	2.7	2.2	2.1	1.9	2.0	1.7	1.6	1.9	2.2
	30 minutes	2.5	1.4	1.1	1.1	1.0	1.1	0.9	1.0	1.2	1.3
	15 minutes	−1.7	−0.9	−0.9	−0.8	−0.8	−0.6	−0.8	−0.8	−0.7	−0.9
Tai Po Tau Treatment Works	360 minutes	−0.1	1.8	2.6	3.1	4.1	4.4	4.3	5.0	5.2	3.4
	240 minutes	0.3	−1.5	−2.2	−2.8	−2.9	−3.3	−3.7	−3.7	−3.7	−2.6
	120 minutes	−1.2	−2.4	−3.0	−3.5	−3.7	−4.0	−4.5	−4.6	−4.7	−3.5
	60 minutes	−0.5	0.5	0.9	1.0	1.5	1.6	1.4	1.7	1.8	1.1
	30 minutes	1.6	2.9	3.5	3.9	4.6	4.8	4.8	5.3	5.5	4.1
	15 minutes	−1.0	−1.7	−2.0	−2.3	−2.3	−2.5	−2.8	−2.7	−2.7	−2.2
Tai Lung Farm	360 minutes	−7.1	−10.5	−10.8	−13.2	−11.0	−13.8	−12.7	−13.1	−14.2	−11.8
	240 minutes	−3.5	−5.7	−6.0	−7.9	−5.9	−8.4	−7.1	−7.7	−8.6	−6.7
	120 minutes	3.5	4.1	4.2	3.3	5.4	3.5	5.0	4.6	3.9	4.2
	60 minutes	4.5	6.5	6.7	6.4	8.3	7.0	8.3	8.2	7.8	7.1
	30 minutes	−0.3	0.3	3.1	3.4	5.1	4.5	5.6	5.7	5.6	3.6
	15 minutes	−0.6	−2.7	−4.3	−5.4	−5.6	−6.9	−7.0	−7.6	−8.1	−5.3
Royal Observatory Headquarters	120 minutes	3.1	2.0	1.6	1.5	0.6	0.8	0.6	0.4	−0.1	1.2
	60 minutes	−4.4	−2.8	−2.0	−1.3	−1.2	−0.4	−0.2	0.1	0.1	−1.3
	30 minutes	−2.5	−1.9	−1.5	−1.2	−1.2	−0.7	−0.6	−0.6	−0.7	−1.2
	15 minutes	4.0	2.9	2.3	1.9	1.3	1.2	0.9	0.6	0.2	1.7
	15 seconds	−0.5	−0.4	−0.2	−0.1	−0.2	−0.1	0.0	0.0	0.0	−0.2

TABLE 20

COMPARISON OF THE CORRESPONDING PEAK INTENSITY OF STORM PROFILES UNDER DIFFERENT EXTREME DISTRIBUTIONS USING 100-YEAR DATA AT ROYAL OBSERVATORY

RETURN PERIOD (YEARS)	PEAK INTENSITY (mm/hr)			[(a) - (c)]*100% / (c)	[(b) - (c)]*100% / (c)
	(a) Gumbel	(b) Jenkinson's 1955 solution	(c) Jenkinson's maximum likelihood		
2	236	238	240	-1.7 %	-0.8 %
5	286	280	282	1.4 %	-0.7 %
10	320	300	301	6.3 %	-0.3 %
20	351	315	314	11.8 %	0.3 %
50	391	331	328	19.2 %	0.9 %
100	422	339	334	26.3 %	1.5 %
200	451	345	341	32.3 %	1.2 %
500	491	351	348	41.1 %	0.9 %
1000	523	357	350	49.4 %	2.0 %

TABLE 21

PERCENTAGE DEVIATION OF THE CORRESPONDING PEAK INTENSITY OF STORM PROFILES FOR THE 11-YEAR PERIOD FROM THAT FOR THE 100-YEAR PERIOD AT ROYAL OBSERVATORY

RETURN PERIOD (YEARS)	PEAK INTENSITY (mm/hr)		[(a) - (b)]*100% / (b)
	(a) 11-YEAR	(b) 100-YEAR	
2	269	236	14.0 %
5	310	286	8.4 %
10	337	320	5.3 %
20	363	351	3.4 %
50	396	391	1.3 %
100	422	422	0.0 %
200	447	451	-0.9 %
500	480	491	-2.2 %
1000	505	523	-3.4 %

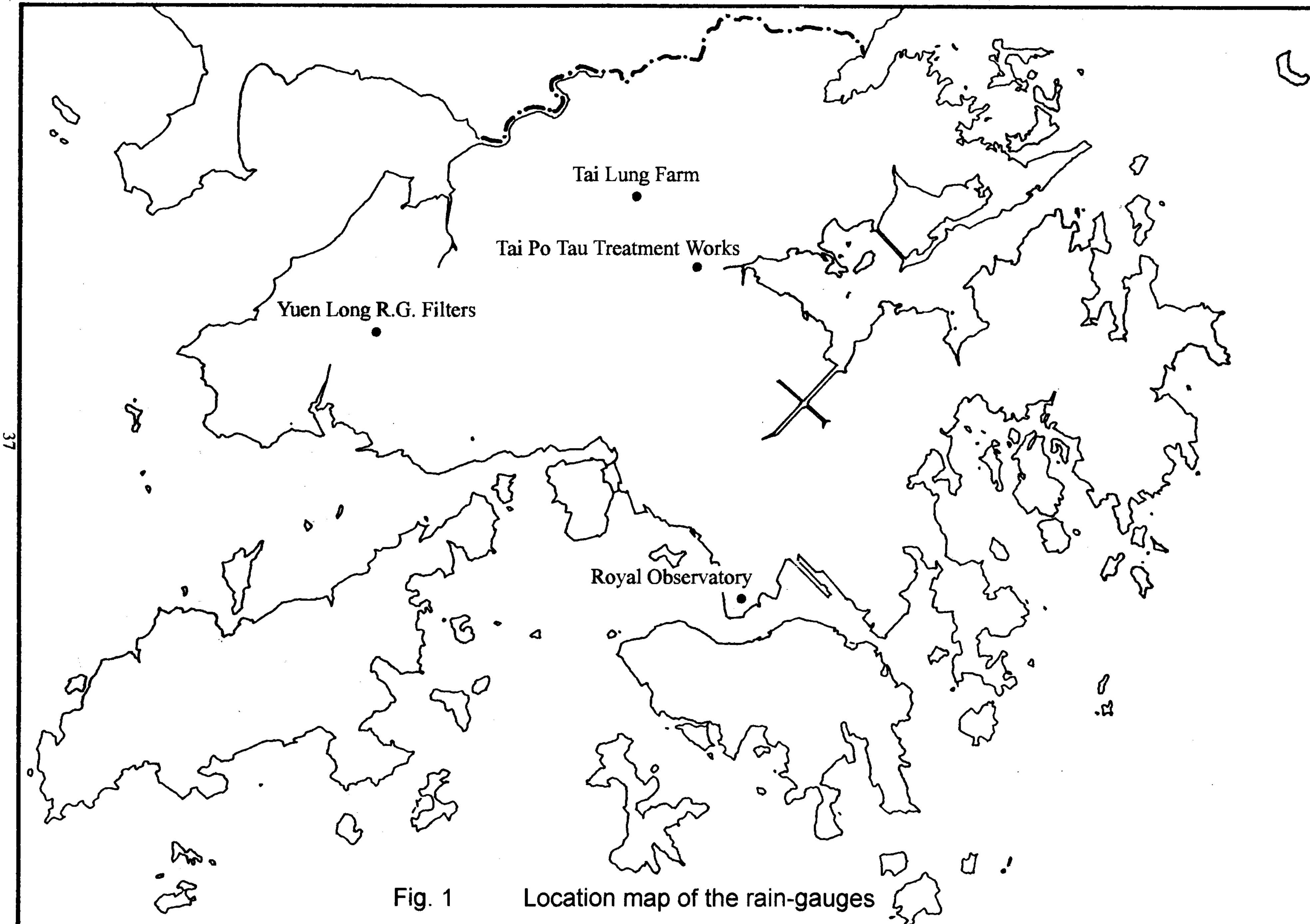


Fig. 1 Location map of the rain-gauges

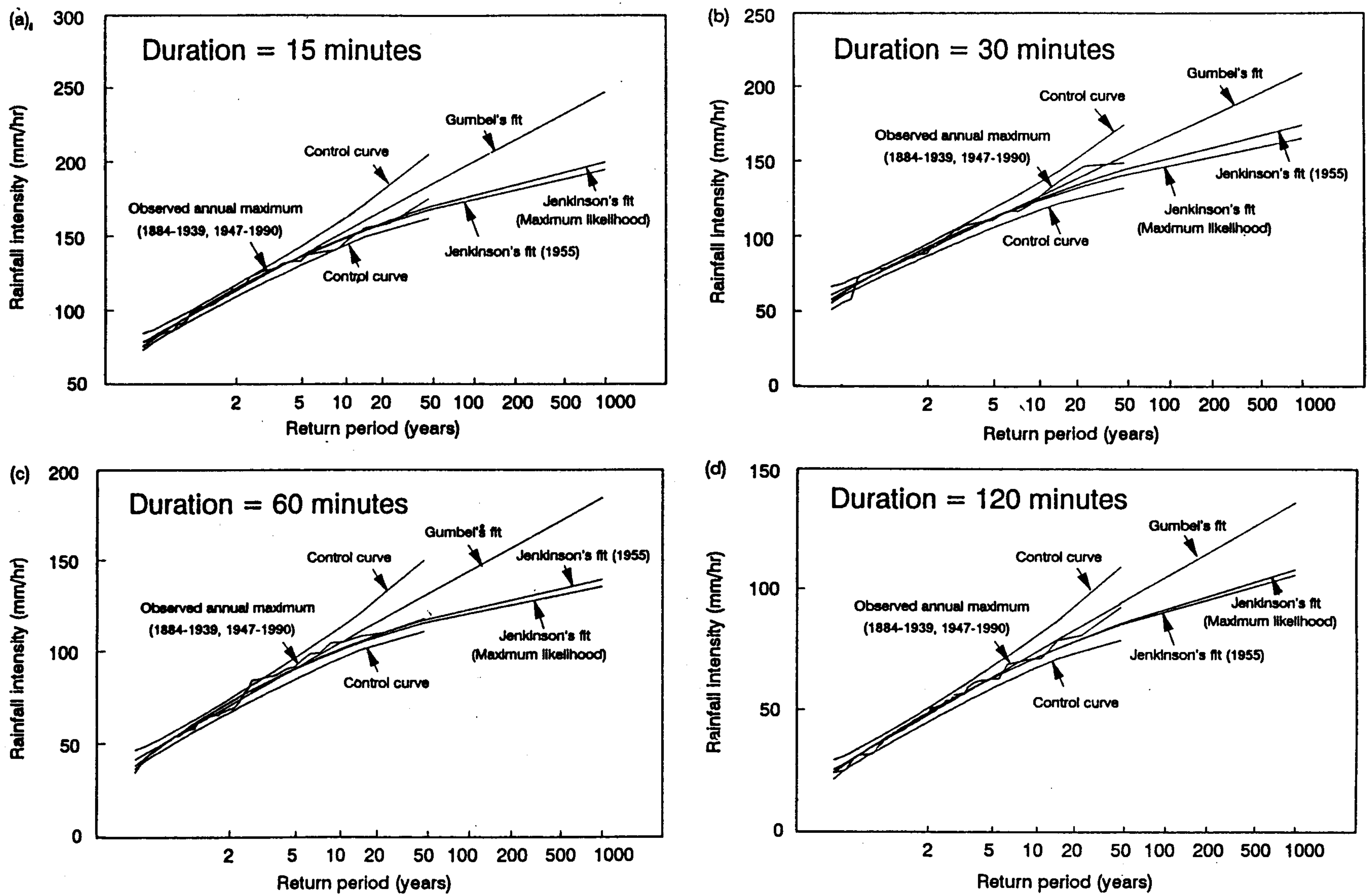


Fig. 2 Annual maxima of rainfall intensity as a function of return period at Royal Observatory using 100-year data

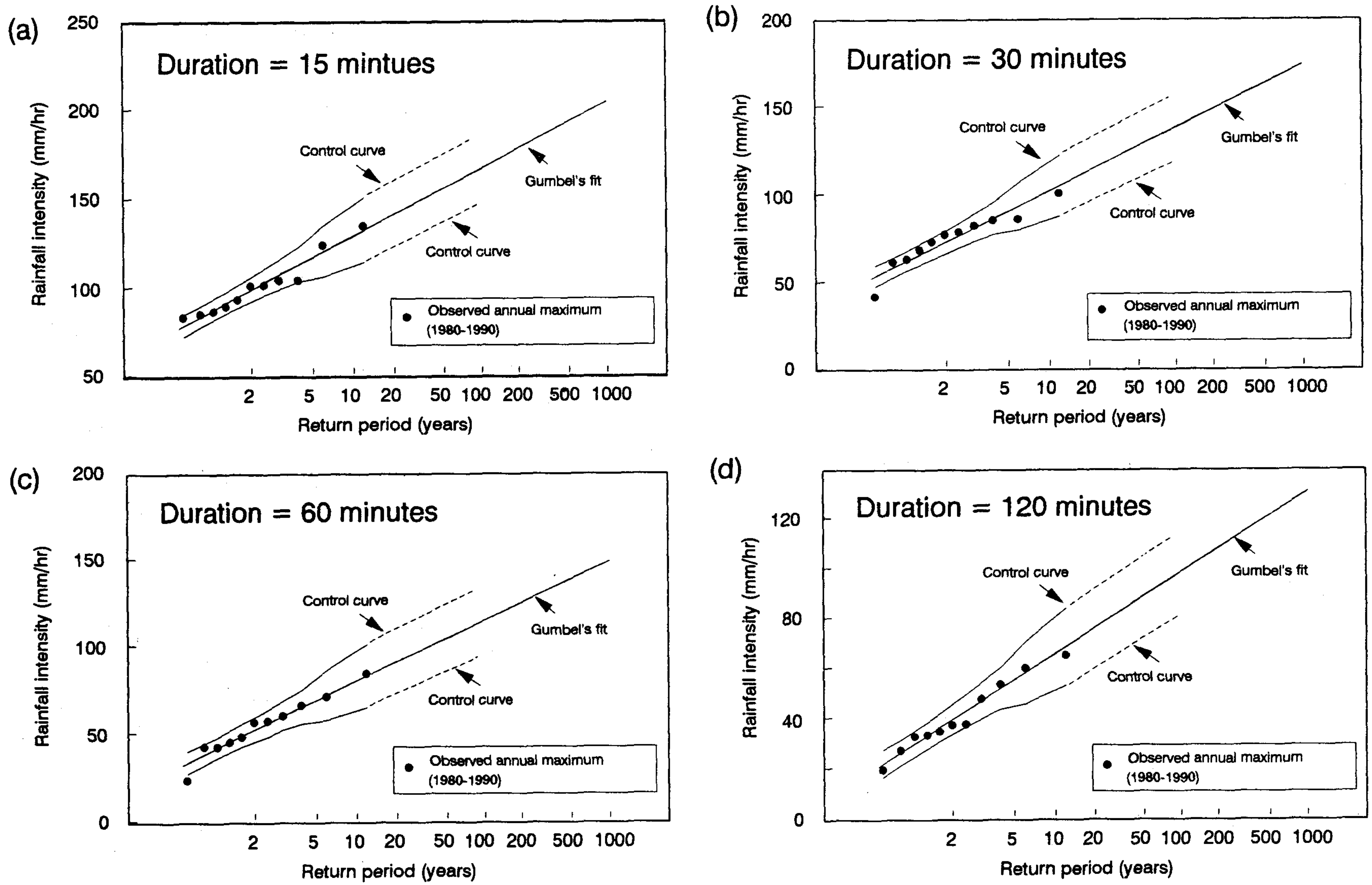


Fig. 3 Annual maxima of rainfall intensity as a function of return period at Yuen Long using 11-year data

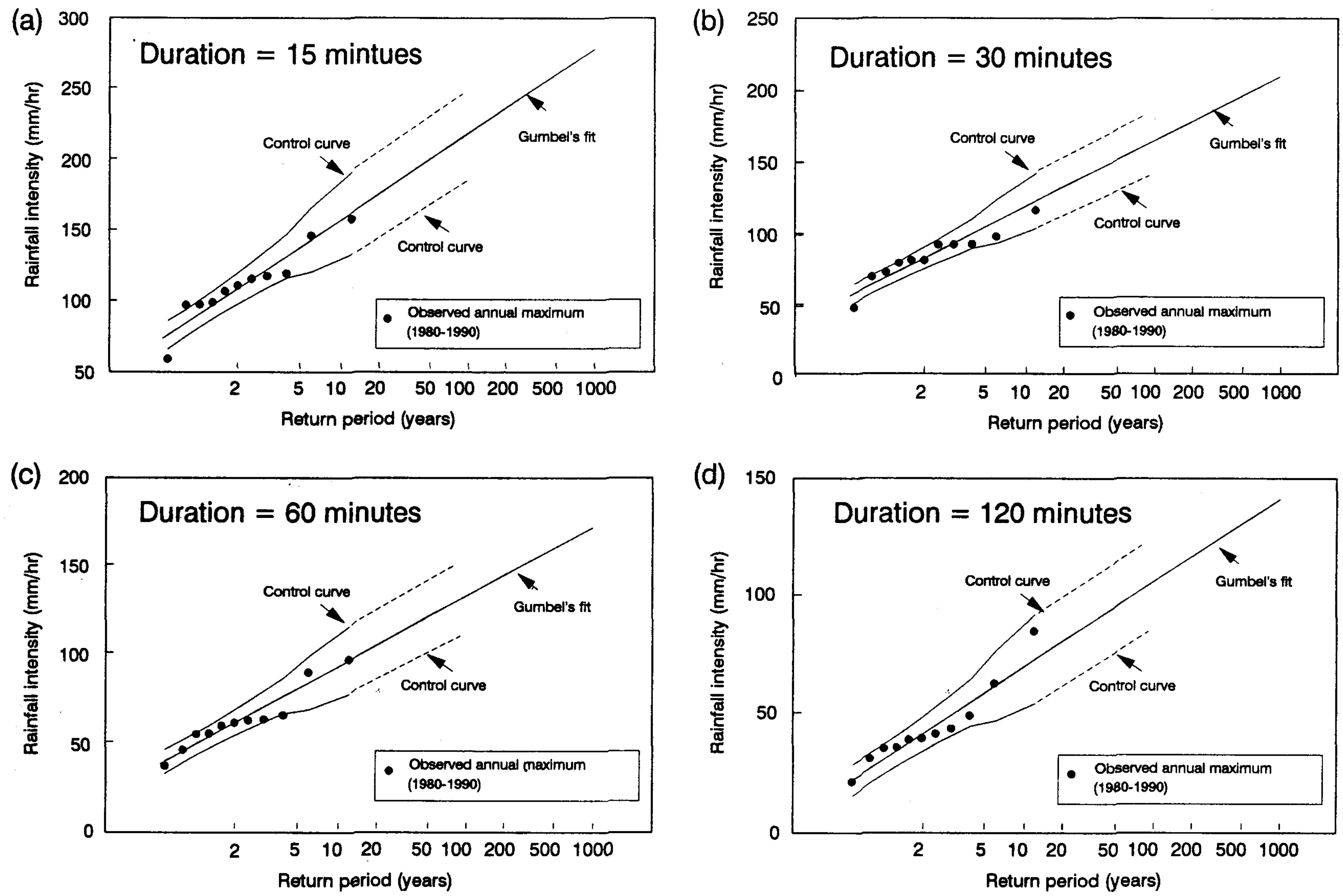


Fig. 4 Annual maxima of rainfall intensity as a function of return period at Tai Po Tau using 11-year data

