UHJAK/2008/PI/H/3

Asian Pacific FRIEND

Rainfall Intensity Duration Frequency (IDF) Analysis for the Asia Pacific Region

November 2008

Edited by: Trevor M. Daniell and Guillermo Q. Tabios III

International Hydrological Programme

ihp

IHP-VII | Technical Documents in Hydrology | No. 2
Regional Steering Committee for Southeast Asia and the Pacific
UNESCO Office, Jakarta 2008

UNESCO

United Nations
Educational, Scientific and
Cultural Organization

friend

Flow Regimes from International Experimental and Network Data

United Nations
Educational, Scientific and
Cultural Organization

INTERNATIONAL HYDROLOGICAL PROGRAM

Asian Pacific FRIEND

Rainfall Intensity Duration Frequency (IDF) Analysis for the Asia Pacific Region

November 2008

Edited by: Trevor M. Daniell and Guillermo Q. Tabios III

Flow Regimes from International Experimental and Network Data

IHP-VII | Technical Documents in Hydrology | No. 2
Regional Steering Committee for Southeast Asia and the Pacific
UNESCO Office Jakarta 2008

United Nations Educational, Scientific and Cultural Organisation
International Hydrological Programme VI

FRIEND: FLOW REGIMES FROM INTERNATIONAL EXPERIMENTAL AND NETWORK DATA

Rainfall Intensity Duration Frequency (IDF) Analysis for the Asia Pacific Region

Report by

IHP Regional Steering Committee
for South East Asia and the Pacific

November, 2008

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1 Introduction

Trevor Daniell and Guillermo Q. Tabios III

1.1 Preamble

During the APFRIEND Meeting in Kuala Lumpur in June 2005 attended by country representatives from Australia, China, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines and Vietnam, it was discussed that the different participating countries employed different methods of analysis for their rainfall intensity-duration-frequency (RIDF) curves. Thus, during this workshop, it was decided that a worthwhile undertaking of the group would be to learn from the various participating countries how their RIDF analysis are conducted. At the end of the workshop, the different country representatives were asked to supply extreme rainfall data from their own countries to be sent to everyone so that a comparison of the various methods used in RIDF analysis and subsequently estimating design rainfalls could be made by individuals from participating countries.

Specifically, annual maximum series of durations ranging from 5 minutes to over 15 days were supplied by participating countries. The list of countries and number of rainfall stations supplied are:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Japan	5 sites
Republic of Korea	3 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites

The ensuing Chapters 2 through 10 present the methodologies and results of RIDF analysis from the nine participating countries. The final Chapter 11 presents a summary and discussions of the RIDF analyses presented by the various participating countries.

1.2 Contributing Countries and Authors

The following are the contributing countries and authors in the order the ensuing chapters are presented.

Chapter	Country	Authors
2	Australia	Trevor Daniell and Ross James
3	People's Republic of China	Qin Huang, Yuanfang Chen, Xinkai Li and Sui Xu
4	Indonesia	Agung Bagiawan Ibrahim
5	Japan	Kaoru Takara and Le Minh Nhat
6	Malaysia	Mohd Zaki M.Amin, Mohd Nor M.Desa and Zalina Mohd Daud
7	New Zealand	Craig Thompson
8	Republic of Korea	Hong-Kee Jee, Woon-Ki Yeo, Joong-Hoon Kim and Soontak Lee
9	Philippines	Guillermo Q. Tabios III
10	Vietnam	Tran Thuc, Dang Quang Thinh, Huynh Lan Huong and Phung Thu Trang

Chapter 2 Australia

Trevor Daniell and Ross James

2.1 Introduction

Investigations of extreme rainfalls by the scientific and engineering community serves several purposes; (i) the estimation of extreme rainfalls for design purposes, (ii) the assessment of the rarity of observed rainfalls, (iii) comparison of methods to estimate design rainfalls. This chapter briefly presents a method to be preferred in design rainfall estimation in Australia

2.2 Methodology

The Australian procedure for calculating rainfall IDF values is specific to Australia and so cannot be applied to data from other countries as shown on the web site BOM (2008). Therefore, for this project a distribution was fitted to each of the data sets provided. The distribution used and the fitting procedure are as recommended by a recent project in Australia (Jacob et al, 2005) undertaken as the first step of a larger project to update the Australian IDF procedure.

In this project five three-parameter distributions were tested for the best fit. These distributions were the Generalised Logistic, Generalised Extreme Value (GEV), Generalised Normal, Pearson Type III and Generalised Pareto. In the majority of cases, the GEV gave the best fit and also gave an acceptable fit to site data in greater than 90% of cases for durations from 1 hour to 72 hours. The Australian analysis for this current project was therefore done using the GEV distribution and the fitting procedure, as recommended by Jakob et al. (2005).

The L-moments for the data were calculated and the parameters of the generalised extreme value (GEV) distribution were estimated. The IDF values were calculated for each station at the durations of the data provided and for ARI of 1, 2, 5, 10, 20, 50 and 100 years. In Australia recommended practise is to calculate IDF for the more frequent events (ARI of 1, 2, 5 and 10 years) from the partial duration series. Therefore, the IDF values for ARI of 1, 2, 5 and 10 years calculated from the provided annual maximum series were adjusted using the relationship between the ARI from annual maximum series (T_A) and partial duration series (T_P) given by

$$T_A = e^{1/TP} / (e^{1/TP} - 1) \qquad (1)$$

The ARI for the annual maximum series corresponding to the partial duration series ARI of 1, 2, 5 and 10 year were 1.58, 2.54, 5.52 and 10.51 respectively

The ARI for the annual maximum series corresponding to the partial duration series ARI of 1, 2, 5 and 10 year are given below.

Table 2.1 ARI values for partial duration series

T_P	T_A
1	1.58
2	2.54
5	5.52
10	10.51

An apparent error was found in the Japanese data. For the site Toyohasi a large value of 12402 appeared against the date 1996 H8 7 8. This was changed to 124.2.

Data from Vietnam was very short in length, 13 years and 6 years. Consequently, the IDF values for larger ARI should be treated with considerable caution. Also, data was provided for both 24 hour and 1 day. It appears that the 24h data came from the continuous rainfall recorder records used to provide the other shorter duration data with the 1 day rainfall data possibly coming from a daily rain gauge. Generally, the IDF values obtained from daily accumulations will be smaller than those from a continuous recorder, as is shown by the calculated 24h and 1 day results.

The IDF curves were plotted and then smoothed to eliminate any crossings. Smoothing was achieved by adjusting the parameters of the distribution. The stations and durations for which smoothing was required are detailed in the following table.

Country	Station	Duration
Australia	Geraldton	720 min
Indonesia	Ngurah Rai, Denpasar, Bali	5, 10 & 360 min
Korea	Andong	2, 3, 4 & 72 h
Malaysia	EMPANGAN GENTING KELAN at W.PERSEKUTUAN	3 h
New Zealand	E14272	2 d
Philippines	Baler	6h, 12 h & 1 d
	Dagupan	10 min, 12 h
Vietnam	Hanoi	1, 2, 6 h & 2 d
	QuyNhon	12 h, 1 & 2 d

An examination of the plotted curves (not included) shows that further improvements could be obtained with additional smoothing however the effort was not considered justified at this stage.

2.3 Data supplied

The Annual maximum series of durations ranging from 5 minutes to over 15 days were supplied by participating countries. Countries that supplied data were:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	2 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

The final IDF values for each station are shown in Appendix 2

2.4 Acknowledgments

The Bureau of Meteorology Australia carried out the analysis and supplied the data for Australia's stations.

2.5 References

Jacob Dorte, Taylor Brian, Xuereb Karin (2005) A Pilot study to explore methods for deriving design rainfalls for Australia, Engineers Australia, 29th Hydrology and Water Resources Symposium, February 21-23, Canberra.

BOM, Hydrometeorological Advisory Service (2008) Design IFD Rainfall, Accessed June 2008, http://www.bom.gov.au/hydro/has/ifd.shtml

2.6 Appendix Chapter2 Results of RIDF Analysis

AUSTRALIA

8051 GERALDTON AIRPORT

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	5.29	6.51	8.20	9.55	10.90	12.87	14.43
2	12 M	8.36	10.48	13.15	15.09	16.88	19.28	21.00
3	18 M	10.45	12.93	15.96	18.07	19.98	22.44	24.14
4	30 M	13.09	16.24	20.40	23.55	26.59	30.82	33.99
5	60 M	16.09	19.95	26.15	31.83	38.28	49.19	59.12
6	120 M	20.53	26.12	34.57	41.87	49.75	62.31	73.08
7	180 M	23.78	30.51	40.52	49.02	58.08	72.29	84.27
8	360 M	29.52	37.77	50.31	61.20	73.01	91.95	108.27
9	720 M	35.87	45.92	60.74	73.23	86.43	106.94	124.10
10	1440 M	42.79	53.91	69.33	81.57	93.87	111.85	126.01
11	2880 M	49.30	61.24	77.03	88.97	100.48	116.53	128.56
12	4320 M	54.45	67.73	85.29	98.57	111.37	129.23	142.61

14015 DARWIN AIRPORT

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	15.64	18.24	21.48	23.78	25.88	28.64	30.59
2	12 M	23.44	26.64	30.62	33.46	36.05	39.44	41.83
3	18 M	30.97	34.84	39.01	41.58	43.66	46.04	47.48
4	30 M	42.33	47.29	52.73	56.14	58.94	62.18	64.18
5	60 M	54.63	62.64	73.22	81.23	88.95	99.72	107.79
6	120 M	66.71	78.36	92.05	101.23	109.23	119.15	125.74
7	180 M	75.07	88.54	103.50	112.99	120.87	130.12	135.91
8	360 M	84.40	100.33	122.82	140.99	159.51	187.10	209.21
9	720 M	96.57	115.82	144.92	170.06	197.20	240.44	277.53
10	1440 M	116.10	142.29	182.77	218.50	257.78	321.76	377.84
11	2880 M	155.85	192.81	246.54	291.21	337.88	409.43	468.45
12	4320 M	185.37	230.19	292.80	342.80	393.29	467.66	526.56

15590 ALICE SPRINGS AIRPORT

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	4.82	6.47	8.82	10.72	12.68	15.61	17.97
2	12 M	7.24	10.02	14.19	17.76	21.59	27.64	32.78
3	18 M	9.03	12.83	18.75	24.03	29.89	39.51	48.03
4	30 M	11.68	16.79	24.90	32.26	40.54	54.40	66.89
5	60 M	15.50	22.35	32.77	41.83	51.67	67.44	81.05
6	120 M	19.91	28.64	41.45	52.18	63.47	80.91	95.42
7	180 M	22.92	32.91	48.13	61.39	75.79	98.94	118.94
8	360 M	28.66	40.99	59.38	75.07	91.82	118.17	140.48
9	720 M	34.82	49.31	71.94	92.13	114.51	151.36	184.00
10	1440 M	41.17	57.80	84.63	109.33	137.49	185.35	229.13
11	2880 M	49.35	71.69	108.28	142.50	182.00	250.18	313.52
12	4320 M	53.41	78.53	119.92	158.83	203.96	282.32	355.52

23000 ADELAIDE WEST TERRACE

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	4.23	5.51	7.38	8.93	10.54	13.00	15.03
2	12 M	6.10	7.82	10.29	12.30	14.38	17.51	20.05
3	18 M	7.27	9.26	12.15	14.57	17.10	20.99	24.21
4	30 M	8.88	11.26	15.12	18.70	22.78	29.76	36.16
5	60 M	11.66	14.61	19.72	24.78	30.91	42.11	53.13
6	120 M	15.00	18.75	25.54	32.52	41.29	57.99	75.11
7	180 M	17.46	21.51	28.93	36.64	46.41	65.21	84.69
8	360 M	23.18	28.62	37.90	46.92	57.69	77.04	95.73
9	720 M	30.19	37.42	48.25	57.52	67.44	83.10	96.40
10	1440 M	36.16	44.96	57.59	67.98	78.71	94.97	108.23
11	2880 M	42.72	51.72	65.24	76.85	89.31	109.04	125.85
12	4320 M	47.13	57.47	72.13	84.02	96.18	114.36	128.99

31011 CAIRNS AERO

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	11.11	13.54	17.08	20.03	23.11	27.84	31.74
2	12 M	18.05	21.28	25.07	27.59	29.78	32.48	34.26
3	18 M	23.79	28.04	32.42	35.01	37.02	39.22	40.49
4	30 M	33.14	38.66	43.76	46.45	48.36	50.23	51.20
5	60 M	48.16	55.88	63.14	67.01	69.80	72.58	74.04
6	120 M	63.67	75.71	88.21	95.63	101.45	107.84	111.59
7	180 M	73.19	88.44	106.22	118.08	128.37	141.03	149.38
8	360 M	95.67	119.98	150.06	171.33	190.71	216.01	233.73
9	720 M	119.29	153.26	198.17	232.14	264.89	310.57	344.80
10	1440 M	156.18	202.56	263.88	310.26	354.96	417.32	464.05
11	2880 M	215.46	279.42	363.97	427.93	489.58	575.57	640.01
12	4320 M	243.41	315.86	415.74	494.51	573.18	687.57	776.99