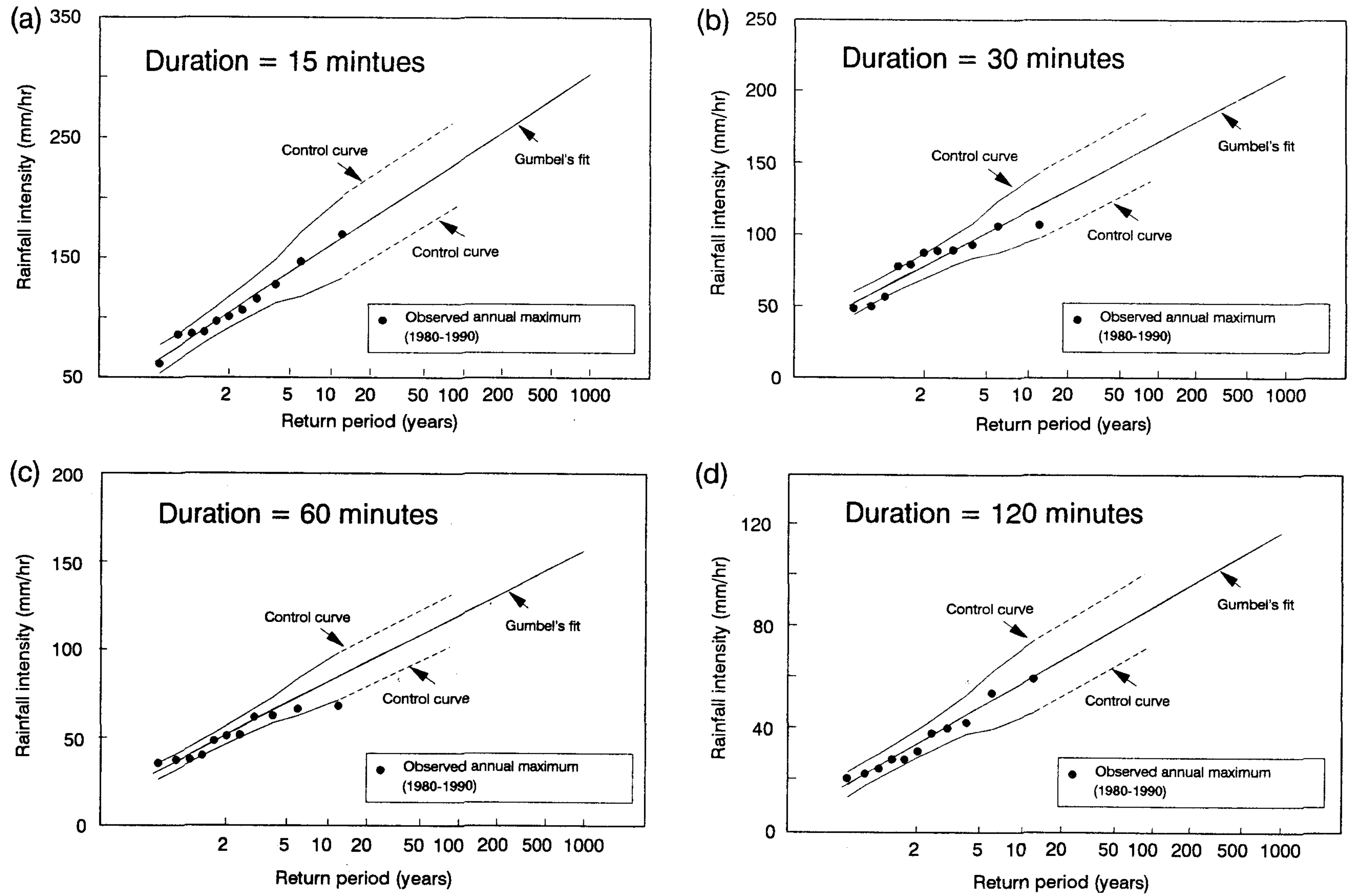


Fig. 5 Annual maxima of rainfall intensity as a function of return period at Tai Lung Farm using 11-year data

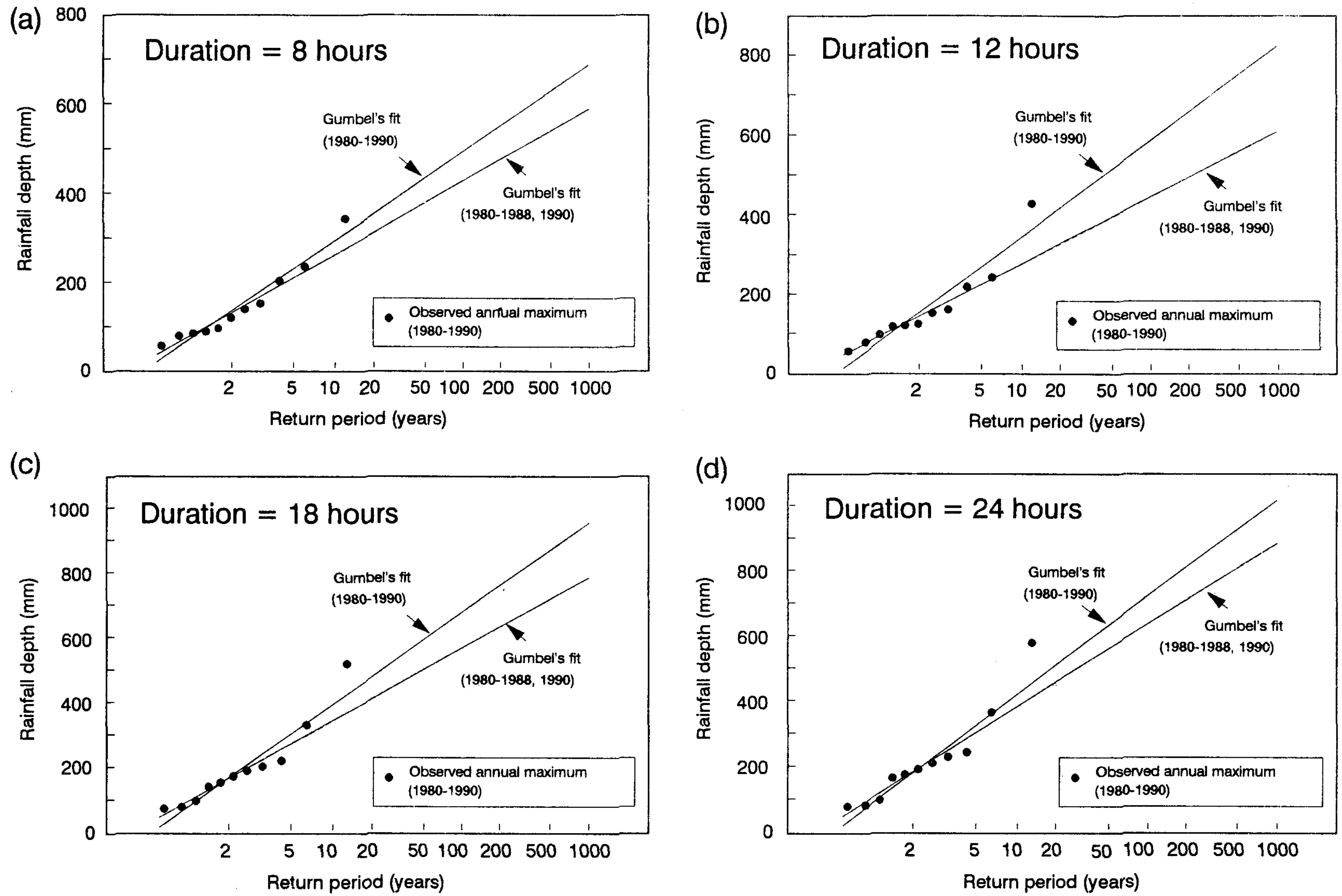


Fig. 6 Annual maxima of rainfall depth as a function of return period at Yuen Long using 11-year data

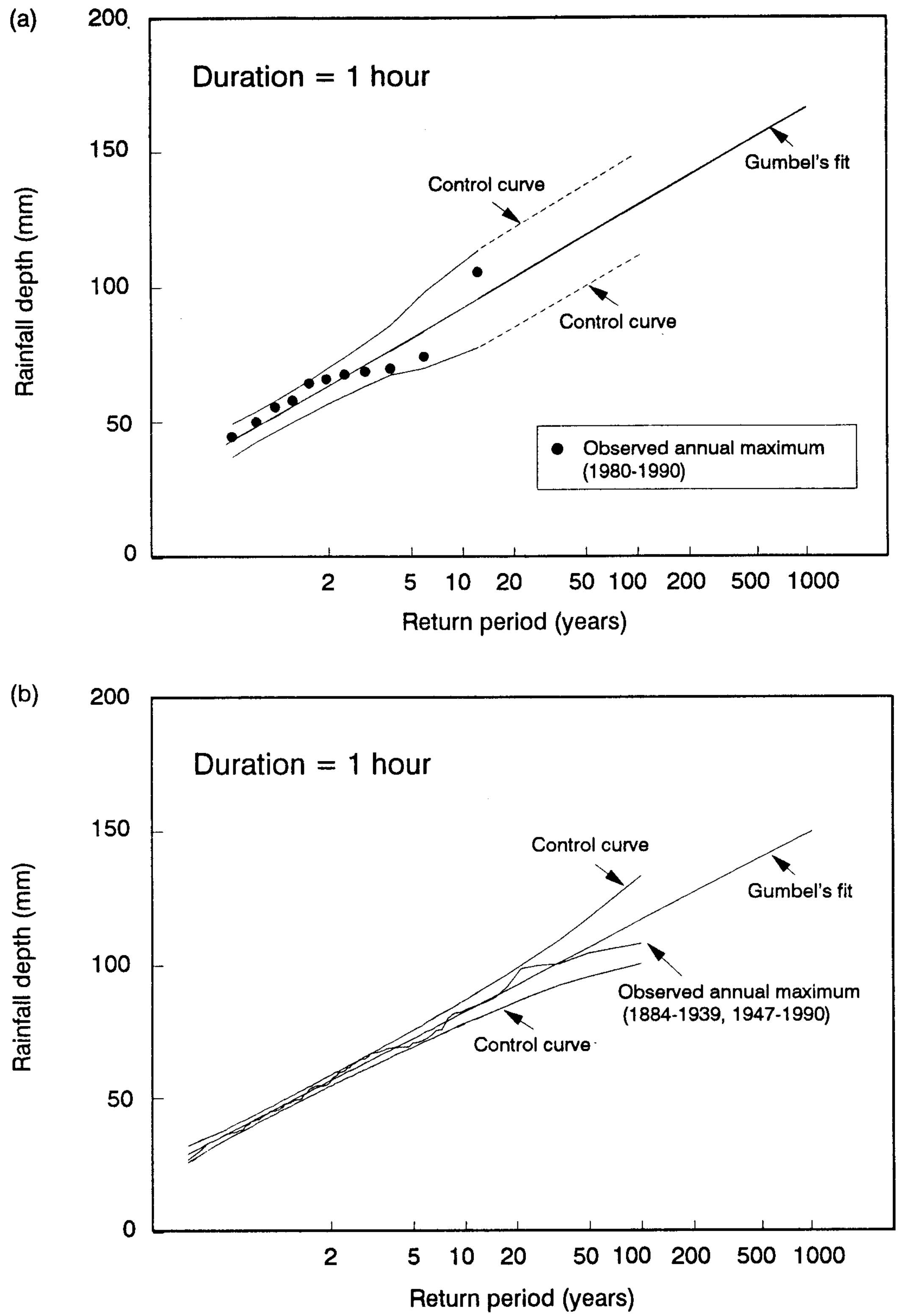
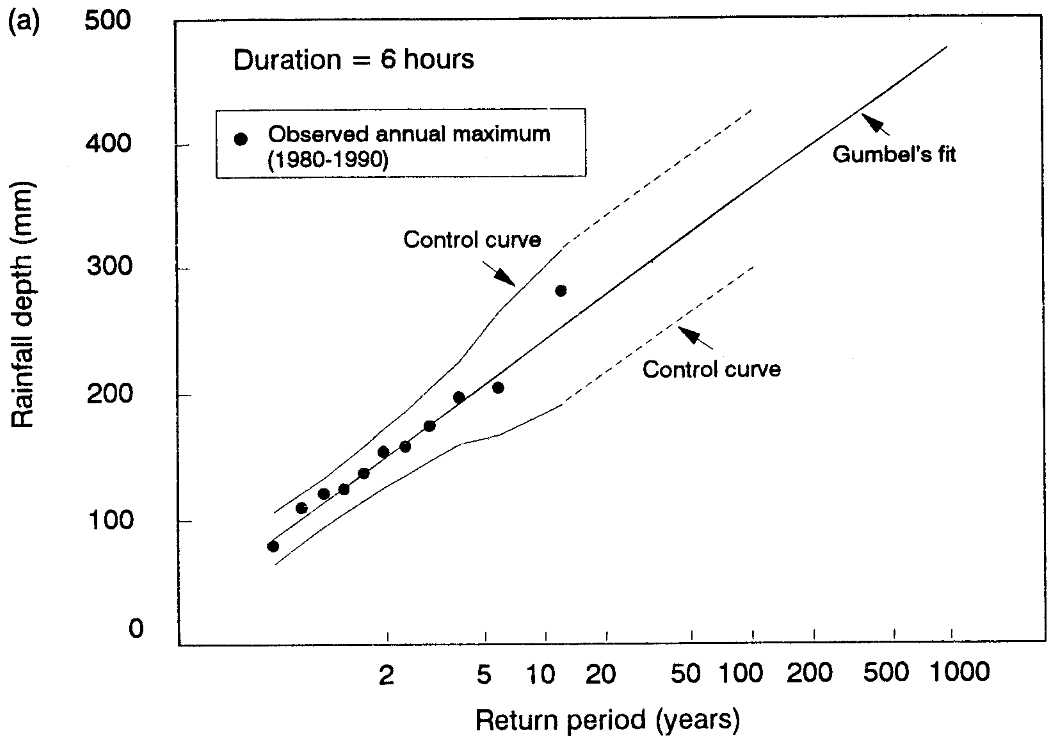


Fig. 7 Annual maxima of 1-hr rainfall depth as a function of return period at Royal Observatory

(a)



(b)

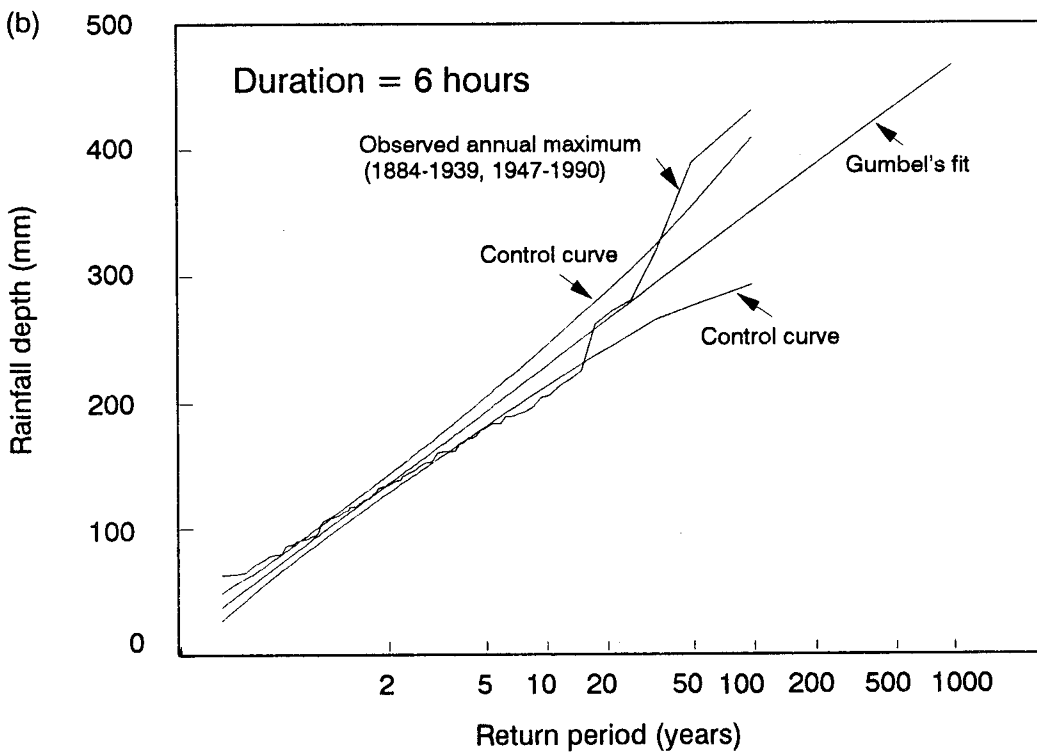
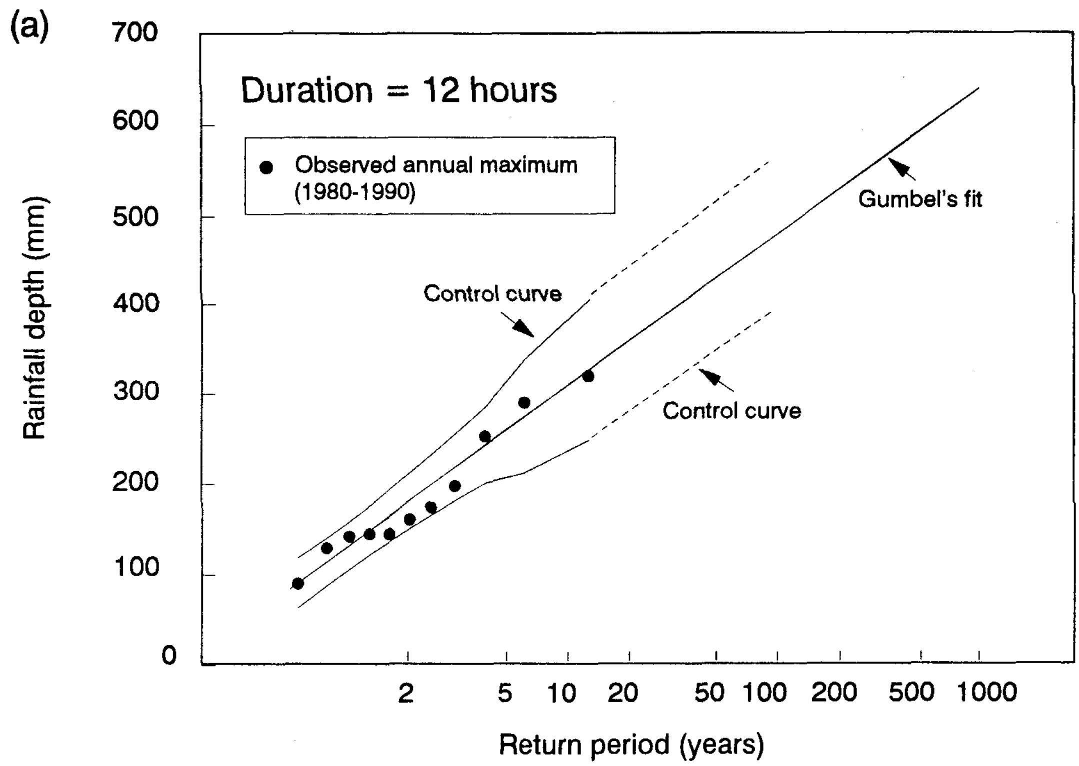


Fig. 8 Annual maxima of 6-hr rainfall depth as a function of return period at Royal Observatory



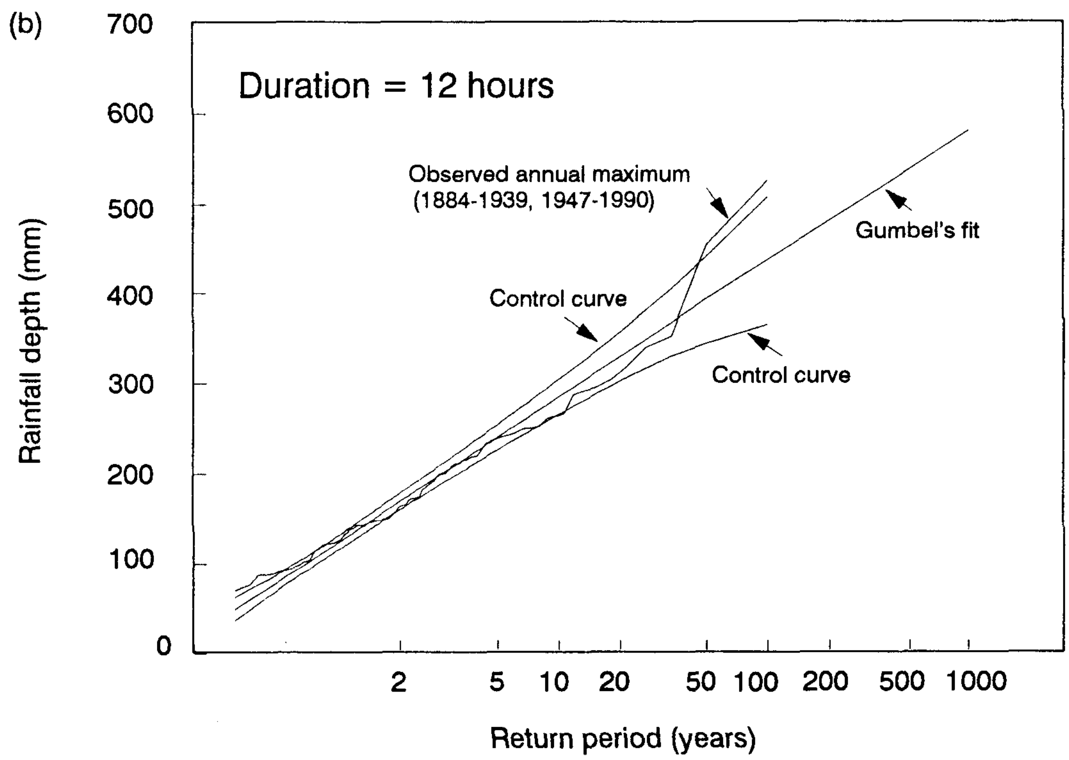


Fig. 9 Annual maxima of 12-hr rainfall depth as a function of return period at Royal Observatory

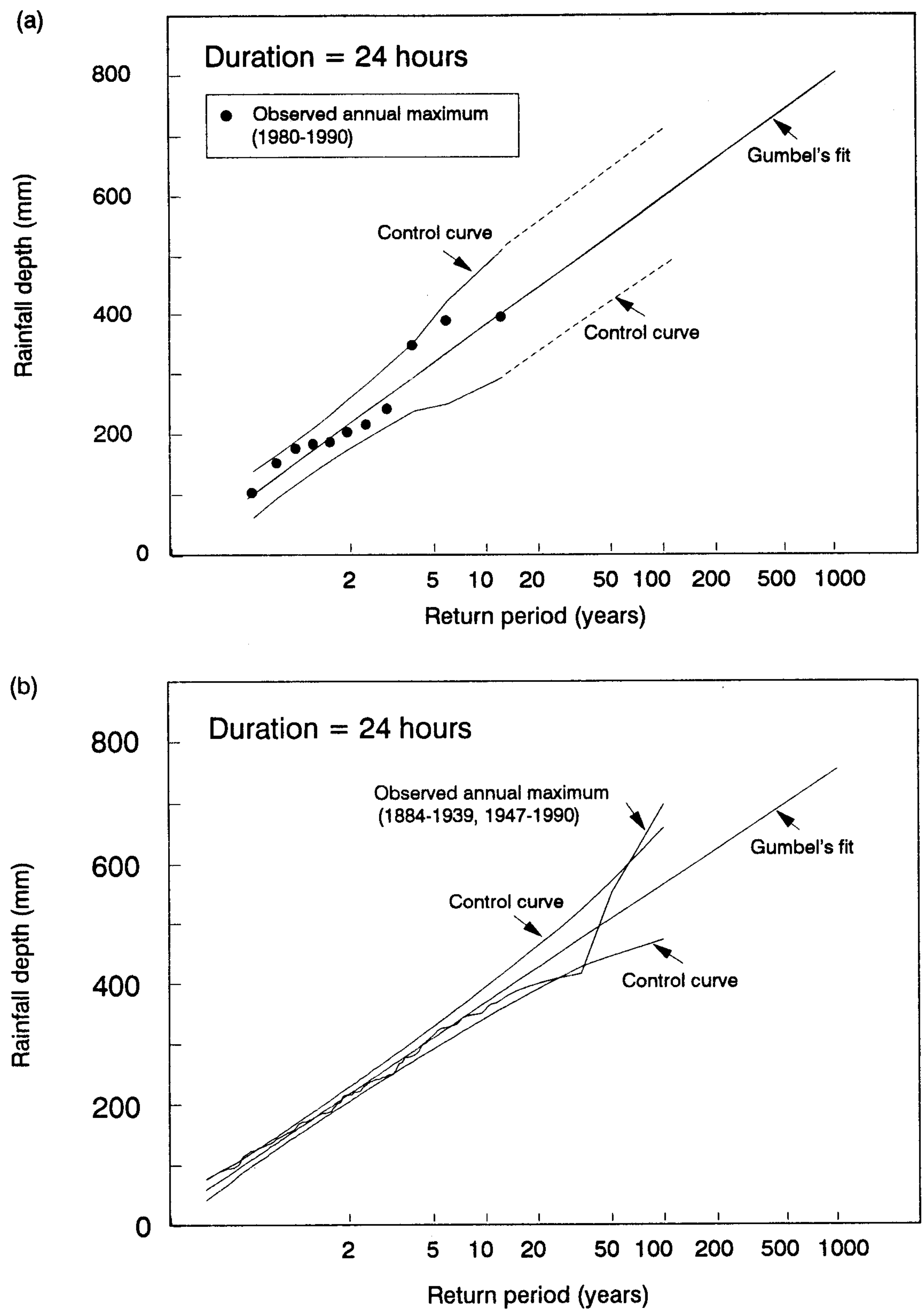


Fig. 10 Annual maxima of 24-hr rainfall depth as a function of return period at Royal Observatory

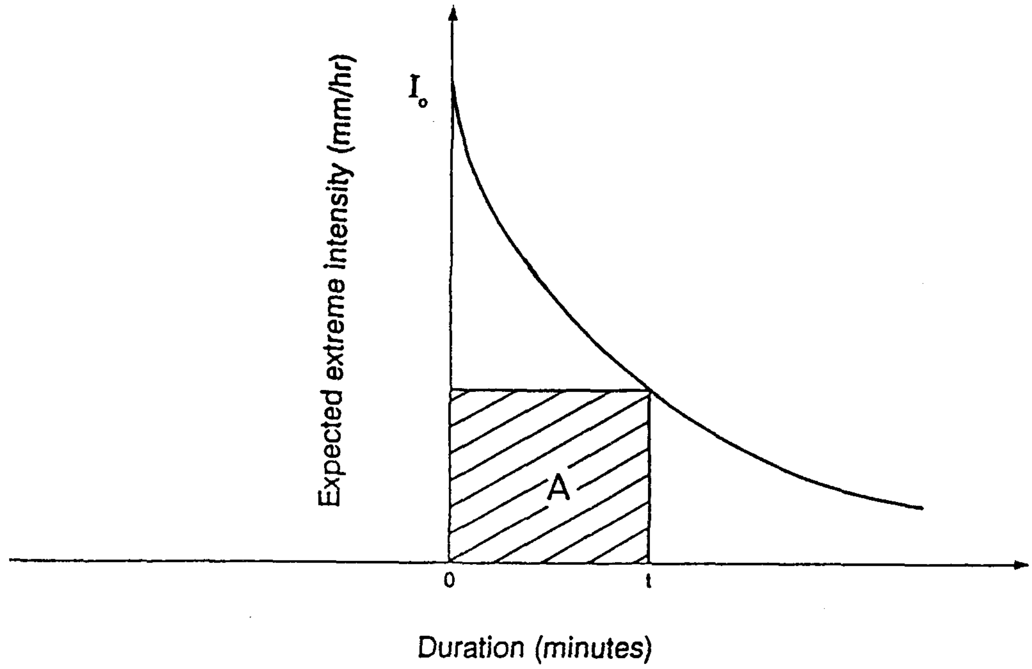


Fig. 11 A typical plot of expected extreme intensity versus duration for a given return period

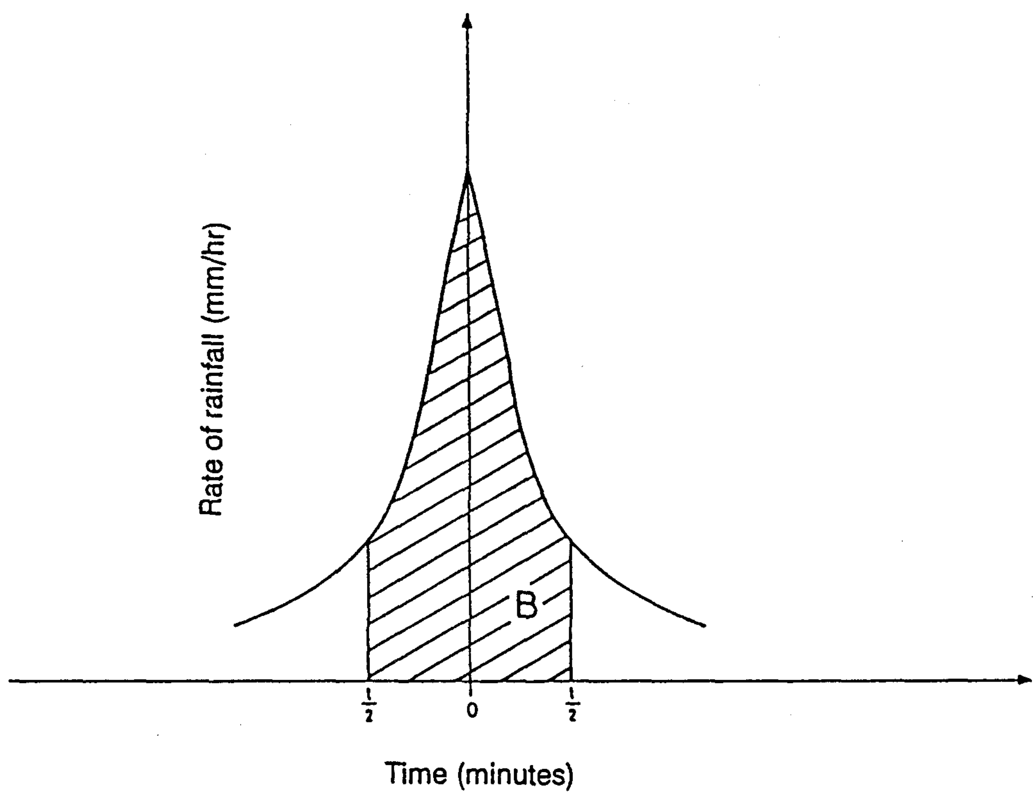
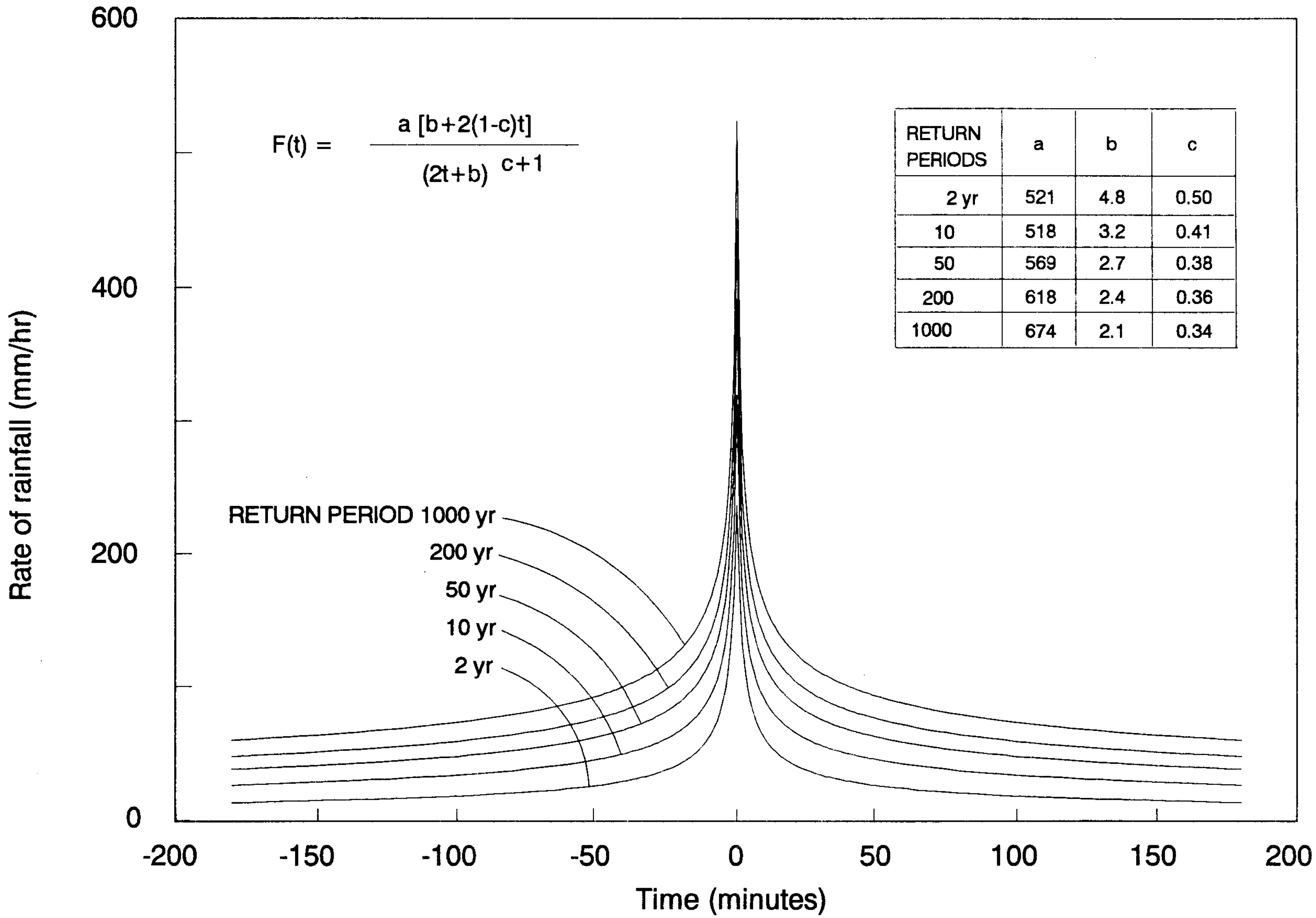


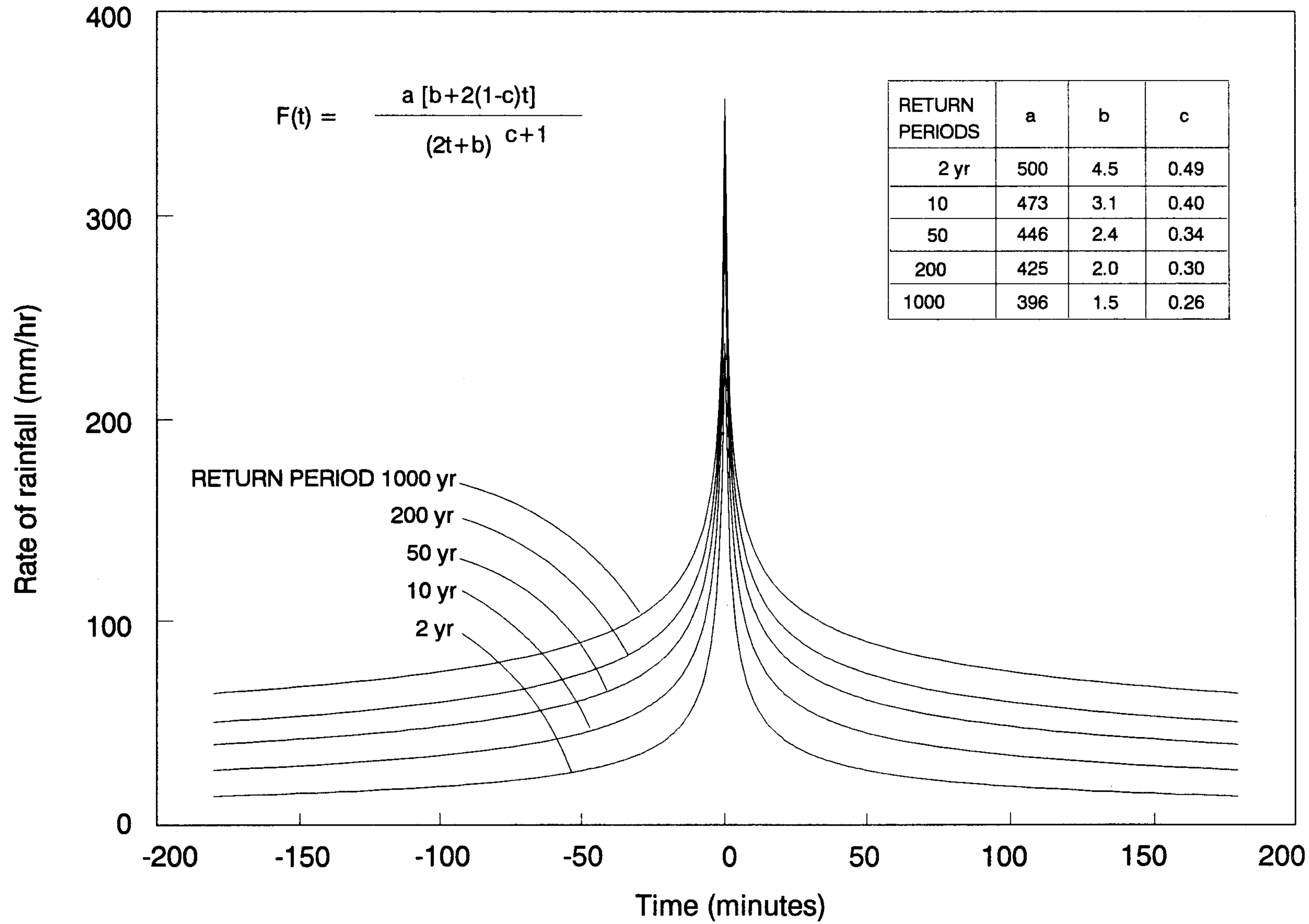
Fig. 12 A schematic diagram showing a design storm profile corresponding to the same return period as in Fig. 11 with the constraint of having shaded area A = area B for any value of t