40223 BRISBANE AERO

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	10.53	13.19	16.69	19.35	21.90	25.47	28.15
2	12 M	15.68	19.67	25.40	30.09	34.93	42.25	48.19
3	18 M	20.41	25.59	32.87	38.71	44.64	53.42	60.41
4	30 M	26.81	33.36	42.42	49.58	56.76	67.23	75.44
5	60 M	34.12	43.25	56.63	67.83	79.61	97.79	112.90
6	120 M	44.22	56.10	72.82	86.29	99.98	120.30	136.53
7	180 M	51.64	64.81	83.44	98.49	113.85	136.74	155.10
8	360 M	68.32	85.39	107.95	125.02	141.47	164.42	181.62
9	720 M	86.53	109.67	140.27	163.41	185.72	216.84	240.16
10	1440 M	110.04	143.48	187.69	221.12	253.35	298.31	332.00
11	2880 M	133.40	175.93	234.99	281.91	329.05	398.10	452.47
12	4320 M	154.46	205.44	272.84	323.82	372.96	441.50	492.87

44021 CHARLEVILLE AERO

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	6.98	8.85	11.32	13.19	14.99	17.51	19.39
2	12 M	11.03	13.88	17.24	19.51	21.49	23.96	25.61
3	18 M	13.68	17.22	21.63	24.76	27.63	31.40	34.06
4	30 M	16.95	20.94	26.22	30.21	34.06	39.42	43.44
5	60 M	21.50	26.68	33.52	38.70	43.69	50.65	55.87
6	120 M	26.22	33.13	42.28	49.20	55.87	65.17	72.14
7	180 M	30.21	37.94	48.16	55.89	63.34	73.73	81.52
8	360 M	38.44	48.26	61.25	71.07	80.54	93.75	103.64
9	720 M	45.97	57.75	74.05	86.94	99.86	118.69	133.47
10	1440 M	55.14	67.86	85.62	99.81	114.14	135.24	151.95
11	2880 M	65.31	81.92	106.20	126.51	147.82	180.69	207.95
12	4320 M	70.36	88.27	114.87	137.45	161.46	199.05	230.72

66062 SYDNEY (OBSERVATORY HILL)

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	8.94	10.96	13.88	16.30	18.82	22.69	25.86
2	12 M	13.02	15.82	19.97	23.47	27.19	32.98	37.84
3	18 M	16.64	20.58	26.24	30.89	35.71	43.01	48.96
4	30 M	21.59	27.00	34.85	41.37	48.17	58.60	67.20
5	60 M	29.76	38.30	50.74	61.09	71.91	88.51	102.22
6	120 M	39.80	51.27	68.14	82.32	97.27	120.46	139.81
7	180 M	47.05	60.28	79.39	95.17	111.55	136.48	156.89
8	360 M	60.63	76.92	100.74	120.66	141.56	173.80	200.54
9	720 M	78.36	100.35	131.01	155.46	180.12	216.38	245.05
10	1440 M	100.64	127.34	165.60	196.95	229.30	278.20	317.95
11	2880 M	125.55	159.25	209.56	252.52	298.42	370.67	431.89
12	4320 M	140.69	178.84	234.81	281.75	331.16	407.59	471.20

86071 MELBOURNE REGIONAL OFFICE

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	5.20	6.69	8.99	11.01	13.23	16.81	19.94
2	12 M	7.65	9.90	13.25	16.09	19.10	23.82	27.79
3	18 M	9.25	11.92	16.00	19.53	23.37	29.52	34.82
4	30 M	11.28	14.52	19.59	24.13	29.18	37.52	44.92
5	60 M	14.45	18.23	24.31	29.92	36.30	47.14	57.05
6	120 M	18.67	23.13	30.09	36.28	43.13	54.38	64.32
7	180 M	22.28	27.33	34.68	40.80	47.18	56.97	65.04
8	360 M	29.37	35.73	44.57	51.61	58.69	69.07	77.27
9	720 M	36.96	45.54	56.89	65.47	73.74	85.27	93.92
10	1440 M	44.54	56.21	72.40	85.24	98.12	116.96	131.77
11	2880 M	53.50	68.11	88.69	105.27	122.15	147.22	167.25
12	4320 M	57.96	74.07	96.80	115.13	133.79	161.55	183.74

94029 HOBART (ELLERSLIE ROAD)

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	6 M	3.17	4.35	6.22	7.91	9.80	12.96	15.80
2	12 M	4.81	6.47	9.01	11.23	13.67	17.60	21.03
3	18 M	6.11	8.13	11.10	13.60	16.25	20.35	23.78
4	30 M	7.93	10.30	13.66	16.36	19.12	23.23	26.53
5	60 M	10.73	13.27	16.80	19.60	22.42	26.55	29.81
6	120 M	15.01	18.09	22.34	25.71	29.07	33.98	37.83
7	180 M	18.43	22.21	27.62	32.04	36.58	43.41	48.94
8	360 M	25.32	31.26	39.66	46.47	53.44	63.84	72.20
9	720 M	34.67	43.63	56.48	66.99	77.83	94.21	107.50
10	1440 M	44.32	56.94	74.78	89.22	103.96	125.95	143.59
11	2880 M	51.87	67.32	89.57	107.90	126.89	155.72	179.28
12	4320 M	56.45	72.60	95.81	114.87	134.58	164.44	188.77

CHINA
Changzhou

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10min	16.62	18.87	21.06	22.27	23.18	24.10	24.61
2	30min	30.04	35.40	40.75	43.79	46.11	48.55	49.93
3	60min	37.14	43.87	50.18	53.55	55.97	58.37	59.63
4	2hr	44.31	51.06	57.69	61.39	64.16	67.03	68.61
5	3hr	52.03	58.94	65.64	69.34	72.08	74.90	76.43
6	9hr	71.91	83.78	99.46	111.32	122.76	138.71	150.66
7	12hr	77.56	92.60	113.59	130.35	147.25	172.13	191.82
8	1day	90.62	108.16	132.82	152.67	172.83	202.74	226.61
9	3day	112.13	134.05	164.84	189.58	214.67	251.83	281.44

Shahe Reservoir

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10min	13.95	16.36	20.28	23.92	28.11	35.30	41.93
2	30min	27.93	33.50	40.31	45.05	49.33	54.83	58.63
3	60min	37.23	43.25	50.36	55.16	59.37	64.61	68.11
4	2hr	43.43	49.10	56.15	61.18	65.78	71.83	76.09
5	3hr	47.36	54.09	62.98	69.70	76.19	85.23	92.00
6	9hr	61.22	71.22	83.16	91.32	98.54	107.64	113.80
7	12hr	64.99	76.32	91.31	102.65	113.57	128.82	140.24
8	1day	80.14	97.06	121.53	141.78	162.85	195.00	221.39
9	3day	104.02	126.40	158.77	185.52	213.34	255.75	290.54

Yongcuan

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10min	43.05	50.95	61.38	69.27	76.88	87.49	95.44
2	30min	60.69	73.91	90.68	102.84	114.15	129.29	140.17
3	60min	74.66	90.56	110.14	123.94	136.47	152.76	164.12
4	2hr	93.14	112.79	138.77	158.42	177.36	203.79	223.59
5	3hr	100.27	124.17	158.80	187.51	217.41	263.11	300.69
6	9hr	152.78	193.41	249.60	294.05	338.57	403.52	454.45
7	12hr	198.29	238.18	295.67	343.05	392.17	466.83	527.86
8	1day	288.28	336.51	400.27	448.50	494.99	559.83	608.43
9	3day	409.51	467.31	543.72	601.52	657.23	734.94	793.18

INDONESIA
Ngurah Rai, Denpasar, Bali

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	11.39	14.13	18.26	21.82	25.67	31.79	37.04
2	10 min	20.02	24.10	28.60	31.44	33.79	36.53	38.24
3	15 min	26.47	31.37	37.43	41.70	45.60	50.68	54.24
4	30 min	43.15	50.05	57.29	61.63	65.06	68.88	71.13
5	45 min	48.56	55.39	64.43	71.26	77.85	87.04	93.92
6	60 min	54.96	63.86	75.63	84.53	93.10	105.07	114.03
7	120 min	66.12	77.70	91.31	100.45	108.42	118.30	124.88
8	360 min	92.33	108.42	122.69	129.88	134.81	139.44	141.74
9	720 min	105.14	133.53	163.17	180.83	194.75	210.12	219.16

JAPAN
Nagoya

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10 min	13.46	15.71	18.23	19.86	21.22	22.84	23.86
2	30 min	23.13	28.44	35.47	40.78	45.90	53.05	58.40
3	60 min	33.52	42.53	55.35	65.76	76.44	92.45	105.35
4	120 min	44.06	57.53	76.12	90.80	105.49	126.88	143.63
5	180 min	50.41	65.32	87.56	106.51	126.74	158.52	185.41
6	6 h	68.04	84.39	109.86	132.52	157.61	198.80	235.19
7	12 h	81.99	101.62	133.57	163.25	197.33	255.78	309.73
8	21 h	100.99	126.23	166.94	204.43	247.16	319.79	386.24

Ohkusa

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10 min	14.18	17.41	20.87	22.99	24.70	26.63	27.80
2	30 min	28.01	34.38	41.54	46.15	50.01	54.61	57.53
3	60 min	37.35	45.93	56.62	64.26	71.27	80.49	87.01
4	120 min	46.11	58.13	75.27	89.24	103.61	125.21	142.69
5	180 min	52.10	66.34	88.02	106.88	127.37	160.26	188.67
6	6 h	65.78	83.10	110.46	135.14	162.77	208.76	249.96
7	12 h	88.70	108.97	139.53	165.88	194.26	239.38	277.97
8	21 h	110.47	135.01	170.27	199.23	229.18	274.55	311.52

Okazaki

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10 min	10.61	13.04	15.96	17.98	19.77	22.05	23.61
2	30 min	20.21	25.19	31.48	36.03	40.25	45.87	49.89
3	60 min	28.68	37.34	48.19	55.96	63.12	72.59	79.31
4	120 min	39.27	51.30	67.21	79.24	90.83	107.01	119.13
5	180 min	48.37	62.44	81.04	95.11	108.68	127.60	141.78
6	6 h	64.75	82.20	104.31	120.35	135.28	155.25	169.60
7	12 h	81.66	101.99	128.86	149.19	168.78	196.11	216.59
8	21 h	101.28	125.29	157.03	181.03	204.18	236.46	260.65

Taguchi

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10 min	11.39	13.30	16.08	18.39	20.81	24.51	27.57
2	30 min	24.41	28.22	33.49	37.63	41.78	47.80	52.51
3	60 min	37.13	43.60	52.14	58.60	64.83	73.52	80.04
4	120 min	53.97	64.32	76.92	85.69	93.57	103.70	110.67
5	180 min	64.30	77.88	95.83	109.41	122.50	140.75	154.43
6	6 h	95.16	116.89	144.33	164.16	182.54	207.04	224.57
7	12 h	135.89	167.18	204.70	230.41	253.23	282.10	301.68
8	21 h	181.81	219.48	261.85	289.06	311.93	339.09	356.34

Toyohashi

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10 min	11.49	13.62	16.45	18.58	20.64	23.51	25.66
2	30 min	22.49	27.38	33.83	38.72	43.42	49.99	54.91
3	60 min	32.95	40.73	51.00	58.77	66.26	76.71	84.54
4	120 min	45.62	55.89	70.99	83.68	97.07	117.83	135.14
5	180 min	54.89	67.92	86.38	101.32	116.58	139.38	157.68
6	6 h	75.11	91.85	115.31	134.10	153.13	181.25	203.59
7	12 h	92.74	113.98	146.08	173.81	203.75	251.45	292.36
8	21 h	111.21	135.70	172.24	203.41	236.68	289.04	333.35

KOREA

Daegu

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10min	10.48	13.23	16.56	18.88	20.96	23.62	25.46
2	30min	20.10	25.48	32.59	37.97	43.15	50.38	55.80
3	1hr	28.76	36.07	45.73	53.03	60.07	69.90	77.26
4	2hr	38.97	48.72	61.60	71.35	80.74	93.84	103.66
5	3hr	45.25	56.71	71.86	83.31	94.36	109.76	121.30
6	6hr	57.35	72.14	91.69	106.48	120.74	140.63	155.53
7	9hr	65.08	82.35	105.19	122.46	139.11	162.33	179.74
8	12hr	71.27	90.35	115.57	134.64	153.03	178.67	197.89
9	15hr	76.64	97.58	125.26	146.19	166.37	194.53	215.62
10	18hr	81.70	104.13	133.78	156.21	177.83	207.98	230.58
11	24hr	92.93	119.06	152.14	176.09	198.35	228.08	249.41
12	48hr	108.87	138.72	175.90	202.40	226.69	258.63	281.15
13	72hr	120.53	154.35	199.07	232.88	265.48	310.96	345.03