$$F(t) = \frac{a\,[b+2(1-c)t]}{(2t+b)^{\,c+1}}$$

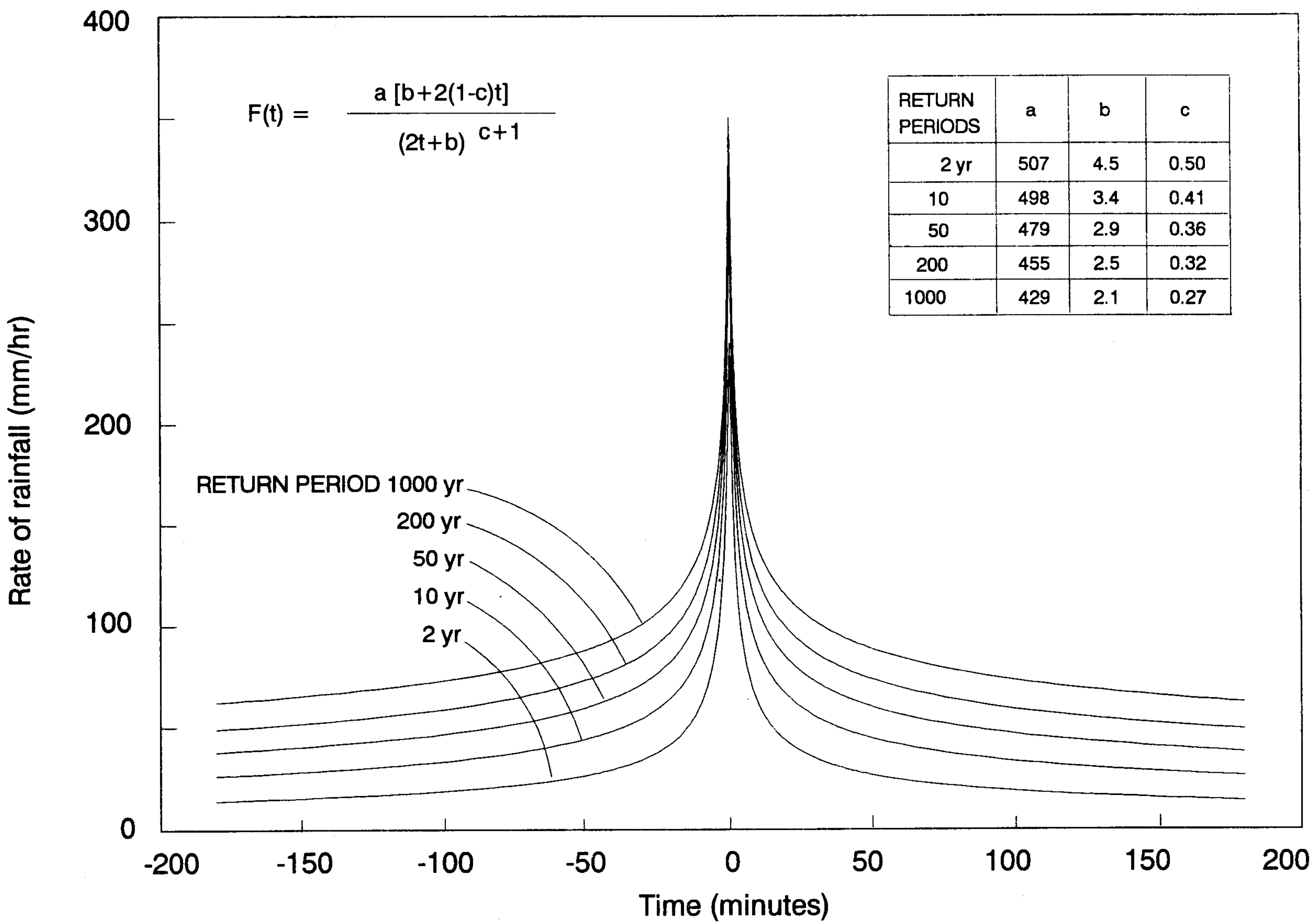
RETURN PERIODS	a	b	c
2 yr	521	4.8	0.50
10	518	3.2	0.41
50	569	2.7	0.38
200	618	2.4	0.36
1000	674	2.1	0.34

Fig. 13(a) Storm profiles for various return periods at Royal Observatory using 100-year data (Gumbel's solution)



RETURN PERIODS	a	b	c
2 yr	500	4.5	0.49
10	473	3.1	0.40
50	446	2.4	0.34
200	425	2.0	0.30
1000	396	1.5	0.26

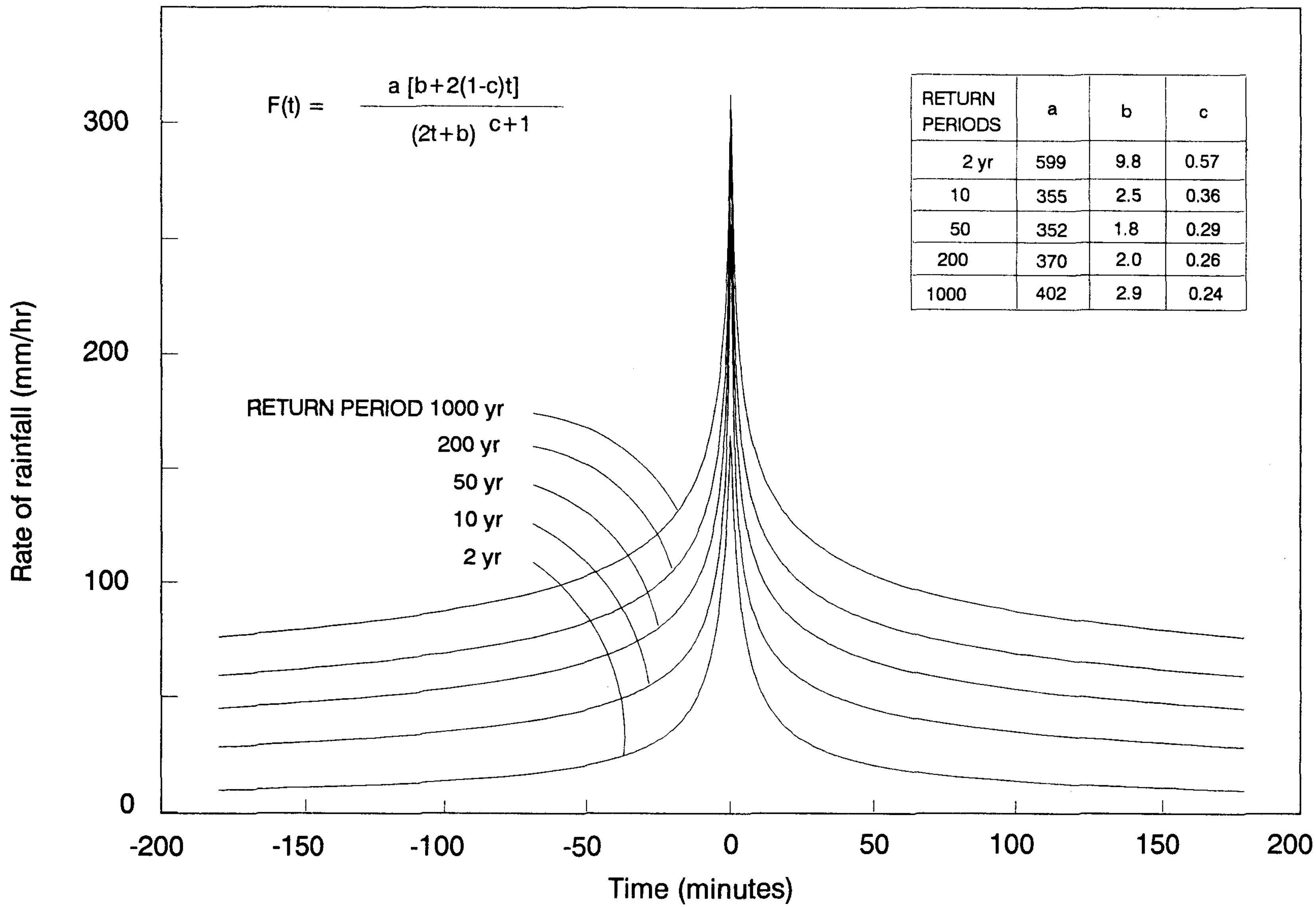
Fig. 13(b) Storm profiles for various return periods at Royal Observatory using 100-year data (Jenkinson's 1955 solution)



$$F(t) = \frac{a\,[b+2(1-c)t]}{(2t+b)^{\,c+1}}$$

RETURN PERIODS	a	b	c
2 yr	507	4.5	0.50
10	498	3.4	0.41
50	479	2.9	0.36
200	455	2.5	0.32
1000	429	2.1	0.27

Fig. 13(c) Storm profiles for various return periods at Royal Observatory using 100-year data (Jenkinson's maximum likelihood solution)



RETURN PERIODS	a	b	c
2 yr	599	9.8	0.57
10	355	2.5	0.36
50	352	1.8	0.29
200	370	2.0	0.26
1000	402	2.9	0.24

Fig. 14 Storm profiles for various return periods at Yuen Long using 11-year data (Gumbel's solution)

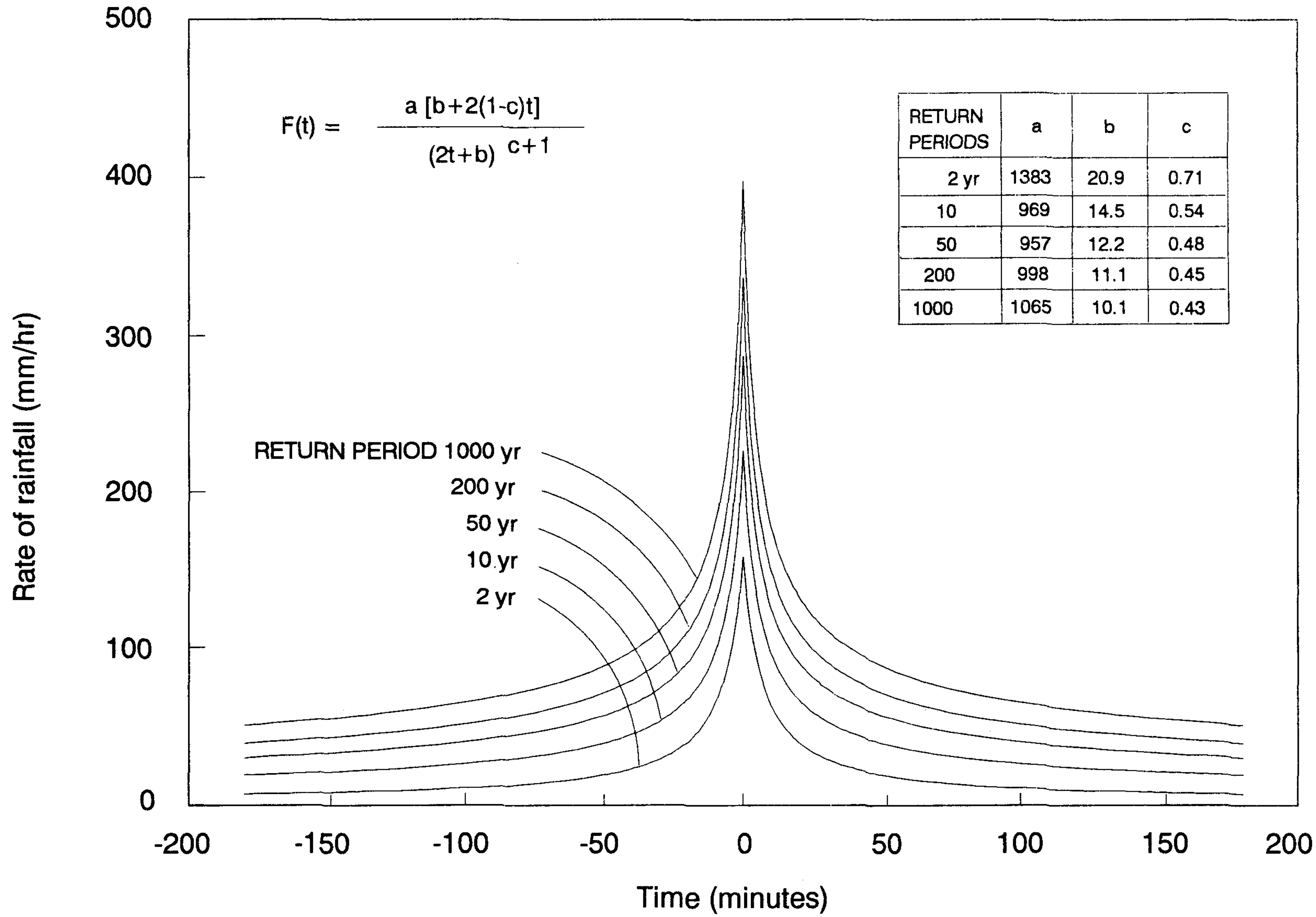
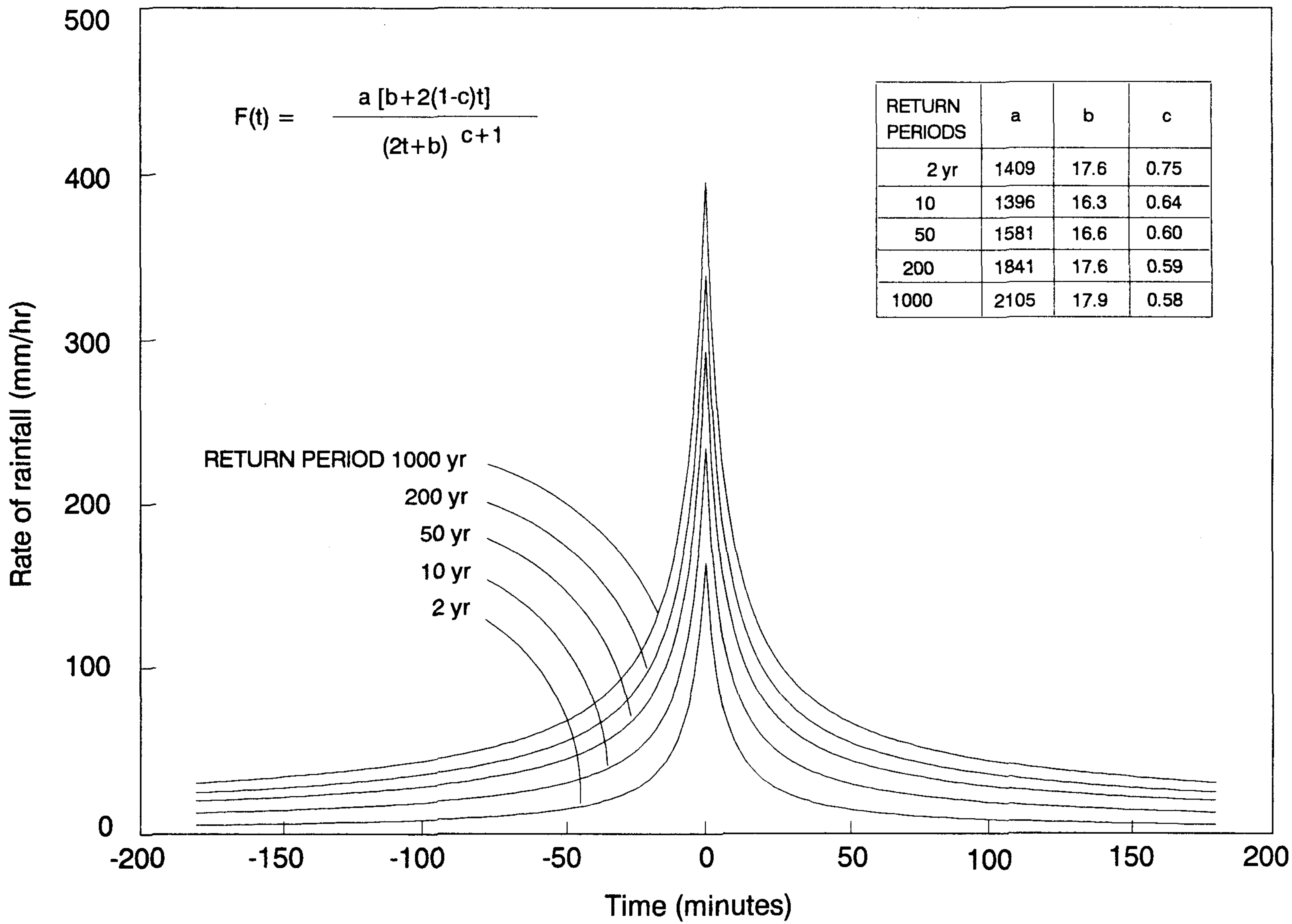


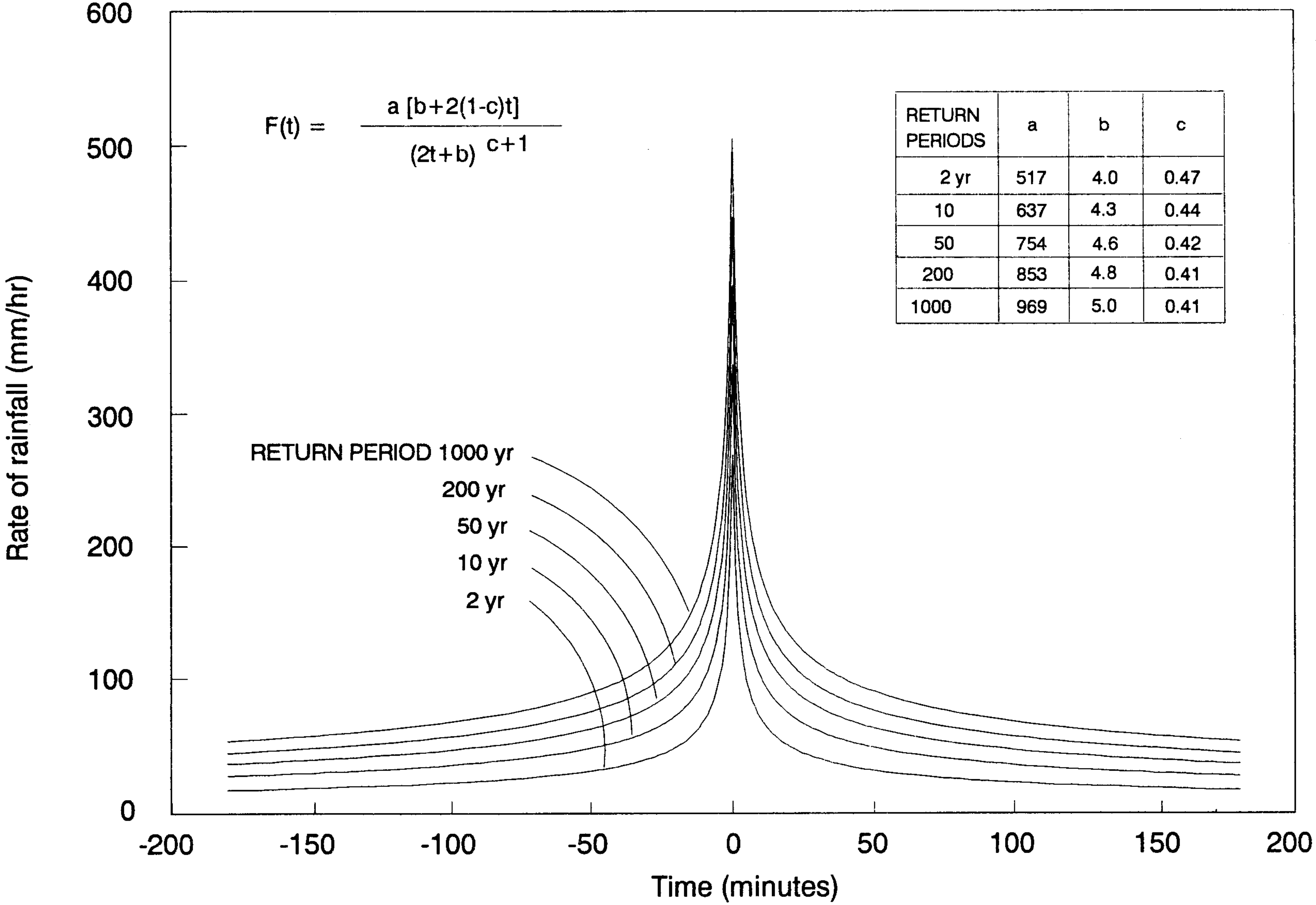
Fig. 15 Storm profiles for various return periods at Tai Po Tau using 11-year data (Gumbel's solution)



$$F(t) = \frac{a\,[b+2(1-c)t]}{(2t+b)^{c+1}}$$

RETURN PERIODS	a	b	c
2 yr	1409	17.6	0.75
10	1396	16.3	0.64
50	1581	16.6	0.60
200	1841	17.6	0.59
1000	2105	17.9	0.58