Andong

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10min	10.53	12.57	15.82	18.78	22.11	27.69	32.72
2	30min	17.10	20.08	25.12	29.99	35.78	46.10	56.01
3	1hr	23.68	28.44	36.11	43.15	51.15	64.70	77.06
4	2hr	33.60	39.04	48.06	56.60	66.56	83.97	100.33
5	3hr	40.41	47.57	58.26	67.38	77.12	92.43	105.40
6	4hr	48.34	56.95	68.79	78.12	87.42	100.92	111.46
7	6hr	53.29	61.20	72.39	81.46	90.72	104.55	115.65
8	9hr	61.71	70.81	82.83	91.92	100.68	112.91	122.07
9	12hr	69.52	80.47	94.94	105.88	116.43	131.15	142.17
10	24hr	79.46	90.47	109.05	126.93	148.08	185.67	221.62
11	48hr	93.72	113.55	144.17	171.17	200.84	249.13	291.41
12	72hr	102.14	127.71	164.35	194.38	225.37	272.20	310.27

MALAYSIA

Site 3117070 PUSAT PENYELIDEKAN at JPS AMPANG, SELANGOR

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	15min	32.01	38.49	46.46	52.05	57.13	63.71	68.29
2	30min	45.17	53.61	63.13	69.25	74.40	80.53	84.42
3	60min	61.09	71.32	81.93	88.21	93.13	98.53	101.69
4	3hrs	80.33	91.28	103.43	111.12	117.52	125.01	129.70
5	6hrs	87.77	97.50	107.59	113.55	118.23	123.35	126.35
6	12hrs	93.98	103.87	114.25	120.47	125.39	130.86	134.10
7	24hrs	107.18	117.91	130.81	139.67	147.54	157.54	164.33
8	72hrs	140.25	158.49	180.56	195.83	209.50	226.95	238.91

Site 3216001 KG. SG. TUA at W.PERSEKUTUAN

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	15min	27.61	32.86	38.20	41.31	43.71	46.30	47.78
2	30min	38.82	44.53	50.82	54.79	58.07	61.89	64.27
3	60min	53.21	62.09	73.83	82.71	91.27	103.21	112.16
4	3hrs	71.70	82.82	97.52	108.63	119.35	134.29	145.49
5	6hrs	79.36	89.31	104.96	119.00	134.66	160.61	183.74
6	12hrs	84.60	97.00	115.62	131.59	148.73	175.83	198.91
7	24hrs	94.07	107.87	127.96	144.69	162.20	189.08	211.29
8	72hrs	133.40	150.57	175.22	195.46	216.37	248.03	273.80

Site 3217002 EMPANGAN GENTING KELAN at W.PERSEKUTUAN

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	15min	28.34	33.05	37.95	40.88	43.18	45.73	47.23
2	30min	38.92	45.04	52.50	57.71	62.40	68.44	72.61
3	60min	52.78	60.90	72.18	81.14	90.15	103.34	113.72
4	3hrs	74.34	85.96	99.47	108.44	116.20	125.71	131.95
5	6hrs	82.45	96.41	111.23	120.21	127.39	135.46	140.28
6	12hrs	85.11	100.25	116.71	126.94	135.28	144.87	150.76
7	24hrs	96.10	111.76	128.82	139.42	148.09	158.07	164.20
8	72hrs	133.31	155.38	181.08	198.19	213.01	231.22	243.22

NEW ZEALAND

E14272

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10m	5.68	6.81	8.59	10.20	12.01	15.01	17.71
2	20m	8.62	10.42	13.21	15.69	18.42	22.90	26.85
3	30m	10.94	13.03	16.44	19.60	23.24	29.49	35.25
4	60m	15.86	18.43	22.96	27.50	33.07	43.42	53.74
5	2h	22.42	26.21	32.31	37.93	44.32	55.16	65.07
6	6h	39.94	46.35	54.83	61.24	67.43	76.05	82.51
7	12h	52.69	60.57	71.90	81.22	90.88	105.53	117.48
8	24h	66.76	79.12	96.62	110.77	125.22	146.78	164.08
9	48h	81.35	97.23	119.58	137.58	155.88	183.04	204.73
10	72h	90.06	107.70	131.02	148.66	165.66	189.38	207.16

E15021

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10m	7.37	8.67	10.10	10.99	11.73	12.58	13.11
2	20m	10.88	12.67	14.71	16.03	17.16	18.51	19.38
3	30m	13.25	15.66	18.70	20.90	22.93	25.64	27.58
4	60m	19.72	22.91	26.57	28.99	31.07	33.60	35.25
5	2h	29.53	33.81	38.73	41.96	44.71	48.06	50.23
6	6h	54.99	66.48	80.92	91.30	100.89	113.61	122.66
7	12h	76.99	93.56	117.22	136.56	156.45	186.42	210.70
8	24h	104.01	122.97	150.93	174.50	199.40	238.11	270.48
9	48h	131.98	156.29	188.43	212.73	236.16	268.84	293.33
10	72h	148.70	171.30	201.18	223.77	245.56	275.94	298.71

E14296

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10m	5.97	7.24	9.16	10.83	12.63	15.52	18.01
2	20m	9.56	11.19	13.35	14.98	16.55	18.74	20.38
3	30m	12.63	14.64	16.85	18.24	19.39	20.73	21.56
4	60m	17.42	19.88	22.46	23.99	25.20	26.54	27.33
5	2h	22.86	26.60	32.47	37.73	43.58	53.24	61.84
6	6h	46.63	56.76	72.78	87.28	103.53	130.66	155.03
7	12h	71.36	87.29	112.98	136.62	163.54	209.27	251.07
8	24h	103.30	126.18	160.92	191.06	223.69	275.91	320.87
9	48h	138.39	173.16	219.12	253.88	287.39	334.13	369.15
10	72h	159.78	197.83	248.15	286.20	322.88	374.05	412.39

E14272

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	1D	57.25	67.84	83.30	96.22	109.77	130.64	147.95

2	2D	76.35	92.01	113.56	130.53	147.46	172.02	191.20
3	3D	86.76	104.38	127.66	145.27	162.24	185.92	203.67

E15011

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	1D	82.91	104.34	131.51	151.22	169.55	194.09	211.71
2	2D	110.49	138.65	175.87	204.02	231.16	269.02	297.38
3	3D	124.25	152.36	189.53	217.64	244.74	282.54	310.86

E14294

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	1D	95.56	122.73	162.00	194.43	228.13	279.47	321.54
2	2D	137.47	178.31	238.57	289.41	343.16	426.78	496.77
3	3D	159.07	207.72	278.00	336.07	396.40	488.30	563.61

PHILIPPINES
NAIA

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	11.61	14.19	18.55	22.77	27.77	36.68	45.23
2	10 min	18.11	22.37	29.34	35.84	43.34	56.26	68.25
3	15 min	23.34	29.27	38.66	47.15	56.67	72.57	86.84
4	20 min	28.29	35.40	46.42	56.20	66.98	84.61	100.12
5	30 min	34.64	44.03	58.39	70.95	84.65	106.74	125.92
6	45 min	40.87	52.50	70.19	85.58	102.28	129.06	152.17
7	60 min	44.57	57.62	77.88	95.83	115.64	148.02	176.52
8	80 min	50.69	65.02	87.83	108.58	131.96	171.21	206.65
9	100 min	55.76	71.89	97.69	121.27	147.95	192.95	233.78
10	120 min	58.71	76.22	104.55	130.72	160.63	211.64	258.46
11	150 min	64.12	84.23	116.20	145.22	177.88	232.62	281.97
12	3 hrs	68.70	90.85	125.87	157.48	192.90	251.91	304.81
13	6 hrs	89.64	120.11	167.11	208.53	254.01	327.96	392.68
14	12 hrs	112.20	149.97	207.56	257.77	312.36	400.13	476.07
15	1-day	119.62	164.71	233.87	294.50	360.73	467.83	561.02
16	2-day	164.41	222.70	315.28	399.26	493.74	651.91	794.40
17	3-day	196.51	265.62	371.62	464.53	566.05	730.19	873.01

Baler

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	14.25	17.31	22.44	27.35	33.15	43.39	53.14
2	10 min	20.65	24.89	32.19	39.35	47.96	63.59	78.84
3	15 min	26.13	30.88	39.44	48.22	59.19	80.02	101.28
4	20 min	30.30	35.61	45.43	55.73	68.86	94.39	121.05
5	30 min	36.68	43.88	56.99	70.57	87.68	120.48	154.28
6	45 min	44.54	53.68	69.90	86.32	106.58	144.49	182.63
7	60 min	51.00	61.50	79.80	98.00	120.14	160.81	201.01
8	80 min	60.53	73.23	94.56	115.01	139.12	181.80	222.45
9	100 min	68.74	83.37	107.79	131.07	158.39	206.47	252.02
10	120 min	74.90	91.25	118.66	144.87	175.71	230.16	281.90
11	150 min	83.31	103.18	135.29	164.91	198.71	256.26	308.99
12	3 hrs	88.91	111.43	147.64	180.88	218.66	282.67	341.05
13	6 hrs	114.79	144.56	190.82	231.89	277.25	351.56	417.05
14	12 hrs	138.33	172.19	223.95	269.17	318.45	397.88	466.76
15	1-day	175.26	208.00	256.86	298.53	343.02	413.01	472.26
16	2-day	237.46	279.28	334.56	376.38	416.69	472.92	515.05
17	3-day	268.74	313.70	377.66	429.70	483.08	563.16	627.79

Ambulong

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	11.32	14.53	19.69	24.44	29.84	39.01	47.39
2	10 min	17.77	22.69	30.01	36.24	42.88	53.29	62.09
3	15 min	23.24	29.32	38.16	45.52	53.21	65.02	74.77
4	20 min	28.35	35.38	45.45	53.69	62.19	75.03	85.46
5	30 min	35.10	43.86	56.65	67.34	78.55	95.82	110.14
6	45 min	40.96	51.51	67.48	81.30	96.24	120.09	140.57
7	60 min	45.53	57.61	75.65	91.05	107.50	133.40	155.35
8	80 min	51.46	64.73	85.17	103.15	122.87	154.88	182.85
9	100 min	55.63	70.44	93.65	114.41	137.50	175.63	209.51
10	120 min	60.03	76.22	101.44	123.88	148.72	189.50	225.54
11	150 min	64.82	82.84	110.96	136.03	163.81	209.50	249.93
12	3 hrs	68.69	87.81	118.19	145.74	176.74	228.63	275.38
13	6 hrs	87.43	113.04	154.01	191.45	233.82	305.27	370.11
14	12 hrs	110.86	144.02	194.78	239.21	287.69	365.94	433.92
15	1-day	132.01	172.29	231.57	281.46	334.11	415.81	484.03
16	2-day	178.10	234.54	319.23	391.88	469.82	593.12	698.09
17	3-day	201.45	264.20	357.17	435.90	519.44	649.92	759.57

Puerto

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	7.77	9.43	12.13	14.64	17.51	22.42	26.94
2	10 min	11.73	14.26	18.54	22.67	27.58	36.34	44.75
3	15 min	14.94	18.15	23.61	28.91	35.22	46.53	57.43
4	20 min	17.66	21.40	27.70	33.73	40.84	53.43	65.42
5	30 min	21.91	26.53	34.17	41.40	49.83	64.54	78.36
6	45 min	26.58	31.93	40.79	49.16	58.90	75.91	91.87
7	60 min	29.44	35.28	45.02	54.28	65.13	84.21	102.25
8	80 min	33.66	40.49	52.01	63.08	76.17	99.41	121.62
9	100 min	38.82	46.42	59.23	71.54	86.09	111.94	136.64
10	120 min	42.30	50.64	64.68	78.17	94.10	122.38	149.38
11	150 min	46.70	56.03	71.73	86.81	104.63	136.25	166.44
12	3 hrs	50.92	61.02	78.04	94.39	113.70	147.97	180.68
13	6 hrs	67.01	80.44	102.97	124.53	149.92	194.78	237.44
14	12 hrs	81.90	98.57	126.27	152.51	183.16	236.81	287.33
15	1-day	92.91	111.90	143.56	173.68	208.99	271.02	329.68
16	2-day	125.82	158.45	209.49	255.08	305.72	389.21	463.27
17	3-day	142.51	179.54	238.11	291.03	350.36	449.28	538.04