Fig. 16 Storm profiles for various return periods at Tai Lung Farm using 11-year data (Gumbel's solution)



$$F(t) = \frac{a\,[b+2(1-c)t]}{(2t+b)^{c+1}}$$

RETURN PERIODS	a	b	c
2 yr	517	4.0	0.47
10	637	4.3	0.44
50	754	4.6	0.42
200	853	4.8	0.41
1000	969	5.0	0.41

Fig. 17 Storm profiles for various return periods at Royal Observatory using 11-year data (Gumbel's solution)

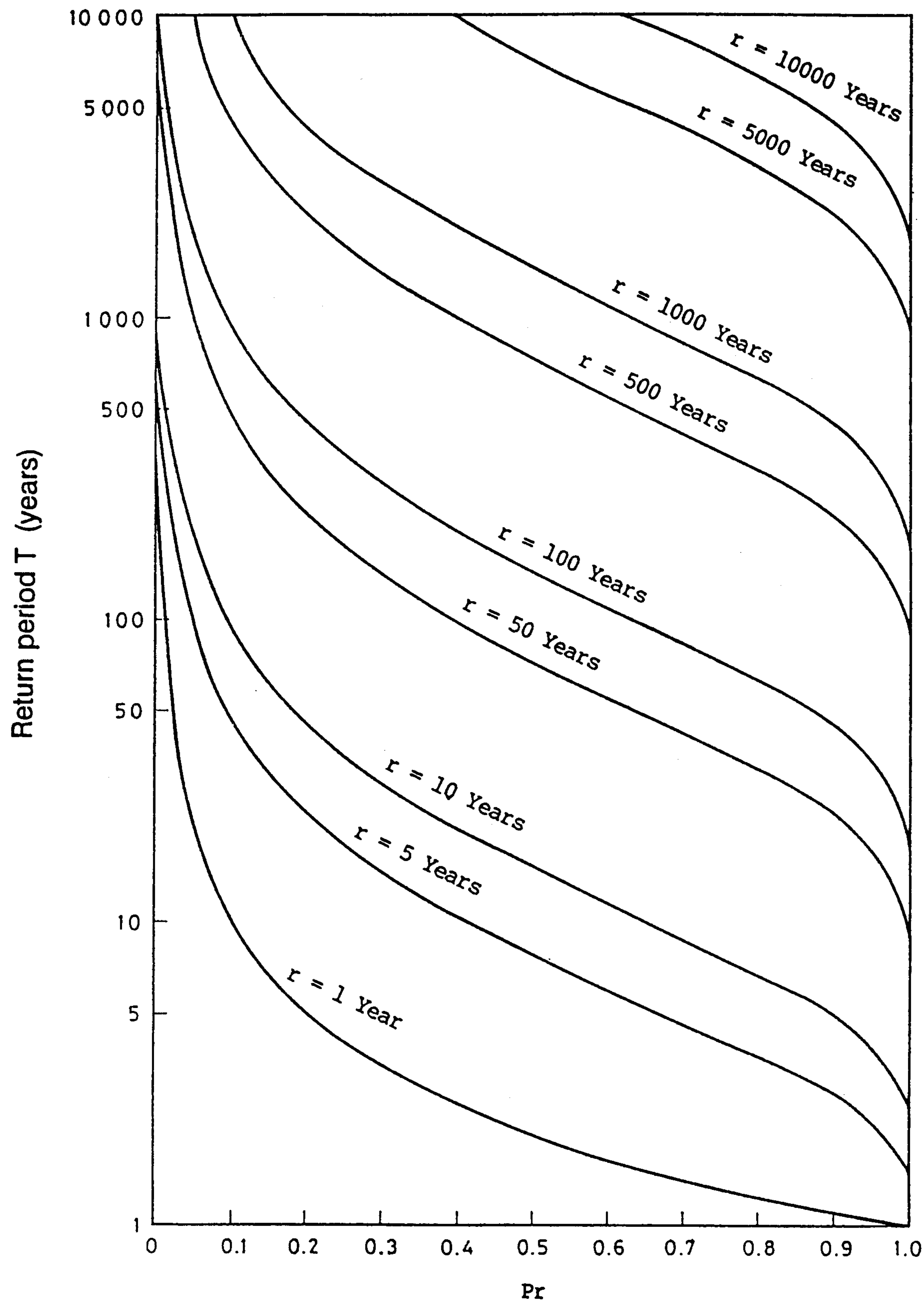


Fig. 18 The probability that a level with a return period T will be reached or exceeded at least once in a period r

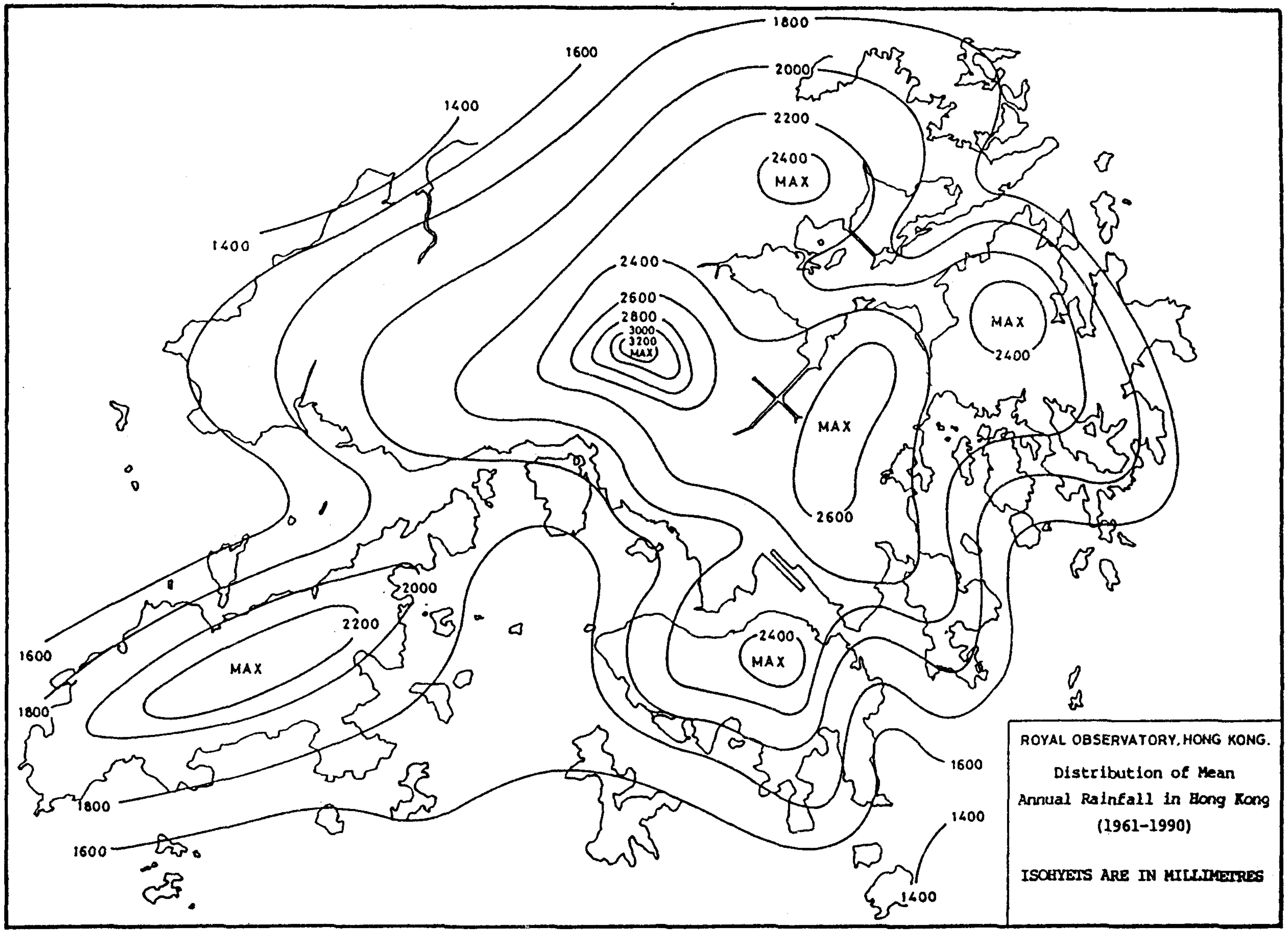


Fig. 19 Mean annual rainfall distribution map of Hong Kong using 30-year data (1961-1990)

APPENDIX 1

Determination of the parameters of Gumbel and Jenkinson distributions

1. Gumbel's solution

Suppose X is the extreme depth or extreme intensity of rainfall,
m is the rank of the observed maximum,
N is the total number of observations.

(i) Calculate the mean $\overline{X}$ and the standard deviation S_X of the observed annual extremes.

(ii) Compute the plotting position $\frac{m}{N+1}$. Then the probability of an event being less than or equal to X is

$$P_X = 1 - \frac{m}{N+1}\ .$$

(iii) Compute the reduced variate $Y = -\ln(-\ln P_X)$ for each P_X.

(iv) Determine the mean $\overline{Y_N}$ and the standard deviation σ_N of Y.

(v) The parameter $\frac{1}{\alpha}$ is then given by $\frac{S_x}{\sigma_N}$ and μ is $\overline{X} - \frac{\overline{Y_N}}{\alpha}$.

2. Jenkinson's 1955 solution

Jenkinson described a simple method for estimating the three parameters by the method of moments in 1955. The steps of finding the parameters are summarized below:

(i) Find the mean ξ_1 and the standard deviation σ_1 of the observed annual maxima.

(ii) Compute the standard deviation σ_2 of the observed biennial maxima. Since the cumulative distribution for biennial maxima is the square of the cumulative distribution for annual maxima, we can simulate biennial maxima from a sample of annual maxima by giving the annual maxima a weight of

$$f' = m^2 - (m-1)^2 = 2m - 1.$$

(iii) The value of k is derived from the equation

$$2^{-k} = \frac{\sigma_2}{\sigma_1} .$$

(iv) Having derived the value of k, α is determined from the formula

$$\alpha = \sigma_1 \frac{k}{[(2k)! - (k!)^2]^{1/2}} .$$

X_0 can then be obtained by substituting values of k and α in

$$X_0 = \xi_1 - \alpha\left(\frac{1 - k!}{k}\right) .$$

The following table is useful for finding the parameters.

k	σ_2 / σ_1	α / σ_1	$\frac{1-k!}{k}$
-0.5	1.414	0.000	1.545
-0.4	1.319	0.260	1.223
-0.3	1.231	0.411	0.993
-0.2	1.149	0.547	0.821
-0.1	1.072	0.670	0.686
0.0	1.000	0.779	0.577
0.1	0.933	0.873	0.487
0.2	0.871	0.951	0.409
0.3	0.812	1.011	0.342
0.4	0.758	1.053	0.282
0.5	0.707	1.079	0.227

For example, suppose σ_1 = 3.39, σ_2 = 2.97 and ξ_1 = 21.0 then σ_2 / σ_1 = 0.876 and therefore $k = -\ln(\sigma_2 / \sigma_1) / \ln 2 = 0.191$. Interpolating from the above table, we have α / σ_1 = 0.944, $(1 - k!) / k = 0.416$. Hence α = 3.39×0.944 = 3.20 and X_0 = 21.0-3.20×0.416 = 19.7.

3. Maximum likelihood solution

The parameters are estimated by making use of a likelihood function L. As a first step, the solution for the two-parameter model $k = 0$, $Y = (X - X_0)/\alpha$ is found. The parameters α, X_0, k for the three-parameter model are then determined from this solution by iteration. The computational routines are summarized as follows:

(a) Two-parameter model

(i) Arrange the annual maxima in ascending order, $X_1, X_2, \ldots, X_N$. Take each observation notionally 4 times and divide the set of $4N$ into quartiles, with means $QM1$, $QM2$, $QM3$, $QM4$. Initial estimates α, X_0 are then taken as

$$X_0 = QM2,$$

$$\alpha = \frac{QM3 - QM1}{1.57}$$

(ii) For each X_i and $Y_i = \dfrac{X_i - X_0}{\alpha}$, $(i = 1, 2, \ldots, N)$, compute

$$P = 1 - \sum_{i=1}^{N} \frac{1}{N} e^{-Y_i}$$

$$R = 1 - \sum_{i=1}^{N} \frac{1}{N} Y_i + \sum_{i=1}^{N} \frac{1}{N} Y_i e^{-Y_i}$$

$$S = \sum_{i=1}^{N} \frac{1}{N} Y_i + \frac{1}{2} \sum_{i=1}^{N} \frac{1}{N} Y_i^2 e^{-Y_i} - \frac{1}{2} \sum_{i=1}^{N} \frac{1}{N} Y_i^2$$

Repeat the above calculations by letting

$$\alpha = (-0.6079R + 0.2570P)\alpha + \alpha$$

and

$$X_0 = (-0.2570R + 1.1087P)\alpha + X_0$$

Stop the iterations when $|P|$ and $|R|$ both < 0.0025. In case of $P = R = 0$, the two-parameter solution will be the maximum likelihood solution.

(b) Three-parameter model

(i) Take the final values of α, X_0, S in the two-parameter solution, then the initial values of α, X_0, k for the three-parameter model are taken as

$$\alpha = \alpha + 0.147\alpha S$$
$$X_0 = X_0 + 0.258\alpha S$$
$$k = 0.477S$$

(ii) If $|k| < 0.0025$, accept the two parameter solution as the maximum likelihood solution. Otherwise, using the values of step (i) and compute

$$G_i = \frac{\alpha}{k\left[\left(X_0 + \frac{\alpha}{k}\right) - X_i\right]} \qquad i = 1,2,\dots,N$$

$$Y_i = \frac{1}{k}\ln G_i \qquad i = 1,2,\dots,N$$

$$P = 1 - \sum_{i=1}^{N}\frac{1}{N}e^{-Y_i}$$

$$Q = \sum_{i=1}^{N}\frac{1}{N}G_i e^{-Y_i} - (1-k)\sum_{i=1}^{N}\frac{1}{N}G_i$$

$$R = 1 - \sum_{i=1}^{N}\frac{1}{N}Y_i + \sum_{i=1}^{N}\frac{1}{N}Y_i e^{-Y_i}$$

$$U = \frac{P+Q}{k}$$

$$V = \frac{P+Q}{k^2} - \frac{R}{k}$$

$$-L = \ln|\alpha| + (1-k)\sum_{i=1}^{N}\frac{1}{N}Y_i + \sum_{i=1}^{N}\frac{1}{N}e^{-Y_i}$$

(iii) Make use of the matrix below to estimate α', X_0', k'.

$$\begin{pmatrix} \alpha'/\alpha \\ X_0'/\alpha \\ k' \end{pmatrix} = \begin{pmatrix} a & h & g \\ h & b & f \\ g & f & c \end{pmatrix} \begin{pmatrix} -U \\ -Q \\ V \end{pmatrix}$$

The elements a, b, c, f, g, h can be interpolated to an accuracy of 0.001 in the range of k = -0.6 to 0.6 from the empirical expressions

$$a = 0.6528 - 0.5547k + 1.0634k^2 - 0.0521k^3 - 0.0971k^4$$
$$b = 1.2489 - 0.1943k - 0.2239k^2 + 0.0486k^3 + 0.1136k^4$$
$$c = 0.4768 - 0.7866k + 0.2705k^2$$
$$f = 0.2581 - 0.1359k - 0.2970k^2 + 0.0556k^3 + 0.0947k^4$$
$$g = 0.1470 + 0.4272k - 0.4389k^2 - 0.0868k^3 - 0.0118k^4$$
$$h = 0.3366 - 1.1976k - 0.1193k^2 - 0.0347k^3 - 0.0047k^4$$

(iv) Repeat step (iii) by letting

$$\alpha = \alpha' + \alpha$$
$$X_0 = X_0' + X_0$$
$$k = k' + k$$

Make eight iterations. U, Q, V normally approach zero, and $-L$ approaches a minimum value. The solution α, X_0, k that minimize $-L$ is the maximum likelihood solution. It should be noted that sometimes, especially with small N, there are complexities in the L field, and there is drifting from or oscillation about the required solution. Oscillations are damped by taking the precaution of adding only half the calculated corrections α', X_0', k', when V has changed sign from the previous iteration. Accept the iteration with the smallest value of $-L$.

APPENDIX 2

A list of annual maximum rainfall depths extracted for extreme rainfall statistics

Annual maximum rainfall data for different types of durations were extracted and listed below. Rainfall depths for durations indicated in integral number of hours and days were derived from data starting and ending on clock hours. Rainfall intensity was calculated by dividing the rainfall depth by the time duration, not necessarily starting or ending on clock hours. The duration of instantaneous rainfall records for RO was taken as 15 seconds and there was no instantaneous rainfall data for the outstations.