Daet

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	12.28	14.87	19.50	24.20	30.02	40.97	52.04
2	10 min	19.04	22.30	28.24	34.42	42.24	57.29	72.86
3	15 min	24.65	29.15	36.87	44.45	53.55	70.02	86.07
4	20 min	30.13	36.02	45.50	54.22	64.14	80.98	96.37
5	30 min	39.46	45.70	55.47	64.21	73.91	89.93	104.15
6	45 min	46.02	53.33	65.05	75.78	87.95	108.53	127.25
7	60 min	50.93	59.23	72.81	85.50	100.14	125.39	148.82
8	80 min	58.25	68.29	85.07	101.10	119.93	153.12	184.61
9	100 min	63.15	74.60	94.18	113.30	136.20	177.49	217.55
10	120 min	67.42	81.08	104.30	126.82	153.64	201.71	248.04
11	150 min	74.43	91.18	118.88	145.03	175.46	228.51	278.27
12	3 hrs	80.98	99.37	128.99	156.22	187.22	239.83	287.88
13	6 hrs	109.00	132.78	169.80	202.71	239.11	298.84	351.56
14	12 hrs	141.40	175.01	224.43	265.99	309.82	377.79	434.48
15	1-day	171.74	218.12	279.44	325.82	370.54	432.90	479.63
16	2-day	236.11	291.67	365.12	420.68	474.23	548.93	604.91
17	3-day	258.28	315.06	393.77	456.19	518.83	610.43	682.45

Port Area

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	12.77	15.90	20.03	23.15	26.16	30.36	33.51
2	10 min	18.77	23.24	29.72	35.09	40.70	49.27	56.32
3	15 min	24.19	30.08	38.60	45.64	52.95	64.09	73.22
4	20 min	28.22	34.95	44.78	52.98	61.57	74.81	85.77
5	30 min	35.41	44.22	57.16	68.01	79.43	97.09	111.79
6	45 min	43.53	54.49	69.82	82.08	94.48	112.78	127.29
7	60 min	50.46	63.18	80.00	92.71	104.98	122.08	134.90
8	80 min	57.49	72.62	92.62	107.75	122.33	142.67	157.92
9	100 min	63.71	80.64	103.02	119.95	136.27	159.04	176.10
10	120 min	67.29	84.64	109.28	129.28	149.75	180.38	205.04
11	150 min	71.45	90.43	118.09	141.11	165.20	202.20	232.76
12	3 hrs	74.97	95.86	126.53	152.27	179.39	221.37	256.34
13	6 hrs	93.86	123.03	165.51	200.88	237.89	294.72	341.67
14	12 hrs	116.03	153.12	206.18	249.59	294.34	361.84	416.62
15	1-day	129.91	172.75	235.49	288.04	343.27	428.56	499.42
16	2-day	183.74	251.35	340.73	408.32	473.49	564.39	632.50
17	3-day	214.51	290.72	405.26	503.67	609.39	776.90	919.75

Dagupan

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	13.77	17.36	23.35	29.04	35.70	47.38	58.40
2	10 min	20.43	25.29	33.48	41.36	50.66	67.19	82.99
3	15 min	27.44	34.73	45.69	55.10	65.21	81.23	94.89
4	20 min	32.19	40.55	53.30	64.42	76.52	96.00	112.86
5	30 min	39.67	50.37	66.53	80.49	95.57	119.59	140.19
6	45 min	47.15	59.97	79.28	95.91	113.81	142.25	166.56
7	60 min	51.73	66.05	87.66	106.31	126.40	158.37	185.75
8	80 min	58.91	74.83	99.75	122.03	146.80	187.65	223.93
9	100 min	65.81	83.52	111.63	137.11	165.75	213.65	256.78
10	120 min	70.85	89.64	120.04	148.13	180.22	234.96	285.20
11	150 min	77.83	99.15	133.27	164.47	199.82	259.47	313.64
12	3 hrs	84.12	107.98	145.69	179.74	217.89	281.43	338.41
13	6 hrs	110.79	140.44	188.24	232.22	282.31	367.39	445.16
14	12 hrs	137.42	171.11	225.63	275.99	333.55	431.71	521.80

15	1-day	164.86	214.60	285.89	344.32	404.61	495.72	569.78
16	2-day	241.20	330.25	442.71	523.95	599.28	699.68	771.50
17	3-day	276.34	376.29	508.43	608.36	704.71	839.09	939.79

Baguio

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	5 min	14.49	19.35	28.75	39.09	52.79	80.71	111.27
2	10 min	22.60	30.48	45.39	61.46	82.39	124.14	168.89
3	15 min	29.27	39.66	59.13	79.90	106.74	159.76	216.05
4	20 min	34.83	46.95	69.84	94.43	126.41	190.03	258.07
5	30 min	43.24	58.66	87.70	118.79	159.12	239.09	324.34
6	45 min	50.91	69.03	103.50	140.77	189.49	287.07	392.09
7	60 min	56.96	77.12	115.36	156.61	210.43	317.97	433.41
8	80 min	67.21	93.11	140.60	190.14	252.96	374.25	500.15
9	100 min	72.24	106.04	164.93	223.44	294.56	425.13	554.08
10	120 min	84.90	119.98	182.11	244.82	322.08	466.27	610.97
11	150 min	98.14	139.34	210.44	280.39	364.73	518.08	668.07
12	3 hrs	107.48	152.01	228.79	304.28	395.23	560.46	721.95
13	6 hrs	166.81	227.27	328.58	425.44	539.42	740.67	931.90
14	12 hrs	243.52	332.82	464.77	576.26	694.32	878.27	1032.47
15	1-day	305.62	414.33	568.75	694.19	822.67	1015.12	1170.17
16	2-day	474.29	631.13	826.51	965.73	1093.35	1261.14	1379.51
17	3-day	558.56	737.22	941.68	1075.39	1189.44	1327.26	1416.39

VIETNAM
Hanoi

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	10 min	22.35	24.57	27.72	30.27	32.89	36.80	39.94
2	1 hour	47.87	65.71	84.95	96.81	106.42	117.37	124.04
3	2 hour	50.52	71.33	93.98	108.06	119.56	132.78	140.90
4	6 hour	83.79	105.51	125.24	135.43	142.56	149.42	152.91
5	12 hour	117.58	142.84	162.75	171.63	177.12	181.71	183.72
6	24 hour	151.39	172.05	186.01	191.29	194.14	196.19	196.95
7	1 day	121.89	140.89	155.66	162.14	166.11	169.38	170.79
8	2 day	155.87	187.82	226.81	254.02	278.52	310.07	331.86

AnNhon

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	1 hour	30.41	38.10	49.18	58.33	67.82	82.25	94.05
2	2 hour	49.97	56.75	67.94	78.50	90.79	112.18	132.23
3	6 hour	66.14	78.52	94.88	107.25	119.18	135.82	148.28
4	12 hour	94.62	118.39	143.41	158.44	170.37	183.64	191.52
5	24 hour	154.06	191.50	223.56	239.13	249.48	258.87	263.36
6	1 day	133.20	167.68	197.47	212.07	221.85	230.80	235.12
7	2 day	189.97	229.67	271.88	297.51	318.03	341.09	354.92

QuyNhon

		1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100yr
1	1 hour	32.89	39.91	49.18	56.19	62.95	72.37	79.44
2	2 hour	46.28	57.09	70.81	80.75	90.01	102.39	111.29
3	6 hour	74.41	92.40	111.73	123.59	133.17	144.05	150.64
4	12 hour	89.65	105.35	128.10	146.96	166.61	196.64	221.33
5	24 hour	115.11	144.99	178.68	200.38	218.65	240.39	254.24
6	1 day	89.28	116.84	150.45	173.91	195.04	222.24	241.03
7	2 day	157.44	186.83	215.05	230.49	241.82	253.33	259.54

Chapter 3 People's Republic of China

Qin Huang, Yuanfang Chen, Xinkai Li and Sui Xu

3.1 Introduction

Investigations of intensity duration frequency (IDF) curves using data from nine countries have several purposes; (i) the assessment of the rarity of observed rainfalls, (ii) the estimation of extreme rainfalls for design purposes, (iii) comparison of formulas to estimate design rainfalls and IDF.

The report arose from an APFRIEND Workshop in Kuala Lumpur in June 2005, whereby the country representatives attending the workshop were asked to supply extreme rainfall data so that a comparison of the various methods used in estimating design rainfalls / calculation of IDF could be made. This chapter briefly presents method used in the design rainfall estimation and calculation of IDF in China.

3.2 Methodology

Rainfall data analysis for nine countries have been carried out. Those data are used for estimating design rainfall. The Pearson Type III (P-III) probability distribution is commonly used in China for frequency analyses. Then, design rainfalls from those analyses are used to calculate rainfall intensity by using following formulas.

1. Sherman Formula

$$I = \frac{a}{t^n} \qquad (1)$$

2. Improved Sherman Formula

When the duration and rainfall intensity are plotted in a log-log plot, they result in some inconsistency. So, the formula was improved as follows

$$I = \begin{cases} \dfrac{a}{t^{n_1}}, & t \le T \\ \dfrac{a}{t^{n_2}}, & t > T \end{cases} \qquad (2)$$

Where, T is the duration at the point of intersection, and a is the rainfall intensity at duration 1h.

3. Horner Formula

$$I = \frac{a}{(t+b)^n} \qquad (3)$$

Where, a, b are the parameters to be estimated, and n is a parameter associated to a storm index.

The rainfall intensity and constant parameters of each method for each return period are calculated by the three formulas mentioned above. Least square method is used to determine the parameters of the three formulas used to represent intensity-duration relationships. In particular, the parameters are determine based on minimum of root mean square error.

3.3 Data supplied

Annual maximum rainfall series from durations ranging from 5 minutes to over 15 days were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries that supplied data were:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	2 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

The record lengths of each rainfall data series varied from a minimum of 6 years to over 90 years. Since it was assumed that each contributing country would have undertaken quality assurance checks before supplying data, no further error checking was undertaken.

3.4 Results

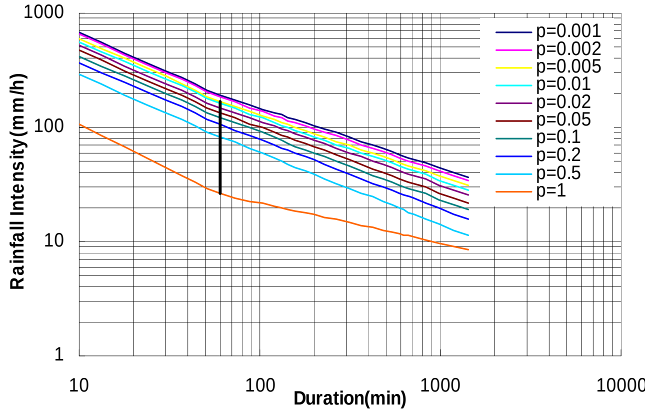
Table 3.1 Parameters of the 3 formulas for Philippines

station	parameter		P						
			0.005	0.01	0.02	0.05	0.1	0.2	0.5
Naia	1	n	-0.5570	-0.5566	-0.5563	-0.5560	-0.5563	-0.5590	-0.5730
		lnb	3.4689	3.3407	3.1946	2.9651	2.7525	2.4953	2.0543
	2	n1	-0.5144	-0.5144	-0.5144	-0.5134	-0.5134	-0.5144	-0.5254
		n2	-0.6704	-0.6704	-0.6714	-0.6724	-0.6744	-0.6814	-0.7024
	3	n	0.6321	0.6378	0.6439	0.6542	0.6641	0.6813	0.7145
		a	49.52	45.15	40.54	34.29	29.37	24.76	17.86
		b	6.1977	6.7988	7.4546	8.5317	9.5464	11.0675	12.8516
Port Area	1	n	-0.5350	-0.5379	-0.5411	-0.5469	-0.5525	-0.5602	-0.5766
		lnb	3.1821	3.0874	2.9808	2.8181	2.6695	2.4892	2.1575
	2	n1	-0.4934	-0.4964	-0.4994	-0.5054	-0.5104	-0.5174	-0.5284
		n2	-0.6514	-0.6554	-0.6574	-0.6654	-0.6714	-0.6834	-0.7134
	3	n	0.6217	0.6265	0.6333	0.6444	0.6574	0.6761	0.7179
		a	39.82	36.66	33.65	29.50	26.59	23.69	19.81
		b	7.7194	7.8813	8.2009	8.6515	9.3555	10.3806	12.8008

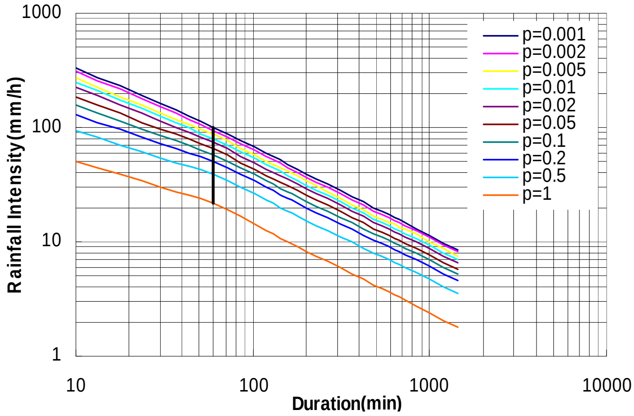
Table 3.2 Parameters of the 3 formulas for selected stations.

station	parameter		P						
			0.005	0.01	0.02	0.05	0.1	0.2	0.5
Ambulong	1	n	-0.5604	-0.5614	-0.5629	-0.5649	-0.5670	-0.5695	-0.5746
		lna	3.2212	3.1266	3.0212	2.8556	2.7028	2.5114	2.1347
	2	n_1	-0.5204	-0.5114	-0.5014	-0.4824	-0.4634	-0.4384	-0.4234
		n_2	-0.7284	-0.7104	-0.6894	-0.6534	-0.6154	-0.5644	-0.4584
	3	n	0.6330	0.6359	0.6423	0.6469	0.6564	0.6658	0.6895
		a	38.09	35.05	32.46	27.92	25.06	21.53	16.52
		b	5.9233	6.0911	6.5428	6.7493	7.4662	8.0919	9.9161
Baguio	1	n	-0.5767	-0.5659	-0.5526	-0.5296	-0.5061	-0.4753	-0.4348
		lna	4.3576	4.1639	3.9361	3.5604	3.1914	2.7101	1.8560
	2	n_1	-0.5204	-0.5114	-0.5014	-0.4824	-0.4634	-0.4384	-0.4234
		n_2	-0.7284	-0.7104	-0.6894	-0.6534	-0.6154	-0.5644	-0.4584
	3	n	0.6968	0.6786	0.6558	0.6188	0.5798	0.5285	0.4491
		a	157.28	124.10	93.40	59.02	37.25	20.41	6.94
		b	10.4621	9.9189	9.1662	8.0806	6.7855	4.9780	1.3029
Baler	1	n	-0.5953	-0.5898	-0.5834	-0.5732	-0.5640	-0.5532	-0.5378
		lna	3.4680	3.3484	3.2130	3.0022	2.8098	2.5749	2.1533
	2	n_1	-0.5364	-0.5294	-0.5214	-0.5094	-0.4994	-0.4874	-0.4744
		n_2	-0.7494	-0.7464	-0.7424	-0.7364	-0.7294	-0.7194	-0.6964
	3	n	0.6941	0.6871	0.6817	0.6723	0.6628	0.6532	0.6421
		a	56.95	50.05	44.00	35.81	29.51	23.51	14.04
		b	8.0024	7.9271	8.1413	8.3942	8.5382	8.8680	7.9799
Dagupan	1	n	-0.5614	-0.5648	-0.5688	-0.5753	-0.5814	-0.5887	-0.5961
		lna	3.5905	3.4867	3.3696	3.1855	3.0144	2.7980	2.3613
	2	n_1	-0.5114	-0.5164	-0.5214	-0.5304	-0.5374	-0.5454	-0.5514
		n_2	-0.6884	-0.6874	-0.6874	-0.6874	-0.6874	-0.6884	-0.6864
	3	n	0.6195	0.6220	0.6307	0.6406	0.6518	0.6648	0.6824
		a	50.65	45.39	41.48	35.21	30.55	25.45	17.46
		b	4.5827	4.4527	4.8294	5.0653	5.4485	5.8758	6.7102
Diet	1	n	-0.5207	-0.5231	-0.5261	-0.5308	-0.5354	-0.5407	-0.5500
		lna	3.1143	3.0195	2.9142	2.7520	2.6063	2.4284	2.1086
	2	n_1	-0.4384	-0.4464	-0.4554	-0.4694	-0.4824	-0.4994	-0.5254
		n_2	-0.6734	-0.6694	-0.6664	-0.6594	-0.6524	-0.6424	-0.6284
	3	n	0.5595	0.5652	0.5725	0.5844	0.5976	0.6137	0.6421
		a	28.12	26.06	24.06	21.33	19.38	17.28	14.04
		b	3.1601	3.4367	3.8107	4.4330	5.2061	6.2002	7.9799

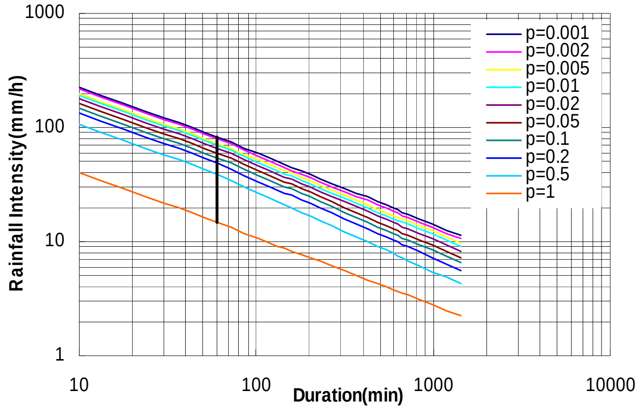
Figure 3.1- 3.6 are the log-log plot of duration and rainfall intensity by the improved Sherman formula



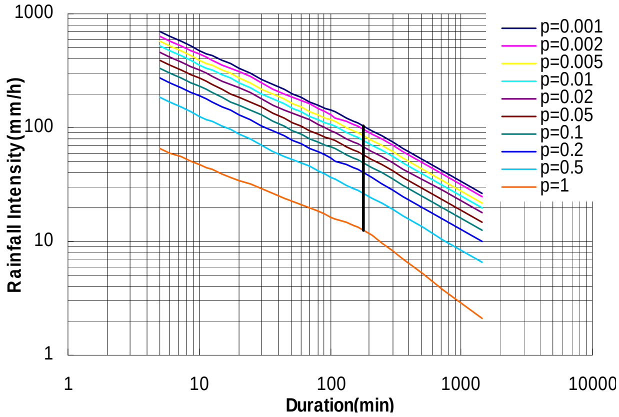
IDF Curve for Yongchun, China



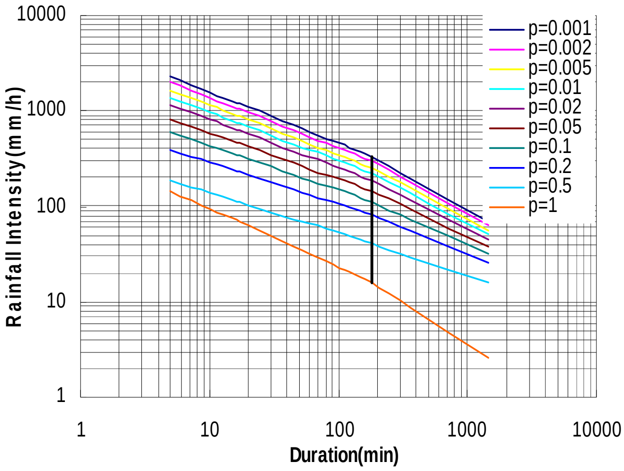
IDF Curve for Changzhou, China



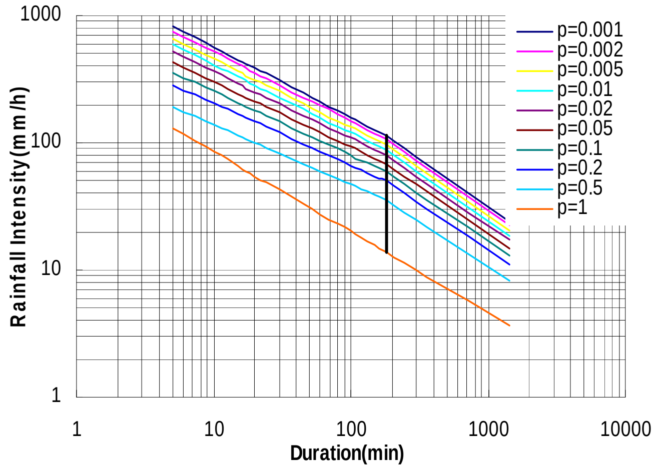
IDF Curve for Shahe, China



IDF Curve for Ambulong, Philippine

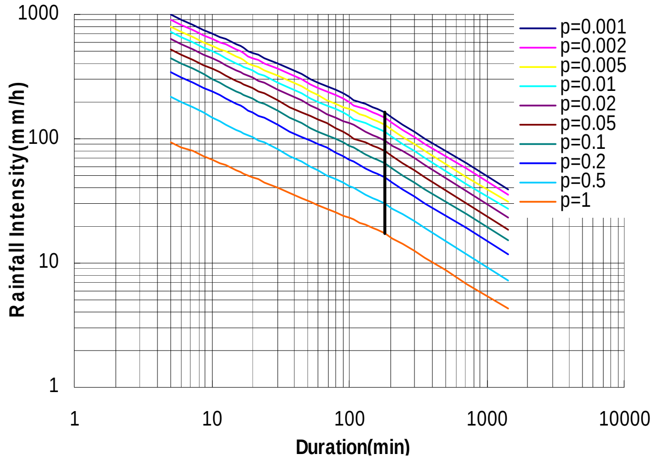


IDF Curve for Baguio, Philippine

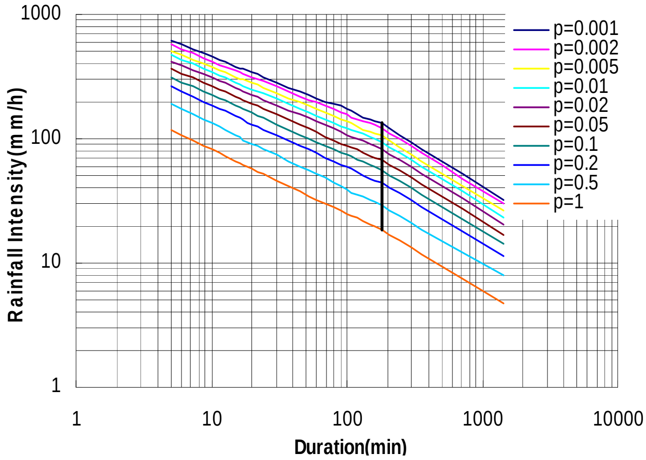


IDF Curve for Baler, Philippine

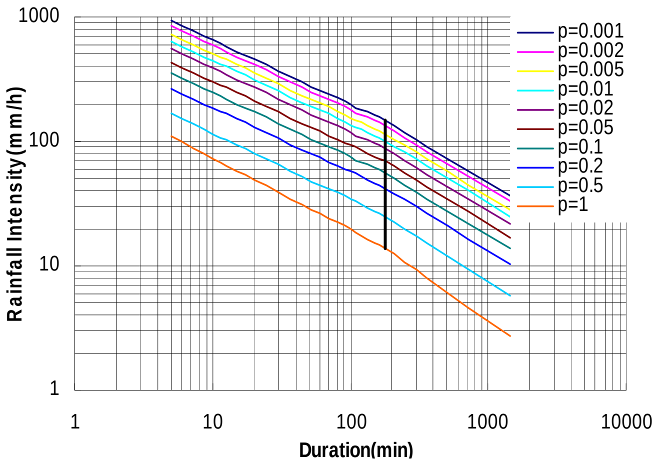
Figure 3.1 IDF for China and Philippine by P-III