Station	Year	15-second (mm/hr)	15-minute (mm)	30-minute (mm)	60-minute (mm)	120-minute (mm)	240-minute (mm)	360-minute (mm)	480-minute (mm)
Royal Observatory Headquarters	1947		25.3	50.5	85.0	114.0			
	1948		26.1	46.3	95.1	125.8			
	1949		27.5	37.4	50.9	72.4			
	1950		34.6	43.5	49.2	79.4			
	1951		28.9	38.0	58.0	62.7			
	1952	208	21.4	27.9	46.2	81.3			
	1953	286	39.6	48.6	91.5	112.8			
	1954	152	19.6	25.4	34.1	50.0			
	1955	320	22.6	42.6	67.6	79.3			
	1956	282	21.4	42.8	57.0	64.2			
	1957	233	33.3	52.0	84.6	125.9			
	1958	307	24.9	43.9	64.9	77.5			
	1959	242	27.3	52.2	68.8	102.2			
	1960	172	27.0	41.1	55.7	63.5			
	1961	216	31.6	39.3	54.0	70.0			
	1962	154	22.7	40.6	57.3	83.4			
	1963	226	20.3	28.8	42.5	48.5			
	1964	301	20.9	36.0	68.7	124.0			
	1965	300	33.3	47.5	78.9	86.0			
	1966	281	30.6	58.2	117.8	184.9			
	1967	302	26.5	44.1	65.2	92.1			
	1968	241	32.0	53.5	104.5	141.7			
	1969	202	25.5	37.7	61.5	113.2			
	1970	284	39.0	73.3	110.0	139.6			
	1971	286	34.3	68.5	98.5	137.7			
	1972	347	25.5	49.4	98.7	161.6			
	1973	314	37.0	55.0	77.0	101.3			
	1974	282	28.5	44.4	51.6	89.0			
	1975	270	33.0	64.2	105.0	122.2			
	1976	204	24.5	41.4	70.3	108.2			
	1977	232	31.1	42.3	61.2	63.0			
	1978	206	28.7	48.1	72.4	82.1			
	1979	187	28.5	54.4	89.1	125.0			
	1980	246	30.9	40.7	53.8	58.2			
	1981	314	25.8	39.2	64.7	95.4			
	1982	238	34.9	58.3	84.3	103.1			
	1983	274	32.9	54.8	86.0	157.7			
	1984	232	23.2	39.1	65.1	108.3			
	1985	234	25.6	39.8	67.0	94.9			
	1986	283	31.7	56.9	87.1	118.9			
	1987	239	35.2	60.3	86.2	96.1			
	1988	299	32.2	55.2	64.3	91.6			
	1989	335	43.7	74.2	108.0	142.6			
	1990	244	29.5	53.9	90.5	103.9			

APPENDIX 2 (cont'd)

Station	Year	Duration 15-second (mm/hr)	15-minute (mm)	30-minute (mm)	60-minute (mm)	120-minute (mm)	240-minute (mm)	360-minute (mm)	480-minute (mm)
Yuen Long	1980		25.42	31.73	43.13	67.33	75.75	80.05	80.05
R.G. Filters	1981		21.37	30.92	43.30	70.03	77.57	82.07	85.57
	1982		31.11	50.51	84.87	130.83	208.66	233.16	236.86
	1983		23.39	41.32	57.02	76.00	105.03	127.22	141.32
	1984		26.13	43.23	60.61	75.11	89.81	96.61	97.21
	1985		33.83	39.53	45.72	54.91	65.91	77.51	93.97
	1986		21.73	34.33	48.70	66.30	115.84	121.21	121.21
	1987		26.14	42.83	58.02	96.35	141.40	151.05	154.28
	1988		22.50	36.75	71.42	107.64	143.95	191.78	207.00
	1989		25.48	38.78	66.71	120.88	210.02	290.76	348.23
	1990		20.90	20.90	23.90	39.73	51.56	56.76	56.86
Tai Po Tau	1980		39.57	46.39	65.39	77.97	94.20	99.00	100.11
	1981		36.70	46.20	55.16	87.35	111.51	122.68	123.48
	1982		29.99	58.33	96.77	169.53	225.33	263.43	271.14
	1983		24.87	40.75	61.28	71.28	78.18	91.05	104.85
	1984		27.86	46.26	59.46	79.17	91.37	96.87	96.87
	1985		26.88	34.90	46.06	62.02	75.13	87.05	97.34
	1986		29.03	49.11	89.65	125.41	162.48	174.28	185.08
	1987		24.46	39.66	54.76	70.70	102.77	112.79	126.90
	1988		29.55	40.74	63.06	82.96	140.93	168.68	188.48
	1989		24.41	36.50	62.55	98.17	105.07	143.34	193.54
	1990		14.79	24.10	37.11	42.51	52.91	55.41	58.92
Tai Lung Farm	1980		36.79	53.57	63.17	85.36	110.60	112.60	126.00
	1981		29.00	46.84	49.04	56.41	60.01	70.44	87.37
	1982		42.50	53.32	67.03	108.35	142.95	200.39	215.89
	1983		22.04	39.16	52.46	62.96	88.22	103.57	109.37
	1984		25.29	44.51	62.41	76.98	87.28	94.08	94.48
	1985		21.50	24.32	38.14	56.75	74.78	82.40	94.58
	1986		26.59	39.81	40.71	41.65	77.82	91.56	104.00
	1987		15.40	25.08	38.54	49.34	58.54	64.98	64.98
	1988		24.30	44.85	68.77	119.74	192.22	221.43	232.43
	1989		32.00	43.96	51.89	80.89	120.69	161.41	200.18
	1990		21.66	28.43	36.35	45.38	46.48	46.58	46.58

APPENDIX 2 (cont'd)

Station	Duration / Year	1-hour (mm)	2-hour (mm)	4-hour (mm)	6-hour (mm)	8-hour (mm)	12-hour (mm)	18-hour (mm)	24-hour (mm)
Royal Observatory Headquarters	1884	51.6	65.4	85.0	103.8	123.2	182.6	225.2	241.6
	1885	61.5	108.8	166.2	206.0	231.8	248.8	312.8	330.2
	1886	88.4	160.5	241.6	261.3	281.0	303.5	333.8	363.8
	1887	35.3	59.7	92.0	111.1	117.6	147.5	149.1	149.4
	1888	69.6	120.9	122.5	145.1	152.2	174.1	203.5	215.5
	1889	86.4	167.7	302.3	389.3	413.5	454.8	544.7	697.1
	1890	49.5	90.1	132.1	134.6	134.6	144.1	153.5	153.8
	1891	45.1	77.5	124.5	162.1	179.8	183.8	264.2	268.9
	1892	54.6	96.5	130.8	184.3	221.7	253.1	283.8	326.7
	1893	46.4	89.3	126.2	133.6	136.9	149.1	162.5	175.6
	1894	38.1	66.1	98.1	128.8	154.7	192.5	247.3	315.6
	1895	41.4	46.5	65.6	73.2	78.3	94.6	137.8	171.8
	1896	46.6	48.4	59.1	79.9	92.9	93.2	125.3	137.5
	1897	64.8	102.9	128.9	137.9	143.3	173.0	183.8	221.7
	1898	27.2	39.5	55.3	65.3	71.5	77.9	88.9	89.1
	1899	45.2	60.9	100.8	106.3	133.8	145.6	171.1	171.9
	1900	72.5	87.0	164.2	172.5	192.1	211.7	213.9	214.7
	1901	48.3	59.6	79.1	91.1	98.5	102.8	103.0	120.3
	1902	42.9	63.2	104.9	142.2	174.7	209.0	254.1	297.7
	1903	55.9	93.2	171.4	189.9	200.9	215.2	332.5	350.8
	1904	41.9	73.1	113.5	148.8	179.6	217.6	254.0	282.5
	1905	71.1	124.9	148.2	179.0	188.7	200.0	202.0	238.6
	1906	49.5	81.3	117.7	123.3	124.0	124.6	124.6	146.5
	1907	49.8	55.6	94.2	114.2	128.6	135.9	139.8	143.0
	1908	39.8	71.6	113.5	145.3	152.0	171.6	177.1	181.9
	1909	45.7	60.4	66.1	86.5	104.3	163.6	227.0	277.9
	1910	64.8	89.4	147.1	162.4	172.6	200.5	207.8	234.2
	1911	59.7	94.2	120.9	183.8	202.3	263.9	325.2	348.4
	1912	45.2	74.7	100.0	117.8	140.7	155.7	155.7	186.1
	1913	37.1	52.7	62.9	87.3	94.5	104.7	122.7	130.6
	1914	45.7	83.5	97.5	109.2	113.9	123.2	135.5	158.6
	1915	54.1	83.3	108.7	117.3	123.5	123.6	123.6	124.2
	1916	54.6	97.3	139.5	168.5	207.8	250.8	292.9	344.0
	1917	60.1	110.4	137.6	150.1	174.6	205.1	216.1	216.2
	1918	61.5	73.6	101.5	133.0	163.3	211.3	227.9	237.3
	1919	34.3	53.5	66.9	79.7	98.1	113.6	122.0	155.8
	1920	36.4	51.3	71.4	89.8	110.1	140.0	186.4	230.4
	1921	82.6	86.7	95.1	114.4	122.9	148.5	166.7	176.6
	1922	41.3	51.0	58.4	75.4	89.3	93.0	109.9	115.1
	1923	71.6	126.2	213.0	271.7	319.5	352.2	372.3	408.8
	1924	44.2	76.0	98.9	122.4	130.4	149.5	179.6	189.0
	1925	80.3	131.4	196.0	213.2	241.7	261.6	268.9	277.8
	1926	100.7	174.4	292.4	430.6	505.1	526.7	542.7	552.2
	1927	53.3	74.2	139.4	172.4	179.7	190.0	192.9	241.8
	1928	43.2	60.3	83.0	92.9	97.9	99.4	126.3	144.9
	1929	69.3	123.1	140.7	142.6	157.1	165.3	196.4	196.4
	1930	60.1	73.8	99.9	107.3	112.0	124.2	187.8	228.3
	1931	64.8	84.1	86.2	91.4	97.9	103.8	128.0	133.1
	1932	63.0	97.0	134.9	138.7	139.2	145.2	155.3	163.3
	1933	30.2	38.1	56.6	63.3	77.6	90.5	113.4	129.3
	1934	54.6	83.8	123.0	161.4	195.4	215.6	227.3	249.6
	1935	69.6	90.2	115.1	124.7	125.3	130.6	130:6	134.6
	1936	71.1	89.6	132.2	132.8	148.1	187.2	221.8	221.8
	1937	54.6	90.4	113.1	120.0	135.6	150.4	161.5	194.7
	1938	37.3	48.6	90.3	94.1	95.1	95.1	95.7	95.7
	1939	69.6	106.9	133.8	138.6	138.6	138.6	170.4	206.1
	1947	85.0	114.0	146.2	151.4	164.1	165.6	171.2	187.4
	1948	84.0	114.5	130.2	133.6	136.8	149.1	207.6	246.2

APPENDIX 2 (cont'd)

Station	Year	1-hour (mm)	2-hour (mm)	4-hour (mm)	6-hour (mm)	8-hour (mm)	12-hour (mm)	18-hour (mm)	24-hour (mm)
Royal Observatory Headquarters	1949	42.0	67.5	80.9	97.2	105.6	149.5	176.9	185.5
	1950	48.2	79.6	91.1	94.2	94.8	121.1	138.6	153.6
	1951	54.6	59.3	69.8	87.1	99.4	153.4	180.5	202.5
	1952	40.2	64.0	100.0	109.9	123.3	144.1	181.1	220.6
	1953	67.8	111.7	117.3	117.7	117.7	117.7	150.4	172.3
	1954	36.7	50.2	60.3	63.9	75.3	89.4	93.5	95.1
	1955	67.6	77.8	115.1	117.4	135.8	150.2	175.4	186.2
	1956	38.0	61.1	67.4	79.1	103.2	116.3	120.1	124.3
	1957	68.8	125.9	145.7	153.5	184.4	219.9	255.2	323.9
	1958	66.6	76.7	85.1	89.6	89.6	98.8	106.7	135.5
	1959	67.3	99.2	135.2	162.0	185.0	267.1	270.1	308.9
	1960	48.0	65.4	95.5	135.6	173.9	240.6	328.7	368.4
	1961	52.3	67.2	96.2	109.6	122.1	151.0	155.9	178.5
	1962	55.1	83.8	101.8	107.8	112.1	126.2	194.2	220.5
	1963	33.1	48.1	69.3	70.9	71.5	71.8	76.6	77.7
	1964	60.5	106.6	155.8	180.2	201.4	243.3	285.9	303.8
	1965	58.5	85.0	110.0	153.5	195.6	238.3	283.2	333.2
	1966	108.2	165.9	273.4	318.8	330.0	340.0	376.6	401.2
	1967	69.1	92.1	101.5	112.4	119.6	133.5	162.1	169.1
	1968	100.0	135.2	165.3	189.7	193.2	233.4	245.1	287.2
	1969	58.1	104.4	144.3	161.2	165.4	175.1	217.2	249.3
	1970	75.6	139.6	176.6	184.1	192.6	233.2	254.5	266.7
	1971	63.3	123.6	193.4	225.5	271.4	295.9	311.4	327.8
	1972	98.7	161.6	185.1	193.8	199.0	219.8	232.2	280.1
	1973	76.1	101.3	194.4	218.4	221.7	245.4	247.8	257.5
	1974	48.4	89.0	123.2	127.8	140.8	165.6	216.6	250.4
	1975	92.4	122.2	133.8	146.5	164.9	200.2	213.8	215.7
	1976	51.5	98.3	132.4	168.6	192.7	292.1	372.0	416.2
	1977	53.8	61.6	75.6	91.5	103.2	123.2	149.7	167.7
	1978	49.1	80.4	124.5	162.3	189.7	241.4	313.4	379.8
	1979	82.1	124.2	148.3	192.1	207.5	227.0	242.2	245.3
	1980	43.9	57.8	64.9	78.2	86.1	89.4	101.7	102.1
	1981	49.4	78.6	118.0	124.3	126.6	127.9	132.6	150.9
	1982	68.3	95.1	135.8	196.8	238.3	250.7	359.2	394.3
	1983	69.4	128.3	236.6	280.7	291.2	317.4	343.5	346.7
	1984	67.2	108.1	151.8	158.2	160.3	172.5	173.6	174.7
	1985	63.9	93.1	139.9	174.2	185.2	195.9	205.8	240.5
	1986	73.9	113.7	144.6	154.0	158.3	159.1	174.3	201.6
	1987	54.9	90.9	102.2	109.2	117.3	143.4	172.8	185.2
	1988	65.5	93.4	129.3	137.0	140.8	140.8	167.8	214.2
	1989	104.8	136.8	202.0	204.3	204.5	288.0	341.8	387.8
	1990	57.4	104.4	113.8	120.8	136.3	143.3	144.8	182.0
Yuen Long R.G Filters	1980	36.53	67.33	74.95	80.05	80.05	80.05	80.05	80.05
	1981	39.02	65.87	76.77	81.97	85.37	119.16	142.17	176.71
	1982	79.98	128.83	208.16	232.36	236.66	244.16	331.53	366.61
	1983	40.81	67.40	105.03	126.72	140.42	153.79	174.49	210.83
	1984	59.41	74.11	89.81	96.21	97.01	99.11	99.61	99.61
	1985	42.78	54.21	65.91	74.11	89.67	126.05	155.50	166.60
	1986	48.23	65.20	115.24	121.21	121.21	121.31	192.00	192.20
	1987	54.57	91.54	138.10	148.94	152.97	162.33	205.21	230.45
	1988	64.61	97.74	132.96	181.07	204.20	220.00	222.10	244.90
	1989	59.11	102.07	197.68	288.75	343.88	429.39	519.87	579.50
	1990	23.63	39.33	50.46	56.66	57.16	57.16	75.69	84.69

APPENDIX 2 (cont'd)

Station	Year	1-hour (mm)	2-hour (mm)	4-hour (mm)	6-hour (mm)	8-hour (mm)	12-hour (mm)	18-hour (mm)	24-hour (mm)
Tai Po Tau	1980	55.79	77.37	89.60	99.00	99.30	100.81	102.21	126.97
	1981	54.16	81.55	100.68	122.48	123.08	125.79	129.49	129.49
	1982	94.43	169.53	223.53	263.03	271.14	282.85	383.95	411.14
	1983	60.65	67.88	78.18	89.68	102.88	109.68	115.28	138.69
	1984	57.15	78.67	89.97	96.87	96.87	112.15	142.98	152.71
	1985	38.36	61.22	74.23	86.65	95.54	138.12	198.21	216.76
	1986	76.79	122.61	161.08	174.28	185.08	197.20	204.70	231.37
	1987	48.66	68.50	98.57	112.79	122.70	201.44	238.47	283.33
	1988	43.76	79.56	134.43	164.98	187.58	217.49	233.39	233.39
	1989	53.82	83.82	103.37	141.74	193.54	262.39	311.47	354.59
	1990	26.41	42.11	52.91	55.31	58.92	74.73	106.48	113.08
Tai Lung Farm	1980	41.19	65.67	105.00	111.80	117.50	152.44	164.86	166.56
	1981	48.04	52.71	59.81	70.04	86.27	88.47	114.17	144.64
	1982	48.18	87.34	141.62	200.39	213.59	224.79	260.43	293.36
	1983	50.46	59.09	86.19	102.02	108.57	140.37	177.72	227.47
	1984	51.66	74.28	86.68	93.08	94.38	97.28	98.08	98.08
	1985	37.24	56.25	74.78	80.88	94.48	100.70	101.10	112.10
	1986	40.61	41.25	77.62	90.46	99.06	143.15	185.66	221.68
	1987	26.98	48.34	57.34	64.78	64.98	64.98	86.78	87.38
	1988	59.35	112.70	185.62	217.18	231.73	254.70	262.19	270.29
	1989	41.35	78.89	120.59	160.01	199.38	259.82	313.78	371.08
	1990	32.13	43.95	46.38	46.58	46.58	47.98	65.18	65.18

APPENDIX 2 (cont'd)

Station	Year	Duration 2-day (mm)	3-day (mm)	4-day (mm)	5-day (mm)	7-day (mm)	15-day (mm)	31-day (mm)
Royal Observatory Headquarters	1884	250.0	275.8	277.6	291.1	293.2	309.4	551.2
	1885	444.6	457.2	457.5	620.3	697.2	741.6	957.9
	1886	384.6	442.9	481.6	514.7	528.4	640.0	757.0
	1887	154.4	172.3	198.4	203.9	219.7	328.3	458.7
	1888	229.7	268.0	280.8	286.5	293.9	561.7	688.9
	1889	841.2	854.9	870.6	908.9	924.6	1238.4	1404.9
	1890	161.4	242.0	242.8	247.5	398.6	417.0	640.9
	1891	331.6	373.9	395.4	397.5	453.1	600.0	874.0
	1892	353.0	481.6	545.8	601.8	611.7	729.5	908.6
	1893	289.7	308.9	321.6	344.2	382.1	540.2	705.3
	1894	409.2	427.2	428.5	433.4	498.2	695.8	922.5
	1895	214.5	269.0	269.0	275.6	281.5	360.7	482.4
	1896	162.8	179.2	184.2	186.1	206.5	293.8	477.1
	1897	245.5	255.4	266.8	279.1	290.1	499.2	663.0
	1898	109.4	116.3	117.2	124.1	130.0	228.3	393.3
	1899	172.4	224.3	239.9	246.5	269.5	390.8	565.0
	1900	282.1	287.5	290.2	348.1	377.0	448.4	726.1
	1901	132.9	138.1	144.7	158.7	195.3	308.8	385.8
	1902	310.9	311.5	311.5	338.4	455.9	617.8	839.0
	1903	369.3	391.1	463.9	464.2	467.1	633.6	817.0
	1904	401.2	430.0	441.4	446.4	446.7	536.2	733.0
	1905	280.1	336.0	339.5	342.2	344.4	489.9	650.1
	1906	146.5	183.5	273.1	280.0	286.5	500.8	801.7
	1907	241.4	285.3	316.4	320.2	348.2	428.4	524.1
	1908	236.0	281.9	288.9	301.2	403.2	494.0	588.3
	1909	321.0	323.5	323.5	324.6	379.0	520.9	635.5
	1910	273.0	390.5	396.8	416.8	468.0	511.2	674.4
	1911	386.8	432.8	437.5	441.1	441.1	681.6	829.5
	1912	192.3	200.6	202.3	202.7	235.6	337.1	476.1
	1913	142.7	177.8	188.9	190.3	268.8	328.8	538.4
	1914	175.9	186.5	225.5	229.0	229.0	438.2	696.3
	1915	193.1	239.2	242.1	243.2	246.3	317.9	542.4
	1916	444.4	537.9	587.9	615.8	655.3	780.1	999.7
	1917	304.6	321.9	332.8	349.4	388.7	713.4	955.8
	1918	317.7	421.3	466.7	489.4	549.3	645.2	823.5
	1919	217.9	261.6	287.2	289.5	297.9	339.8	602.4
	1920	301.0	320.9	326.9	327.7	328.6	481.8	627.6
	1921	187.9	230.9	264.9	309.3	386.3	572.4	858.4
	1922	122.3	140.8	164.3	207.9	241.7	369.3	527.0
	1923	408.9	410.9	421.0	421.1	421.1	563.2	872.3
	1924	229.8	245.0	253.9	312.9	336.5	460.6	622.3
	1925	302.0	346.8	404.2	423.2	477.0	529.1	688.7
	1926	561.2	587.0	656.8	682.6	697.2	726.8	817.0
	1927	261.8	267.9	280.6	341.0	393.8	403.3	667.7
	1928	186.3	237.7	325.4	376.8	393.8	494.0	676.2
	1929	216.5	235.6	260.1	278.9	300.2	418.3	741.6
	1930	334.7	432.0	497.8	534.7	539.3	647.1	750.2
	1931	133.4	138.1	164.0	199.7	221.8	249.7	471.4
	1932	206.2	297.3	328.1	337.2	400.8	663.2	802.8
	1933	144.8	165.7	192.5	212.7	258.9	321.1	502.9
	1934	291.0	336.6	368.6	368.9	395.2	547.8	924.4
	1935	150.3	174.8	234.5	245.0	251.5	375.5	565.4
	1936	237.6	264.0	327.3	334.9	352.2	423.4	659.8
	1937	206.6	221.8	243.1	243.6	285.0	390.0	562.3
	1938	101.8	128.4	132.8	135.9	190.1	205.8	312.8
	1939	214.1	291.0	314.0	314.0	332.1	439.8	597.4
	1947	230.2	269.3	282.3	309.7	372.4	524.3	726.6
	1948	269.9	271.2	277.6	321.2	388.3	470.6	650.3