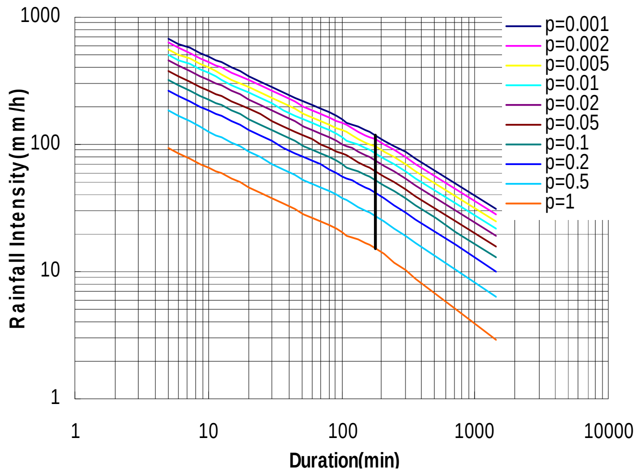
IDF Curve for Dagupan, Philippine



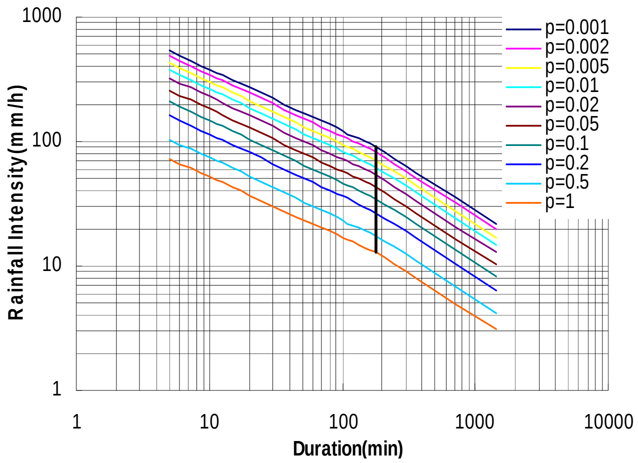
IDF Curve for Diet, Philippine



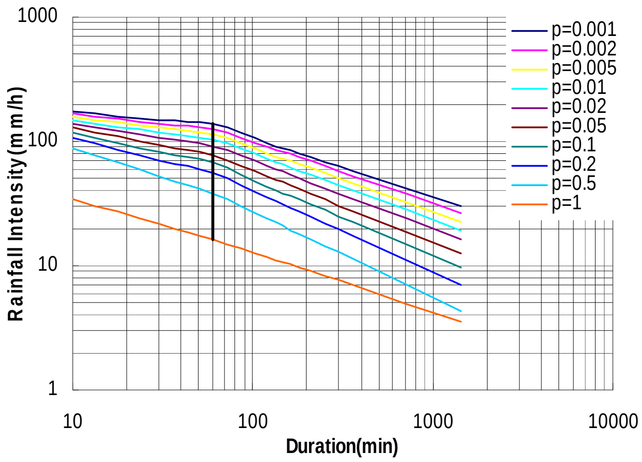
IDF Curve for Naia, Philippines



IDF Curve for Port Area, Philippine

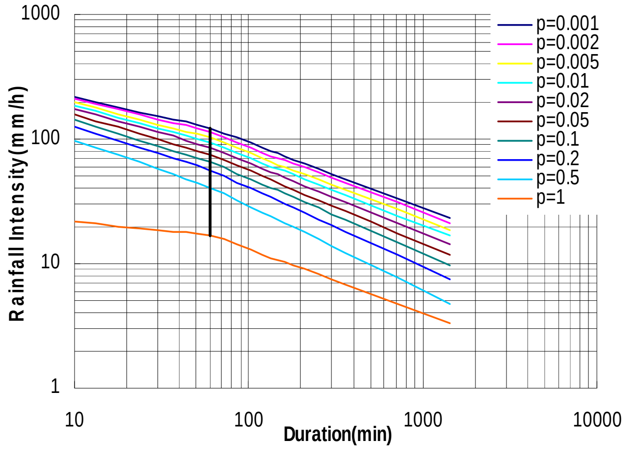


IDF Curve for Puerto Princesa, Philippines

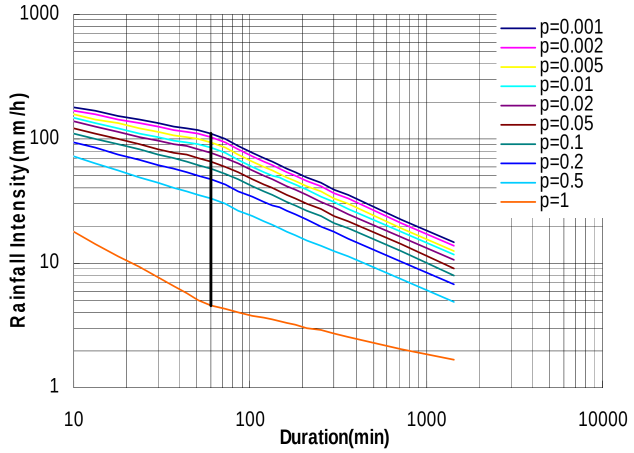


IDF Curve for Nagoya, Japan

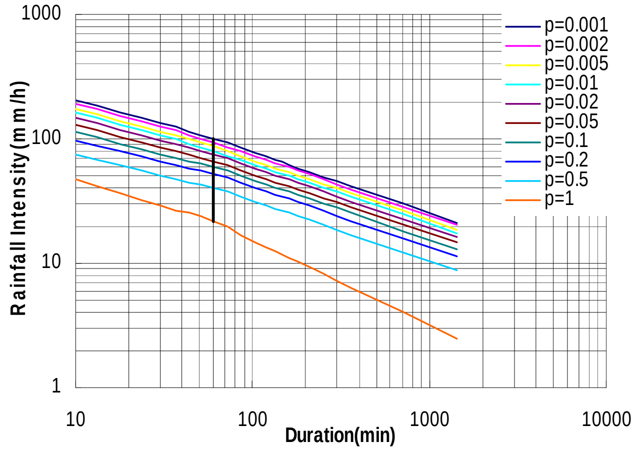
Figure 3.2 IDF for Philippine and Japan by P-III



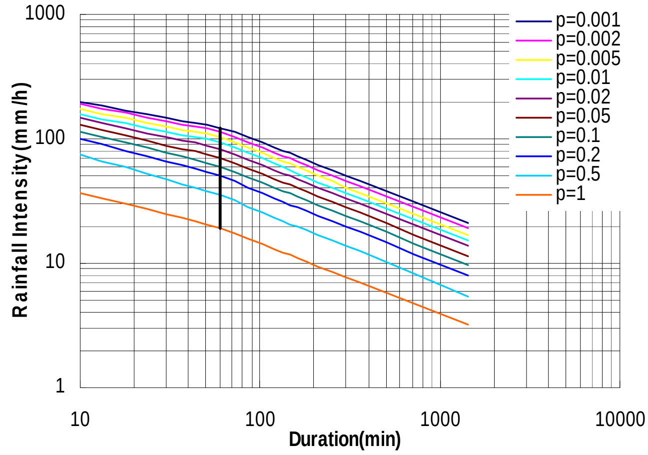
IDF Curve for Ohkusa, Japan



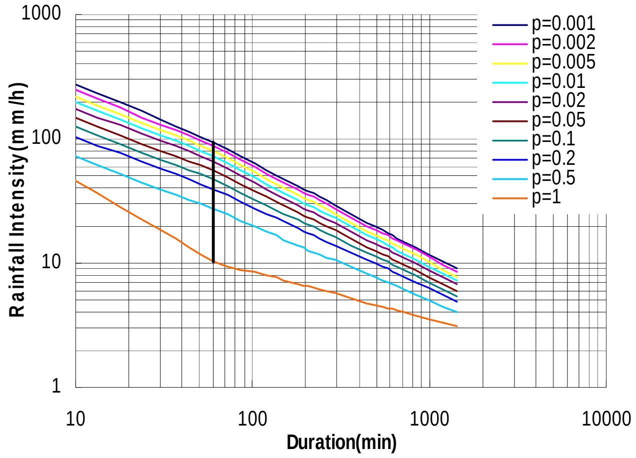
IDF Curve for Okazaki, Japan



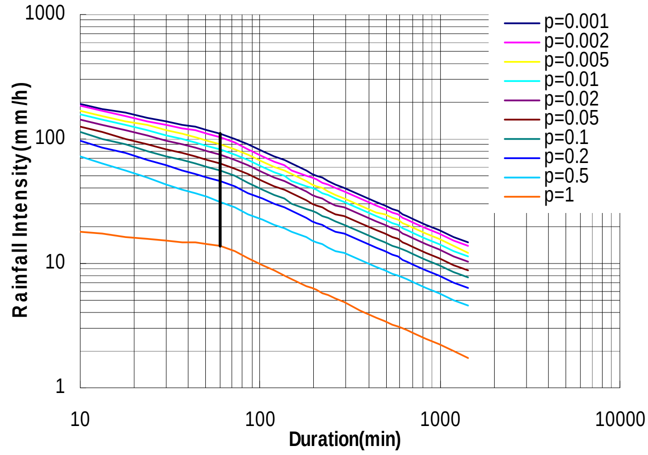
IDF Curve for Taguch, Japan



IDF Curve for ToyohashiSS, Japan

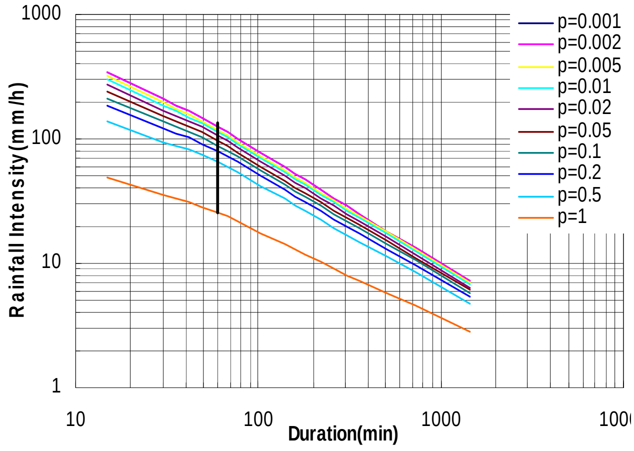


IDF Curve for Andong, Korean

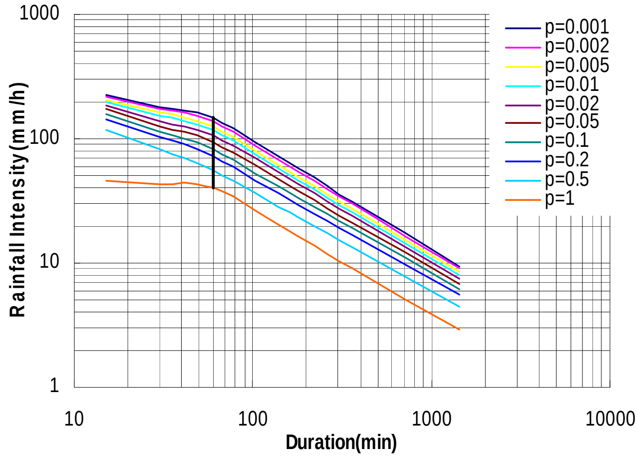


IDF Curve for Daegu, Korean

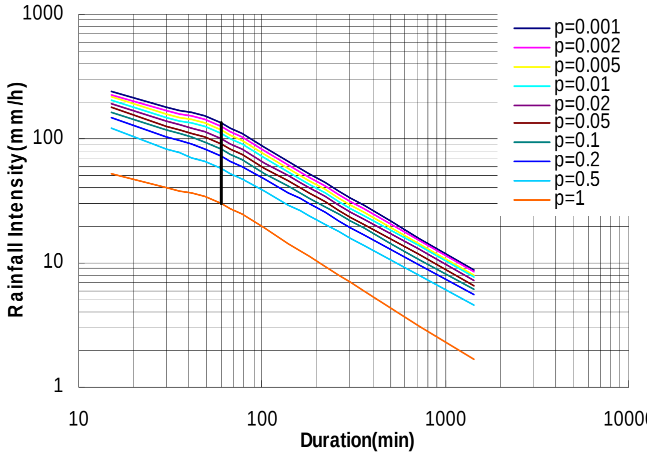
Figure 3.3 IDF for Japan and Korea by P-III.



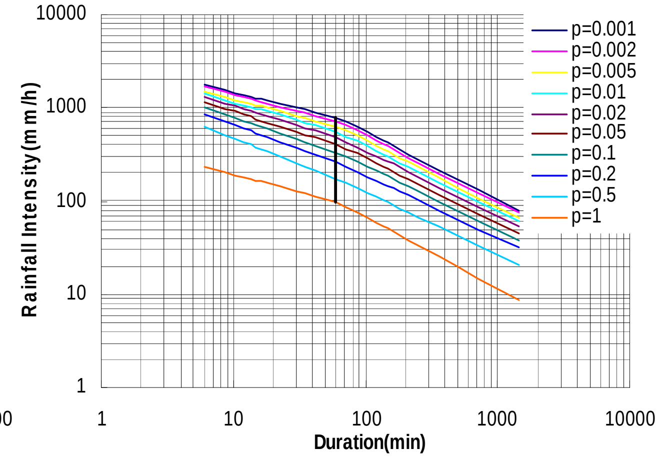
IDF Curve for JPS, Malaysia



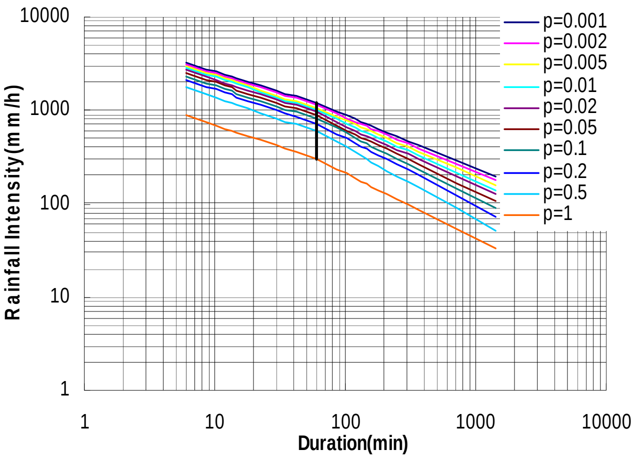
IDF Curve for KG. SG. TUA, Malaysia



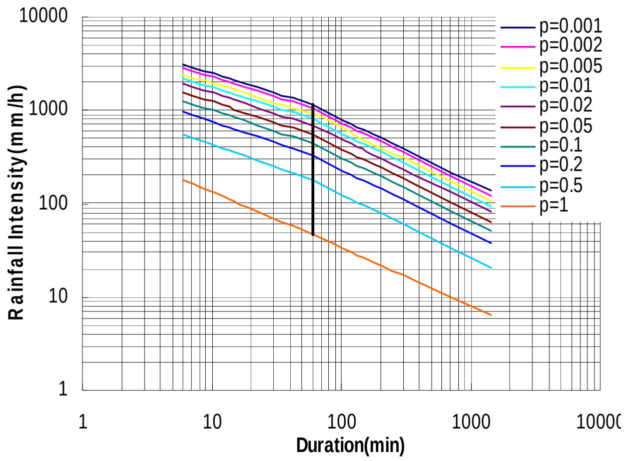
IDF Curve for Kelan, Malaysia



IDF Curve for Geraldton Airport, Australia

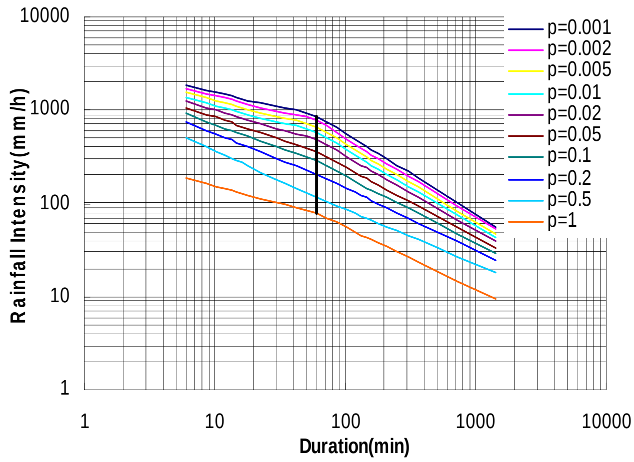


IDF Curve for Darwin Airport, Australia

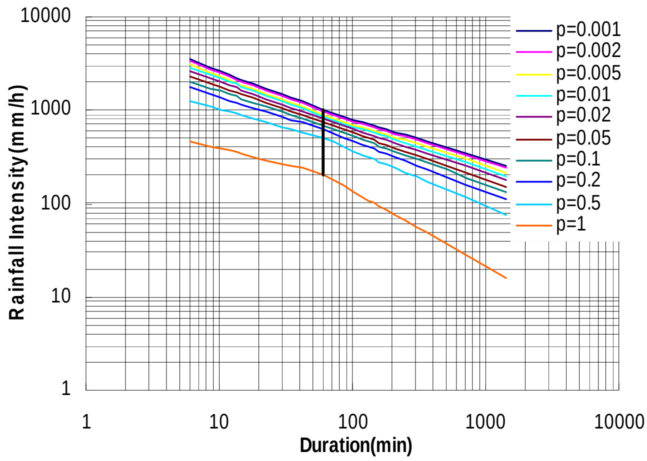


IDF Curve for Alice Springs Airport, Australia

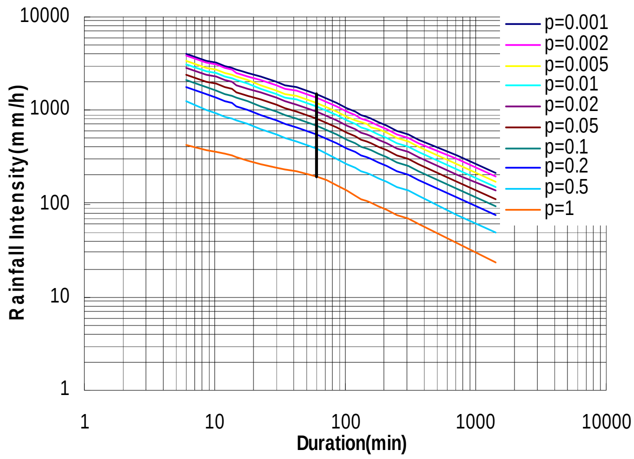
Figure 3.4 IDF for Malaysia and Australia by P-III.



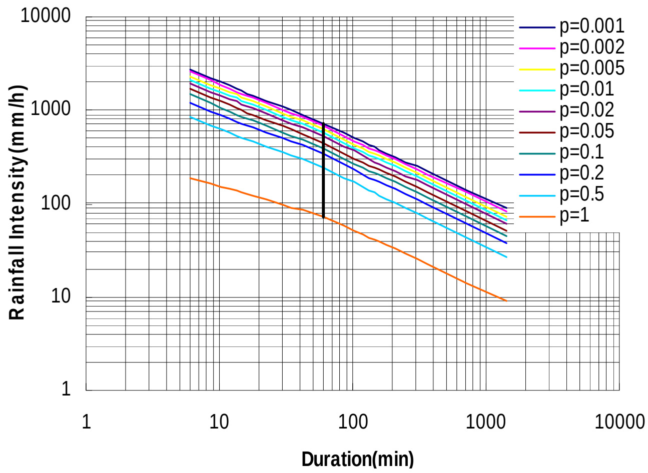
IDF Curve for Adelaide West Terrace, Australia



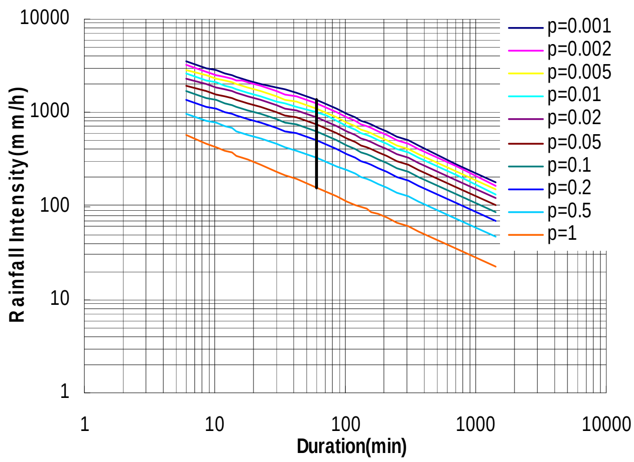
IDF Curve for Cairns Aero, Australia



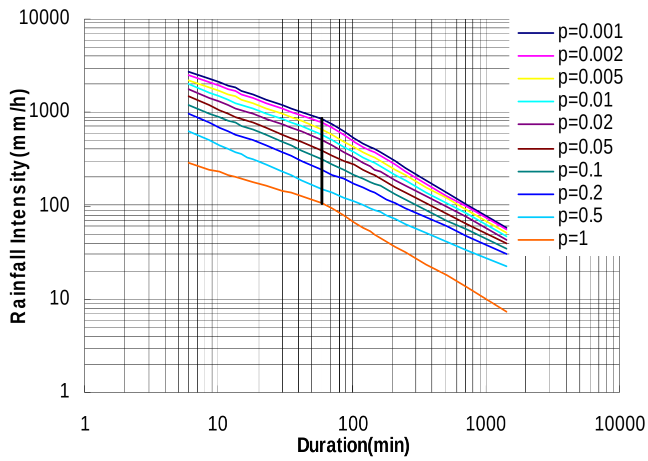
IDF Curve for Brisbane Aero, Australia



IDF Curve for Charleville Aero, Australia

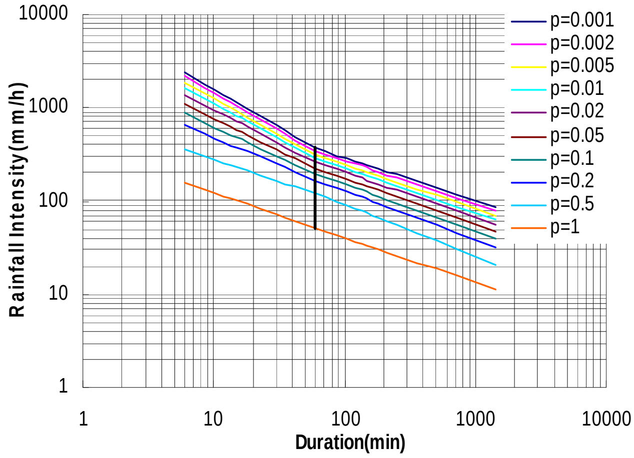


IDF Curve for Sydney, Australia

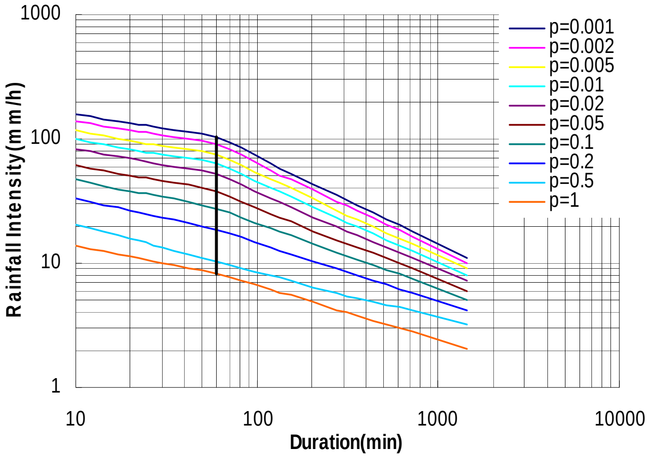


IDF Curve for Melbourne Office, Australia

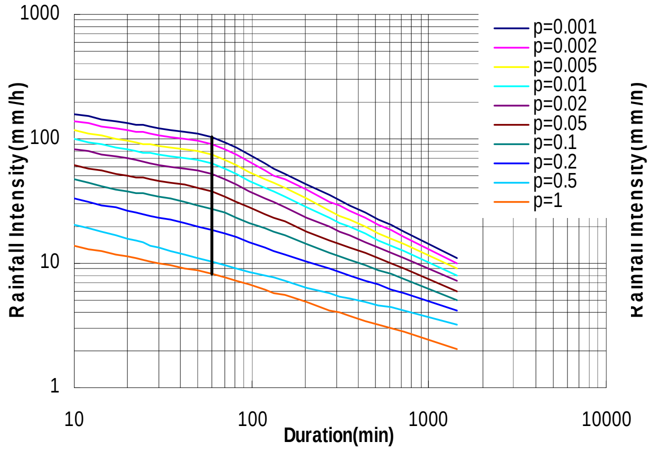
Figure 3.5 IDF for Australia by P-III.



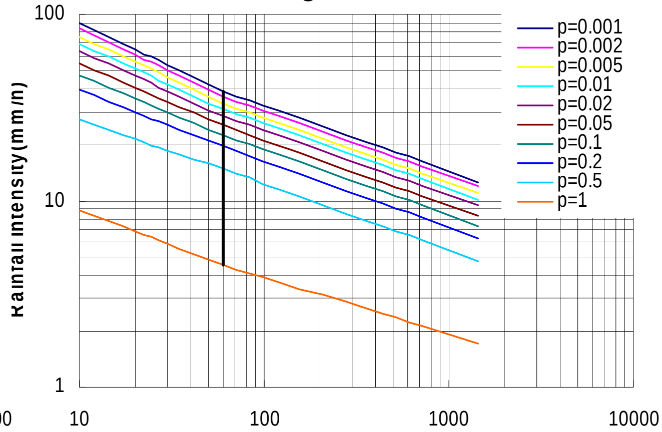
IDF Curve for Hobart, Australia



IDF Curve for Wellington, New Zealand



IDF Curve for Kaitoke, New Zealand



IDF Curve for Wainuiomata, New Zealand

Figure 3.6 IDF for Australia and New Zealand by P-III.