APPENDIX 2 (cont'd)

Station	Year (Duration)	2-day (mm)	3-day (mm)	4-day (mm)	5-day (mm)	7-day (mm)	15-day (mm)	31-day (mm)
Royal Observatory Headquarters	1949	280.0	385.7	391.0	391.2	403.1	463.3	588.9
	1950	177.1	179.0	179.0	215.4	217.8	396.0	484.8
	1951	213.8	228.2	228.2	267.0	294.4	517.6	804.5
	1952	239.7	281.3	319.1	408.1	415.2	650.4	914.4
	1953	188.6	210.1	213.3	224.2	224.2	425.4	586.0
	1954	104.9	118.0	129.1	129.7	138.3	199.0	298.8
	1955	238.7	317.2	386.3	387.0	387.2	525.3	699.3
	1956	152.9	239.4	272.2	276.6	276.6	333.1	507.9
	1957	382.3	414.1	448.2	476.0	526.2	780.3	1045.5
	1958	135.9	210.5	211.0	238.9	241.6	452.8	603.8
	1959	452.0	627.5	724.6	753.4	753.8	858.1	1018.2
	1960	399.2	419.9	427.3	427.5	433.4	507.0	713.2
	1961	206.8	233.3	233.3	251.1	305.1	569.2	757.8
	1962	240.5	271.0	293.3	300.4	300.4	470.5	650.9
	1963	77.8	93.3	154.8	167.5	170.7	237.3	358.8
	1964	331.1	331.2	331.5	332.1	364.2	423.7	637.6
	1965	397.5	413.5	467.9	527.4	536.9	624.1	855.3
	1966	460.4	518.4	572.2	609.0	679.9	840.9	1043.3
	1967	216.5	216.5	226.0	238.1	322.6	506.3	583.0
	1968	326.2	328.6	348.9	380.2	390.2	578.1	870.8
	1969	292.6	294.4	295.9	324.3	336.3	499.3	676.7
	1970	354.6	365.7	392.6	403.7	407.9	471.5	578.2
	1971	340.9	340.9	340.9	359.8	378.2	518.0	689.7
	1972	446.4	652.3	677.2	678.2	702.9	793.1	908.0
	1973	262.3	270.5	288.3	325.0	354.3	676.6	1012.1
	1974	376.3	459.5	469.3	469.7	469.7	695.4	728.5
	1975	216.7	304.9	323.1	339.3	392.0	489.8	832.6
	1976	511.6	516.1	516.1	517.5	517.5	589.9	942.7
	1977	200.3	267.6	268.4	306.4	307.3	317.3	452.5
	1978	405.7	413.1	420.1	450.5	502.4	563.5	737.5
	1979	252.7	308.5	437.8	469.2	547.6	778.5	914.4
	1980	144.9	164.0	201.9	206.1	223.1	290.5	506.6
	1981	178.8	186.2	186.3	188.2	226.3	275.3	414.2
	1982	437.4	474.9	653.9	655.2	677.3	759.6	945.2
	1983	350.5	352.1	360.3	362.7	364.3	423.1	657.8
	1984	201.1	206.2	206.4	216.1	270.8	381.3	664.4
	1985	250.3	267.8	274.9	280.9	293.2	450.9	703.3
	1986	222.1	234.3	242.5	249.3	272.2	505.4	643.5
	1987	227.0	311.2	315.0	345.3	423.7	558.4	672.4
	1988	247.7	248.5	250.6	250.6	252.2	309.4	601.3
	1989	425.7	432.4	433.1	453.5	456.1	480.8	771.9
	1990	189.3	196.7	228.5	230.3	253.0	358.3	501.0
Yuen Long R.G. Filters	1980	110.4	110.4	110.4	110.6	154.3	206.6	367.5
	1981	190.8	193.5	195.3	209.2	240.9	303.4	540.2
	1982	376.8	491.1	537.5	551.5	596.5	729.1	773.4
	1983	216.3	236.8	258.3	278.8	278.8	390.3	531.5
	1984	131.1	158.5	175.0	177.0	229.7	284.4	488.1
	1985	234.3	235.9	247.2	251.9	291.7	447.9	747.9
	1986	195.6	209.2	246.9	249.3	251.3	314.3	522.0
	1987	256.5	257.5	259.4	266.4	288.6	406.5	542.7
	1988	287.1	288.5	288.5	288.5	288.5	322.7	593.5
	1989	590.0	604.5	605.0	614.3	622.3	638.7	852.0
	1990	118.3	128.1	130.8	134.8	142.9	184.5	278.5

APPENDIX 2 (cont'd)

Station	Year	2-day (mm)	3-day (mm)	4-day (mm)	5-day (mm)	7-day (mm)	15-day (mm)	31-day (mm)
Tai Po Tau	1980	286.4	340.1	340.3	354.1	366.2	487.6	713.0
	1981	176.0	231.9	275.5	313.2	378.7	502.8	742.1
	1982	427.6	502.5	547.5	589.5	631.3	737.8	849.1
	1983	252.0	285.5	315.3	337.3	357.5	389.0	677.8
	1984	184.5	211.1	213.2	228.2	254.8	367.5	635.4
	1985	285.6	287.5	291.3	297.1	338.1	546.4	898.5
	1986	294.8	340.3	341.3	348.3	349.8	438.6	719.5
	1987	332.4	360.4	386.1	407.5	421.3	556.2	637.8
	1988	357.7	362.7	373.3	373.3	373.3	435.8	794.7
	1989	383.0	400.8	411.3	412.2	430.8	458.2	728.3
	1990	152.5	178.3	194.8	246.7	265.3	350.3	404.7
Tai Lung Farm	1980	206.9	257.0	275.1	283.4	283.4	396.3	682.4
	1981	168.8	192.3	201.9	219.3	287.7	373.1	603.2
	1982	361.2	460.0	514.0	576.0	609.7	657.2	809.5
	1983	258.8	274.8	291.7	307.7	311.0	364.9	592.1
	1984	155.2	183.3	186.3	205.5	228.9	344.5	533.6
	1985	260.6	260.6	272.3	272.3	368.5	517.7	852.9
	1986	247.8	286.1	286.1	306.1	306.1	359.8	540.5
	1987	244.7	308.2	324.4	333.9	344.8	502.8	551.9
	1988	314.1	316.4	316.4	316.4	316.9	415.0	699.1
	1989	424.9	439.5	449.6	461.2	476.8	506.1	701.3
	1990	152.0	187.2	198.3	204.9	217.0	278.9	435.5

APPENDIX 3

Unadjusted parameters of the frequency distributions for rainfall depths based on 1884-1939; 1947-1990 rainfall data at the Royal Observatory

	Gumbel		Jenkinson's 1955 solution			Jenkinson maximum likelihood		
	μ	$1/\alpha$	X_0	α	k	X_0	α	k
Duration	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	
31 days	609.4	152.7	619.3	167.3	0.14	618.4	168.5	0.13
15 days	427.0	138.7	431.8	140.5	0.06	432.0	141.5	0.06
7 days	312.6	119.1	314.6	111.0	−0.01	314.0	110.5	−0.01
5 days	284.9	117.7	286.1	105.5	−0.03	285.4	104.8	−0.04
4 days	268.7	113.0	269.8	100.7	−0.04	268.9	99.7	−0.05
3 days	249.3	105.0	250.8	96.7	−0.01	250.8	97.1	−0.01
2 days	217.7	96.6	218.9	87.8	−0.02	218.6	87.2	−0.03
24 hours	186.2	82.3	186.8	71.9	−0.05	186.4	71.2	−0.06
18 hours	168.6	72.1	169.3	63.5	−0.05	167.8	61.2	−0.09
12 hours	146.7	63.0	147.1	53.2	−0.07	146.2	51.8	−0.11
8 hours	127.7	56.8	128.0	42.8	−0.14	127.8	42.6	−0.15
6 hours	116.2	50.9	116.4	39.0	−0.13	116.6	39.4	−0.12
4 hours	101.8	40.3	102.2	35.1	−0.05	102.0	35.2	−0.06
2 hours	76.1	24.7	77.1	25.5	0.08	76.8	24.9	0.06
1 hour	51.0	14.3	51.5	14.7	0.07	51.4	14.4	0.05

Unadjusted parameters of the frequency distributions for rainfall intensities based on 1952-1990 data at King's Park*; 1947-1990 data at the Royal Observatory

	Gumbel		Jenkinson's 1955 solution			Jenkinson maximum likelihood		
	μ	$1/\alpha$	X_0	α	k	X_0	α	k
Duration	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)		(mm/hr)	(mm/hr)	
120 minutes	43.3	13.4	44.3	13.9	0.14	44.2	13.7	0.12
60 minutes	64.4	17.3	65.9	18.6	0.18	66.1	18.5	0.20
30 minutes	84.8	18.8	86.1	19.4	0.13	86.4	19.9	0.17
15 minutes	105.8	19.0	107.4	20.3	0.17	107.3	19.9	0.15
15 seconds*	232.6	41.4	241.7	50.0	0.43	242.3	50.0	0.45

Unadjusted parameters of the Gumbel estimates for the extreme rainfall depth based on 1980-1990 rainfall data

	Yuen Long		Tai Po Tau		Tai Lung Farm		RO Headquarters	
Duration	μ (mm)	$1/\alpha$ (mm)	μ (mm)	$1/\alpha$ (mm)	μ (mm)	$1/\alpha$ (mm)	μ (mm)	$1/\alpha$ (mm)
31 days	483.0	168.1	645.3	127.9	574.8	123.6	573.1	141.4
15 days	301.3	166.3	425.4	107.6	376.1	105.3	366.3	139.0
7 days	230.1	155.4	329.7	98.4	285.2	111.6	269.9	135.2
5 days	206.5	156.6	307.3	95.9	261.7	110.6	244.2	136.7
4 days	200.7	154.0	287.3	96.3	251.4	100.3	237.1	135.6
3 days	190.1	149.7	272.6	91.4	242.1	91.3	229.0	101.1
2 days	177.9	136.5	240.4	81.2	211.7	84.9	212.6	97.6
24 hours	149.9	142.6	168.6	97.7	139.0	96.3	186.2	96.8
18 hours	136.4	127.0	152.3	89.5	125.6	81.5	165.3	91.0
12 hours	113.6	102.4	131.3	68.9	106.7	73.0	149.2	70.5
8 hours	104.2	84.2	109.2	61.1	92.6	61.4	138.7	58.0
6 hours	99.5	71.7	99.8	56.1	84.9	55.2	130.7	54.6
4 hours	88.6	51.0	86.2	47.0	74.4	40.7	117.0	45.9
2 hours	65.2	24.8	68.0	33.7	54.9	21.2	89.2	21.7
1 hour	42.2	15.4	46.5	18.0	38.8	9.2	57.5	15.7

Unadjusted parameters of the Gumbel estimates for the extreme rainfall intensity based on 1980-1990 rainfall data

	Yuen Long		Tai Po Tau		Tai Lung Farm		RO Headquarters	
Duration	μ (mm/hr)	$1/\alpha$ (mm/hr)	μ (mm/hr)	$1/\alpha$ (mm/hr)	μ (mm/hr)	$1/\alpha$ (mm/hr)	μ (mm/hr)	$1/\alpha$ (mm/hr)
480 minutes	13.1	10.6	13.8	7.6	11.8	7.7		
360 minutes	16.8	12.1	16.7	9.4	14.3	9.3		
240 minutes	22.5	13.4	22.3	11.8	18.8	10.6		
120 minutes	34.2	13.9	35.5	16.8	29.3	12.6	46.7	13.1
60 minutes	46.7	16.2	54.4	16.9	45.7	12.0	70.1	15.7
30 minutes	67.0	15.4	75.5	17.4	70.5	20.4	93.0	22.1
15 minutes	93.0	16.1	99.2	25.8	92.8	30.3	114.6	22.2
15 seconds							249.3	35.6

APPENDIX 4

Gumbel's method of establishing confidence limits in the plotting of annual maximum values

Confidence limits define the probability density areas on both sides of the mean, or of the mode of an assumed distribution of the data for a given return period. Control curves, that join the equal confidence limits, can then be drawn to show the confidence bands. Gumbel has proposed a method for establishing the confidence limits in the plotting of annual maximum values. The method is based on the principle that the theoretical value of rank *m* situated on the straight line and corresponding to a given return period is the approximation to the most probable *m* th value. For practical purpose, the method can be simplified by the approximate procedure given below (Chow, 1953).

For the largest value with $m = 1$, the half vertical width of the confidence band is

$$\Delta X_1 = sF\ (N) \qquad \text{(A4.1)}$$

where s is the standard deviation of the observed data. $F(N)$ is a function of the N years of record and its value is read from the graph taken from Chow (1964).

For the second largest value with $m = 2$,

$$\Delta X_2 = 0.661\frac{N+1}{N-1}\Delta X_1 \qquad \text{(A4.2)}$$

For intermediate values of rank m,

$$\Delta X_m = \frac{0.877}{\sqrt{N}}\Delta X_1 F(T) \qquad \text{(A4.3)}$$

where $F(T)$ is a function of the return period T. Its value is also read from the graph taken from Chow (1964). When T is greater than 10 years, $F(T) = \sqrt{T}$.

For extrapolation beyond the largest value, Gumbel suggested that the control curves be drawn as two lines parallel to the extrapolated straight line.

In this study, analyses were carried out for $N = 11$, 44, 100 and the values of $F(N)$ were taken as 1.103, 0.98 and 0.94 respectively. Values of $F(T)$ corresponding to specific number of years of record N used in this study were tabulated below. The plotting position formula for return period T was adopted from Weibull (1939)

$$T = \frac{N+1}{m} \tag{A4.4}$$

where N is the total number of records and m is the order number of the records arranged in descending magnitude.

N	m	T	F(T)
11	1	12.00	3.460
	2	6.00	2.450
	3	4.00	2.010
	4	3.00	1.750
	5	2.40	1.570
	6	2.00	1.450
	7	1.71	1.350
	8	1.50	1.280
	9	1.33	1.245
	10	1.20	1.250
	11	1.09	1.330
44	1	45.00	6.708
	2	22.50	4.743
	3	15.00	3.873
	4	11.25	3.354
	5	9.00	3.000
	6	7.50	2.750
	7	6.43	2.540
	8	5.63	2.370
	9	5.00	2.240
	10	4.50	2.130
	11	4.09	2.050
	12	3.75	1.950
	13	3.46	1.870
	14	3.21	1.800
	15	3.00	1.750
	16	2.81	1.690
	17	2.65	1.650
	18	2.50	1.600
	19	2.37	1.550
	20	2.25	1.525
	21	2.14	1.480
	22	2.05	1.450
	23	1.96	1.430
	24	1.88	1.400
	25	1.80	1.370
	26	1.73	1.350
	27	1.67	1.340
	28	1.61	1.320
	29	1.55	1.300
	30	1.50	1.280
	31	1.45	1.270
	32	1.41	1.260
	33	1.36	1.252
	34	1.32	1.250
	35	1.29	1.242
	36	1.25	1.240
	37	1.22	1.248
	38	1.18	1.260
	39	1.15	1.270
	40	1.13	1.300
	41	1.10	1.330
	42	1.07	1.380
	43	1.05	1.440
	44	1.02	1.950

N	m	T	F(T)	m	T	F(T)
100	1	101.00	10.050	51	1.98	1.430
	2	50.50	7.110	52	1.94	1.420
	3	33.67	5.800	53	1.91	1.410
	4	25.25	5.020	54	1.87	1.400
	5	20.20	4.490	55	1.84	1.380
	6	16.83	4.100	56	1.80	1.370
	7	14.43	3.800	57	1.77	1.360
	8	12.63	3.550	58	1.74	1.355
	9	11.22	3.350	59	1.71	1.350
	10	10.10	3.180	60	1.68	1.340
	11	9.18	3.030	61	1.66	1.330
	12	8.42	2.900	62	1.63	1.325
	13	7.77	2.780	63	1.60	1.320
	14	7.21	2.680	64	1.58	1.310
	15	6.73	2.590	65	1.55	1.300
	16	6.31	2.520	66	1.53	1.290
	17	5.94	2.400	67	1.51	1.280
	18	5.61	2.370	68	1.49	1.276
	19	5.32	2.300	69	1.46	1.273
	20	5.05	2.260	70	1.44	1.270
	21	4.81	2.200	71	1.42	1.265
	22	4.59	2.140	72	1.40	1.260
	23	4.39	2.100	73	1.38	1.255
	24	4.21	2.060	74	1.36	1.253
	25	4.04	2.010	75	1.35	1.250
	26	3.88	1.980	76	1.33	1.248
	27	3.74	1.940	77	1.31	1.246
	28	3.61	1.920	78	1.29	1.244
	29	3.48	1.870	79	1.28	1.242
	30	3.37	1.850	80	1.26	1.240
	31	3.26	1.830	81	1.25	1.242
	32	3.16	1.780	82	1.23	1.245
	33	3.06	1.750	83	1.22	1.248
	34	2.97	1.720	84	1.20	1.250
	35	2.89	1.700	85	1.19	1.255
	36	2.81	1.680	86	1.17	1.260
	37	2.73	1.670	87	1.16	1.265
	38	2.66	1.650	88	1.15	1.270
	39	2.59	1.630	89	1.13	1.275
	40	2.53	1.610	90	1.12	1.280
	41	2.46	1.590	91	1.11	1.300
	42	2.40	1.570	92	1.10	1.320
	43	2.35	1.550	93	1.09	1.350
	44	2.30	1.540	94	1.07	1.370
	45	2.24	1.520	95	1.06	1.400
	46	2.20	1.500	96	1.05	1.450
	47	2.15	1.490	97	1.04	1.550
	48	2.10	1.480	98	1.03	1.750
	49	2.06	1.470	99	1.02	1.900
	50	2.02	1.450	100	1.01	2.100

APPENDIX 5

Determination of the constants in the Wisner's formula

The Wisner's formula for the extreme intensity-duration curve is :

$$I = \frac{a}{(t+b)^c} \tag{A5.1}$$

Taking logarithms on both sides of Eqn. (A5.1)

$$\log I = -c\log(t+b) + \log a \tag{A5.2}$$

Provided the value of b is known, a linear regression of $\log I$ versus $\log(t+b)$ will give the slope, $-c$, and the y-intercept, $\log a$.

Given the data set $\{t_i, I_i : i = 1,\ldots,n\}$, various values of b are input, by trial and error, such that

$$\sum_{i=1}^{n} [\log I_i + c\log(t_i + b) - \log a]^2 \tag{A5.3}$$

gives the least value. This value of b is thus adopted and then used in the least-square fit in the plotting of $\log I$ versus $\log(t+b)$ to give estimates of the parameters a and c.

APPENDIX 6

Derivation of an expression for a storm profile from the Wisner's formula

Since the profile is assumed to be symmetric with the maximum occurring at $t = 0$, only the formula for $t \geq 0$ is derived. The formula for $t < 0$ can be found similarly.

Let the shaded area in Figure 11 be A and that in Figure 12 be B, the profile be $F(t)$, then

$$A = \frac{at}{(t+b)^c} \qquad \text{(A6.1)}$$

$$B = 2\int_0^{t/2} F(t)dt \qquad \text{(A6.2)}$$

Equating the two areas in Eqn.(A6.1) and Eqn.(A6.2) gives

$$\int_0^{t/2} F(t)dt = \frac{at}{2(t+b)^c} \qquad \text{(A6.3)}$$

Differentiate both sides of Eqn.(A6.3) with respect to t, we have

$$\frac{d}{dt}\int_0^{t/2} F(t)dt = \frac{a[b+(1-c)t]}{2(t+b)^{c+1}} \qquad \text{(A6.4)}$$

By the Fundamental Theorem of Calculus,

$$\frac{d}{dt}\int_0^{t/2} F(t)dt = \frac{1}{2}F\left(\frac{t}{2}\right) \qquad \text{(A6.5)}$$

Hence

$$F\left(\frac{t}{2}\right) = \frac{a[b+(1-c)t]}{(t+b)^{c+1}} \qquad \text{(A6.6)}$$

Replacing t by $2t$ in Eqn.(A6.6), we get

$$F(t) = \frac{a[b+2(1-c)t]}{(2t+b)^{c+1}} \qquad \text{(A6.7)}$$

APPENDIX 7

A list of recent rainstorms and their reported damage in Hong Kong

Period	Rainfall (mm)*	Effect**	Cause
1960			
9/JUN	236.1 in 1 day	45 dead; 11 missing; 127 injured; 15000 affected	T. Mary
1962			
26/MAY	114.2 in 1 day	Some damage in Sai Kung	Passage of a trough from south
1/SEP	203.0 in 1 day	130 dead; 53 missing; 72000 homeless	T. Wanda
1964			
28/MAY	248.5 in 1 day	Flooding in low-lying paddy fields	T. Viola
10-11/SEP	177.0 in 2 days	Numerous landslides	T. Sally
12-13/OCT	333.1 in 2 days	26 dead; numerous landslides	T. Dot
1965			
26/SEP - 1/OCT	534.2 in 6 days	6 dead; 200 homeless; widespread flooding; numerous minor landslides	T.S. Agnes
1966			
4/APR	190.2 in 1 day	15 dead	Thunderstorms

12/JUN	382.6 in 1 day; 108.2 in 1 hour; 157.0 in 1 hour; a record high at Aberdeen	64 dead; 29 injured; disastrous landslides and washouts on Peak Road, Stubbs Road and Ming Yuen Street; 8561 evacuated from their homes	Prolonged period of rain (2-15 Jun) (documented in R.O. Occasional Paper No. 7)
13-14/JUL	160.0 in 2 days	1 dead; several injured	S.T.S. Lola
18/AUG	125.9 in 1 day	Short period of flooding in low-lying areas	SW Monsoon as T.S. Tess landed near Fuzhou

<u>1967</u>

13-14/JUL	126.0 in 2 days; more than 250.0 fell near Plover Cove and Tai Lam Chung	no damage reported	Upper air disturbance
20-22/AUG	191.8 in 3 days	3 injured; 1500 evacuated from their homes	T. Kate following a T.D. which brought 177.1 mm between 10-14 Aug and T.S. Iris that brought 135.0 mm between 15 - 17 Aug

<u>1968</u>

12-13/JUN	326.2 in 2 days	22 dead; 7 injured; 10 landslides	A surface trough
20-22/AUG	257.9 in 3 days	3 landslides; 4 injured; 3000 evacuated from their homes	T. Shirley

APPENDIX 7 (cont'd)

<u>1969</u>

10-11/AUG	220.8 on 11 Aug and 292.6 on 2 days after the typhoon landed near Fuzhou	Urban flooding; disrupted traffic; 2000 evacuated in Shatin; landslides over many hilly areas	T. Betty (documented in R.O. Tech. Note No. 40)

<u>1970</u>

13/MAY	265.1 in 1 day and 139.6 in 2 hours	Numerous landslides and flooding	A trough
16/JUL	instantaneous rate 378 mm/hr	Landslides	T.S. Ruby
2-3/AUG	223.5 in 2 days	2 killed by lightning; 4 huts affected by flooding	T.D.
16/SEP	197.5 in 24 hrs at Tai Po (RO rainfall was only 2.2 in 1 day	368 evacuated from their homes in Tai Po	Remnant of T. Georgia which landed on 14 Sep

<u>1971</u>

19/MAY	106.1 in 1 day	Flooding in low-lying areas; 29 people homeless	Onset of the SW Monsoon
18/JUN	95.3 in 1 day 183.2 in 2 days (17-18 Jun)	2 dead; 30 injured; 100 affected by flooding in the New Territories	T. Freda
22/JUL	142.5 in 1 day	38 injured; flooding in in the New Territories	T. Lucy

17/AUG	288.1 in 1 day; an instantaneous rate of 513.0 mm/hr was recorded at Tate's Cairn at around 8:30 a.m.	100 killed; hundreds injured	T. Rose
18/DEC	97.8 in 1 day	Some flooding in the New Territories; 1 landslide	Upper air disturbance
1972			
7-11/MAY	325.0 in 2 days; 444.4 in 5 days	Flooding reported in 8 areas; 2 landslides; 6055 people homeless	A trough
16-18/JUN	652.3 in 3 days; 232.6 on the 18 th in which 98.7 from 11 a.m. to noon	Disastrous landslides at Sau Mau Ping and Po Shan Road; 53 flooding; 138 killed; 56 injured; 7800 homeless	A trough (documented in R.O. Tech. Note No. 51)
19-21/AUG	186.8 on the 20 th; 288.4 in 3 days	1 house collapsed; 9 wooden huts damaged; 57 affected	T. Betty landed near Fuzhou on 19 Aug (documented in R.O. Tech. Note No. 40)
1973			
27/JUN	128.9 in 1 day	No damage reported	A trough
16-17/JUL	214.3 in 2 days; 172.1 on 17 Jul	Flooding with water 1 m high in Tin Shui Wai, Yuen Long; 238 affected	T. Dot
9-13/AUG	247.8 in 5 days	1 killed	T. Georgia

21/AUG	212 in 5 hours; (5 a.m. - 10 a.m.) 251.5 in 1 day	3 flooding; 1 killed; 1 injured	T.S. Joan
19/SEP	83.2 in 1 day	Flooding with water 1 m high in Sai Kung; 10 affected	A cold front
1974			
7-9/APR	142.9 in 3 days	Rock fell on roads in the New Territories	A cold front
23/AUG	128.3 in 1 day	Flooding in urban areas	S.T.S Mary
18-20/OCT	459.5 in 3 days	Flooding in low-lying areas; 1000 evacuated from their homes	T. Carmen
29-31/OCT	225.2 in 3 days	Some flooding and minor landslide	T. Elaine
2/DEC	177.3 in 1 day	No damage reported	T. Irma
1975			
28-30/APR	149.7 in 1 day; 92.4 from noon to 1 p.m. on 30 APR; 304.9 in 3 days	Widespread flooding, especially in Sai Kung and Kowloon Bay	A trough
20/MAY	215.7 in 1 day	Flooding in Kwai Chung, Sai Kung, Tai Po, and Kwun Tong; water 1 m high in Pokfulam village	A trough
1-7/JUN	82.1 on 5 JUN; 271.1 in 7 days	Widespread flooding	SW Monsoon
12-16/JUL	240.7 in 5 days	2 drowned in the New Territories	Upper air disturbances

APPENDIX 7 (cont'd)

1976

2-3/JUN	197.4 in 2 days	Flooding in Sam Shing Hui and Tuen Mun with water 8 ft high; 200 evacuated from their homes	A trough
24-27/JUL	271.7 in 4 days	Some minor flooding	S.T.S. Violet
24-25/AUG	416.2 in 24 hrs. starting 11 a.m. on 24 Aug; 511.6 in 2 days	Landslips in many places including Sau Mau Ping where 18 killed; 2424 evacuated from their homes; water 4 ft high on King's Road.	S.T.S. Ellen

1977

23/JUN	91.9 in 1 day	60 homeless; affected places included Lam Tin, Lei U Mun and Sau Mau Ping	A trough
4-6/SEP	267.6 over the weekend	Many roads flooded; a wooden hut was damaged near Lion Rock	T.S. Carla

1978

2/JUN	97.6 in 1 day; 70.0 in 1 hour	Flooding in Chai Wan and Shatin	A trough
24-30/JUL	502.4 in 7 days	2 drowned and 1 killed in a landslip	S.T.S. Agnes
16-17/OCT	120.9 on 16 Oct; 284.8 on 17 Oct	Minor landslip and flooding	S.T.S. Nina

APPENDIX 7 (cont'd)

1979

11/JUN	113.6 in 1 day	3 landslips; 200 evacuated from their homes	A trough
29-31/JUL	260.2 in 3 days	Flooding in the New Territories	S.T.S. Gordon
2/AUG	209.0 in 1 day	Severe damage to property in H.K.; numerous minor landslips	T. Hope
23/SEP	245.2 in 1 day	Many roads flooded; several minor landslips	T. Mac

1980

24-28/JUN	82.7 in 5 days	Some roads flooded; a few minor landslips	S.T.S. Herbert
10-14/JUL	190.8 in 4 days	1 missing at Sheung Shui	S.T.S. Ida
22-23/JUL	61.9 in 2 days	2 killed, 1 missing; 59 injured	T. Joe
26-28/JUL	136.3 in 3 days	2 landslips; flooding at Tai Po, Sheung Shui	T. Kim

1981

10-11/MAY	178.8 in 2 days	Widespread landslip; flooding in Shatin, Tai Po; 1 killed; 650 evacuated	A trough
30-31/MAY	88.4 in 2 days	Landslips in Yau Tong, Kwun Tong and Sau Ping; over 100 evacuated	A trough
5/JUN	33.3 in 1 day	Landslip on King's Road; 1 killed	A trough

APPENDIX 7 (cont'd)

5-8/JUL	83.7 in 4 days	Landslips at Diamond Hill, Yau Tong and Shau Kei Wan; 32 injured	S.T.S. Lynn
2-3/AUG	5.7 in 2 days	Landslip at Sau Mau Ping	A trough
4/SEP	126.1 in 1 day	Landslips at Sau Mau Ping, Kwun Tong and Diamond Hill	A trough

<u>1982</u>

28-31/MAY	653.9 in 4 days	Many landslips and extensive flooding	SW Monsoon
1-3/AUG	114.9 on 1 Aug 204.2 on 3 Aug	25 killed; 4 missing 1 missing; 1 injured	SW Monsoon
15-19/AUG	334.2 on 16 Aug 522.8 in 5 days	Many flooding and landslips 5 killed	S.T.S. Dot
16-17/SEP	73.8 on 16 Sep	Some flooding and landslips; 4 squatter huts destroyed; 2 collapsed	Heavy rain and thunderstorms
26-27/OCT	70.5 on 26 Oct	A mudslip in Tsim Sha Tsui	Heavy rain
26/NOV	38.8 on 26 Nov	A mudslip in Lam Tin and 4 squatter huts affected	Heavy rain

<u>1983</u>

2/MAR	81.4 on 2 Mar	Landslips in Ngau Tau Kok and Tsing Yi; flooding in Tuen Mun	Heavy rain and thunderstorms

APPENDIX 7 (cont'd)

25-27/MAR	98.6 on 27 Mar 65.5 on 25 Mar	Many flooding and minor landslips	Heavy rain and thunderstorms
5-8/APR	57.7 on 8 Apr	Many flooding	Heavy rain and thunderstorms
15/MAY	90.6 on 15 May	2 mudslips and many flooding	Heavy rain and thunderstorms
20-21/MAY	56.1 on 21 May	1 mudslip and many flooding	Heavy rain and thunderstorms
26-28/MAY	56.1 on 27 May	Many mudslips and many flooding	Heavy rain and thunderstorms
17/JUN	274.4 in 5 hrs between 5 -10 a.m. on 17 Jun; 346.7 on 17 Jun	393 flooding and 134 landslips; 1 killed; 12 injured	Heavy rain and thunderstorms
15/AUG	56.8 on 15 Aug	Minor flooding	Heavy rain and thunderstorms
22-25/AUG	63.4 on 22 Aug 64.5 on 24 Aug	Minor landslip and some flooding 2 squatter huts damaged	Heavy rain and thunderstorms
8-9/SEP	172.4 on 9 Sep	10 dead; 12 missing; 333 injured; 1607 homeless	T. Ellen
29-30/SEP	66.3 on 30 Sep	Mudslip in Punshan Tsuen	S.T.S. Georgia
13-15/OCT	100.1 on 13 Oct	58 injured; 559 affected; many flooding; some minor landslips	T. Joe
<u>1984</u>			
17/APR	65.8 on 17 Apr 54.4 between 1-2 p.m. on 17 Apr	2 dead; minor flooding	Rainstorm

APPENDIX 7 (cont'd)

17-18/MAY	72.0 on 17 May	Minor flooding	Rainstorm
29-30/MAY	150.0 on 30 May	150 flooding; 14 landslips	Rainstorm
16-21/JUN	174.7 on 16 Jun	41 flooding; 4 landslips	Rainstorm
19-26/JUN	56.4 on 25 Jun	Minor landslip	S.T.S. Wynne
5-9/JUL	70.3 on 9 Jul	Minor damage to crops	S.T.S. Betty
4/AUG	75.2 on 4 Aug	Minor flooding	Rainstorm
10-12/AUG	69.0 on 11 Aug	11 flooding; minor landslip	Rainstorm
1-2/SEP	83.8 on 1 Sep	No damage reported	Rainstorm
10-11/OCT	67.2 between 11 p.m. to mid-night on 10 Oct	Some flooding	Rainstorm

<u>1985</u>

7-8/FEB	41.3 on 8 Feb	Minor flooding and landslip	Rainstorm
9-13/APR	65.6 on 9 Apr	Some flooding and landslips	Rainstorm
19-25/JUN	208.1 on 25 Jun 63.9 between 2-3 a.m. on 25 Jun	1 dead; 24 injured; 532 homeless	T. Hal
25-27/AUG	117.4 on 26 Aug	29 flooding; 19 landslips	Rainstorm
2-7/SEP	114.3 on 6 Sep	2 dead; 12 injured; many flooding and landslips	T. Tess

1986

20-22/APR	86.2 on 21 Apr	Minor flooding and landslip	Rainstorm
11-12/MAY	127.7 on 11 May	3 injured	Rainstorm
6-7/JUN	73.9 between 9-10 a.m. on 6 Jun; 175.1 on 6 Jun	Minor flooding; 1 landslip	Rainstorm
24-25/JUN	65.8 on 25 Jun	1 missing; 2 injured	Rainstorm
3-4/JUL	126.3 on 4 Jul	39 flooding; 5 landslips 11 injured	Rainstorm
11-12/JUL	168.9 ON 12 Jul	1 dead; 26 injured; 172 homeless	T. Peggy
9-12/AUG	98.5 on 10 Aug	3 injured; 67 flooding; 5 landslips	T.D.
19/AUG - 7/SEP	65.4 on 7 Sep	3 dead; 15 injured	T. Wayne
16/SEP	72.1 on 16 Sep	11 flooding; 5 injured	Rainstorm
15-19/OCT	25.4 on 19 Oct	4 injured	T. Ellen

1987

16-17/MAR	50.1 between 9-10 a.m. on 17 Mar; 126.4 on 17 Mar	116 flooding; 4 mudslips; 2 vehicles damaged	Rainstorm
5-6/APR	137.8 on 6 Apr	133 flooding; 9 landslips; 5000 heads of livestock drowned	Rainstorm
12-13/APR	52.8 on 12 Apr	1 dead; 2 injured	Rainstorm
7-8/MAY	68.8 on 7 May	2 injured	Rainstorm

APPENDIX 7 (cont'd)

16-17/MAY	67.2 on 16 May	2 injured; 7 huts destroyed; minor landslips	Rainstorm
22-23/MAY	107.5 on 22 May	66 flooding; 6 landslips	Rainstorm
4-5/JUN	87.3 ON 4-5 Jun	Minor landslip	Rainstorm
22/JUL	97.3 on 22 Jul	7 flooding; some landlips	Rainstorm
28-30/JUL	138.2 on 30 Jul	88 flooding; 46 landslips	Rainstorm
21/SEP	94.2 on 21 Sep	Some minor flooding	Rainstorm
16-28/OCT	47.9 on 28 Oct	1 injured; 2 huts damaged; 2 vehicles damaged	T. Lynn
27-29/NOV	46.3 on 28 Nov	10 dead; 7 injured	T. Nina
<u>1988</u>			
23-26/JUN	88.5 on 26 Jun	3 minor flooding	Rainstorm
19-20/JUL	203.5 on 19 Jul 65.5 between 3-4 a.m. on 19 Jul	1 dead; 5 injured; 118 flooding; 5 minor landslips	T. Warren
14-18/AUG	56.9 on 18 Aug	3 injured; 51 flooding; some minor landslips	Rainstorm
30-31/AUG	74.2 on 31 Aug	7 dead; 14 injured	Rainstorm
30-31/DEC	61.5 on 30 Dec	No damage reported	Upper air disturbance
<u>1989</u>			
22/APR	12.0 on 22 Apr	25 flooding	Rainstorm

APPENDIX 7 (cont'd)

2/MAY	208.4 on 2 May 104.8 between noon and 1 p.m. on 2 May	3 dead; 1 injured; 24 flooding	Rainstorm
16-21/MAY	322.8 on 20 May	7 dead; 119 injured; 118 flooding; 100 landslips	T. Brenda
22/JUN	64.5 on 22 Jun	No damage reported	Rainstorm
11-19/JUL	119.7 on 18 Jul	2 dead; 38 injured; 13 flooding; 3 landslides	T. Gordon
20-23/AUG	75.6 on 22 Aug	3 dead; 18 flooding; 2 landslips	Rainstorm
6-7/SEP	59.4 on 7 Sep	No damage reported	Rainstorm
<u>1990</u>			
9-11/APR	72.9 on 11 Apr	1 dead; 1 injured; 30 flooding; 1 landslip	Rainstorm
1/JUN	144.8 on 1 Jun	19 flooding	A trough
15-19/JUN	58.4 on 16 Jun	6 dead; 1 injured	S.T.S. Nathan
21-30/JUN	83.0 on 30 Jun	1 dead; 30 flooding; 3 landslips	T. Percy
27-31/JUL	57.6 on 31 Jul	1 injured; 1 car damaged	S.T.S. Tasha
2-3/AUG	73.3 on 2 Aug	1 dead; 1 landslip; 2 houses destroyed	SW Monsoon
9-12/SEP	105.4 on 10 Sep	87 landslides; 61 families homeless	Rainstorm
10-20/SEP	97.5 on 19 Sep	1 injured; minor flooding	T. Ed

APPENDIX 7 (cont'd)

* All rainfall amounts are measured at the Royal Observatory unless otherwise stated.

** Effects of the rainstorms are quoted from ESCAP reports (1960-1990) prepared by the Royal Observatory.