Table 3.3 Comparison of the three formulas (unit: mm/min)

country	station	equation	MSE	RMSE	country	station	MSE	RMSE
Australia	Brisbane Aero	1	2.0775	0.0806	Philippine	Dagupan	0.3914	0.1235
		2	0.7472	0.0477			0.2563	0.0584
		3	0.4104	0.0289			0.2243	0.0645
	Charleville Aero	1	1.2983	0.0836		Diet	0.1903	0.0992
		2	0.5903	0.0522			0.1692	0.0578
		3	0.2101	0.0182			0.1099	0.0452
	Sydney (Observatory)	1	1.8307	0.0981		Naia	0.3856	0.1255
		2	0.5659	0.0363			0.1893	0.0483
		3	1.1037	0.0438			0.0908	0.037
	Melbourne Regional	1	1.6083	0.0941		Port Area	0.3178	0.1341
		2	0.362	0.0571			0.1462	0.052
		3	1.4446	0.168			0.1238	0.041
	Hobart (Ellerslie Road)	1	1.1244	0.1217		Puerto Princesa	0.2151	0.1225
		2	0.4917	0.0576			0.0765	0.0368
		3	0.8934	0.1081			0.085	0.0493

Table 3.4 Comparison of the three formulas (unit: mm/min)

country	station	equation	MSE	RMSE	country	station	MSE	RMSE
China	Changzhou	1	0.1033	0.0811	Indonesia	Jakarta	0.2471	0.1175
		2	0.0709	0.0882			0.1769	0.0748
		3	0.072	0.0718			0.1096	0.0363
	Shahe	1	0.1202	0.084		Tahun	0.3747	0.151
		2	0.0508	0.0833			0.0415	0.0431
		3	0.06	0.062			0.0535	0.033
	Yongchun	1	0.2191	0.0735	Korea	Andong	0.1433	0.0869
		2	0.1341	0.059			0.0643	0.0598
		3	0.2179	0.0862			0.0291	0.0405
Japan	Nagoya	1	0.2023	0.1131		Daegu	0.1971	0.171
		2	0.0322	0.0169			0.0966	0.0432
		3	0.0351	0.0255			0.0377	0.0644
	Ohkusa	1	0.1847	0.1253	Malaysia	Kg. Sg. Tua	0.1794	0.0681
		2	0.0925	0.081			0.0194	0.0378
		3	0.0712	0.0576			0.0236	0.0298
	Okazaki	1	0.2121	0.1437		Empangan Genting Kelang	0.2688	0.1543
		2	0.0637	0.0344			0.1113	0.1029
		3	0.0262	0.0234			0.1086	0.0851
	Taguch	1	0.078	0.0638		JPS Ampang	0.2795	0.1186
		2	0.045	0.0249			0.0257	0.0404
		3	0.0261	0.0354			0.0325	0.0251
Australia	Toyohashiss	1	0.2078	0.1209	New Zealand	Wellington	0.1719	0.118
		2	0.0594	0.0453			0.0702	0.0542
		3	0.0255	0.0271			0.0275	0.0408
	Geraldton Airport	1	1.4826	0.1405		Kaitoke	0.0416	0.0537
		2	0.3516	0.0546			0.0158	0.0391
		3	0.5078	0.0439			0.0338	0.057
	Darwin Airport	1	1.5972	0.0843		Wainuiomata	0.0442	0.0759
		2	0.8137	0.0426			0.0273	0.0783
		3	0.8669	0.0386			0.0359	0.0671
	Alice Springs Airport	1	3.2568	0.1448	Philippine	Ambulong	0.2907	0.1235
		2	1.8213	0.0855			0.1626	0.0566
		3	1.114	0.0642			0.0993	0.0316
	Adelaide West Terrace	1	1.8729	0.1494		Baguio	0.9946	0.1442
		2	0.3012	0.0345			0.4656	0.0613
		3	0.5861	0.0447			0.2483	0.0478
	Cairns Aero	1	1.6959	0.0836		Baler	0.3335	0.1384
		2	0.9632	0.0585			0.0831	0.0451
		3	1.0448	0.0464			0.2242	0.0642

3.5 Conclusions

From the above results, three conclusions can be drawn as follows

1. From the figures, T (duration at point of intersection) of the most countries are 60mins, but the Philippine is an exception (T=180mins).

2. Generally, the value of parameter $n_1 > n_2$, but in Hobart of Australia and Wainuiomata of New Zealand the parameters $n_1 < n_2$.

3. From the table 3.1 and table 3.2, the improved Sherman Formula is much fitter than the Sherman Formula. If the data for more short durations are available, the error of the improved Sherman Formula is close to that of the Horner Formula, the sites in Philippine are examples. Compared with the Horner Formula, it is much easier to estimate the parameters of the improved Sherman Formula.

3.6 References

Chow, V.T.; Maidment, David R.; Mays, L.W. (1988), *Applied Hydrology*, McGraw-Hill, New York.

Demetris Koutsoyiannis(1998), *A mathematical framework for studying rainfall Intensity Duration Frequency relationships*, J. Journal of Hydrology.

Yang Kai etal.(1996), *Statistical Methods to Estimate Parameter b in Rainfall Intensity Equation*, Hydrology,25(4).

Chapter 4 Indonesia

Agung Bagiawan Ibrahim

4.1 Introduction

Investigations of intensity duration frequency (IFD) by using data from nine countries have several purposes: (i) the assessment of the rarity of observed rainfalls; (ii) the estimation of extreme rainfalls for design purposes; and, (iii) comparison of methods to estimate design rainfalls and IDF.

The report arose from an APFRIEND Workshop in Kuala Lumpur in June 2005, whereby the country representatives attending the workshop were asked to supply extreme rainfall data so that a comparison of the various methods used in estimating design rainfalls / calculation of IDF could be made. This chapter briefly presents a method used in the design rainfall estimation and calculation of IDF used in Indonesia.

4.2 Methodology

Rainfall data for nine countries have been carried out. Those data are evaluated and fitted to suitable distribution functions before it used for estimating design rainfall. SMADA software is used to select the best distribution function of each data set and estimates the value of design rainfall for various return periods.

The steps for determining the best suitable distribution function are as follows:

1. Rainfall data from different durations are analysed and fitted to several distribution functions such as Normal, 2 Parameter Log Normal, 3 Parameter Log Normal, Pearson Type III, Log Pearson Type III and Gumble Type I Extreme Values by using package program SMADA.
2. The distribution function which gives the best fit between observed and calculated data is selected.
3. Calculation of design rainfall for different durations and return periods by using the selected distribution function.

Design rainfalls from those analyses are used to calculate rainfall intensity by using Talbot, Sherman and Ishiguro methods. The procedures are as follows:

1. Design rainfall for different duration are changed to mm/hour
2. Calculation rainfall intensity and constant parameters of each method for each return periods by using Talbot, Sherman and Ishiguro methods.

Calculation of Rainfall Intensity using Talbot Formula.

$$I_2 = \frac{a}{t+b} \qquad (1)$$

$$a = \frac{\left[\sum (I.t)\right]\left[\sum (I^2)\right] - \left[\sum \left(I^2.t\right)\right]\left[\sum (I)\right]}{N.\left[\sum \left(I^2\right)\right] - \left[\sum (I)\right]\left[\sum (I)\right]} \qquad (2)$$

$$b = \frac{\left[\sum(I.t)\right]\left[\sum(I)\right] - \left[\sum(I^2.t)\right]N}{N.\left[\sum(I^2)\right] - \left[\sum(I)\right]\left[\sum(I)\right]} \quad (3)$$

Calculation of Rainfall Intensity using Sherman Formula

$$I_2 = \frac{a}{t^n} \quad (4)$$

$$\log a = \frac{\left[\sum(\log I)\right]\left[\sum(\log t)^2\right] - \left[\sum(\log t.\log I)\right]\left[\sum(\log t)\right]}{N.\left[\sum(\log t)^2\right] - \left[\sum(\log t)\right]\left[\sum(\log t)\right]} \quad (5)$$

$$n = \frac{\left[\sum(\log I)\right]\left[\sum(\log t)\right] - \left[\sum(\log t.\log I)\right]N}{N.\left[\sum(\log t)^2\right] - \left[\sum(\log t)\right]\left[\sum(\log t)\right]} \quad (6)$$

Calculation of Rainfall Intensity using Ishiguro Formula

$$I_2 = \frac{a}{\sqrt{t} + b} \quad (7)$$

$$a = \frac{\left[\sum(I\sqrt{t})\right]\left[\sum(I^2)\right] - \left[\sum(I^2.\sqrt{t})\right]\left[\sum(I)\right]}{N.\left[\sum(I^2)\right] - \left[\sum(I)\right]\left[\sum(I)\right]} \quad (8)$$

$$b = \frac{\left[\sum(I\sqrt{t})\right]\left[\sum(I)\right] - \left[\sum(I^2.\sqrt{t})\right]N}{N.\left[\sum(I^2)\right] - \left[\sum(I)\right]\left[\sum(I)\right]} \quad (9)$$

3. Comparison the rainfall intensity results calculated from Talbot, Sherman and Ishiguro methods with the calculation of rainfall intensity from the best fit of distribution function.
4. Selecting the best method which is based on the minimum error between calculated rainfall intensity by using those three methods and rainfall intensity calculated from the best fit of distribution function. This process will be carried out for all the return periods

The diagram for analysing IDF can be seen in Figure 4.1

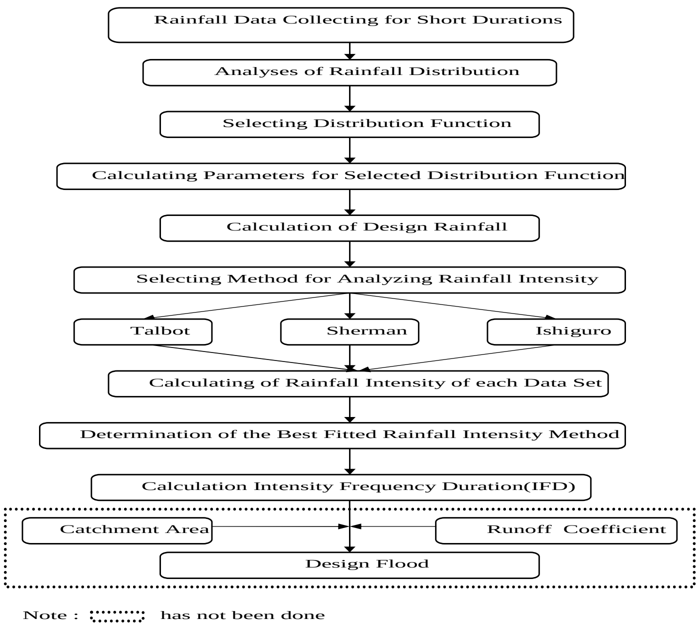


Figure 4.1 Flow Diagram for Calculating IDF

4.3 Results

Tabel 4.1. The best fit distribution function and rainfall intensity method for Australia

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Geraldton Airport	28.80 S	114.70 E	33.00	Log Pearson Type III	Talbot
Darwin Airport	12.42 S	130.89 E	30.40	Log Pearson Type III	Sherman
Alice Springs Airport	23.80 S	133.89 E	546.00	Log Pearson Type III	Talbot
Adelaide West Terrace	34.93 S	138.58 E	40.00	Log Pearson Type III	Talbot
Cairns Aero	16.87 S	145.75 E	3.00	Pearson Type III	Ishiguro
Brisbane Aero	27.42 S	153.11 E	4.00	Log Pearson Type III	Sherman
Charleville Aero	26.42 S	146.25 E	301.50	Log Pearson Type III	Sherman
Sydney (Observatory)	33.86 S	151.21 E	39.00	Log Pearson Type III	Ishiguro
Melbourne Regional	37.81 S	144.97 E	31.15	Log Pearson Type III	Sherman
Hobart (Ellerslie Road)	42.89 S	147.33 E	50.50	Log Pearson Type III	Ishiguro

Tabel 4.2. The best fit distribution function and rainfall intensity method for China

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Shahe Reservoir	31° 19’ N	119° 26’ E	25.60	Log Pearson Type III	Sherman
Changzhou	31° 46’ N	119° 59’ E	3.63	Log Pearson Type III	Sherman
Yongchun	25° 32’ N	118° 28’ E	120.00	Log Pearson Type III	Sherman

Tabel 4.3. The best fit distribution function and rainfall intensity method for Indonesia

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Bandung	6° 55’ 00’’ S	107° 36’ 00’’ E	791.00	Pearson Type III	Talbot
Dermaga Bogor	6° 30’ 00’’ S	106° 45’ 00’’ E	250.00	Log Pearson Type III	Talbot
Jakarta	6° 25’ 00’’ S	106° 09’ 00’’ E	28.00	Pearson Type III	Talbot
Semarang	6° 59’ 02’’ S	110° 20’ 05’’ E	3.00	Log Pearson Type III	Talbot
Bali	8° 45’ 00’’ S	115° 10’ 00’’ E	3.05	Log Pearson Type III	Sherman

Tabel 4.4. The best fit distribution function and rainfall intensity method for Japan

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Nagoya	35° 10.0’ N	136° 57.9’ E	51.00	Log Pearson Type III	Talbot
Okazaki	34° 55.1’ N	137° 11.6’ E	47.00	Log Pearson Type III	Talbot
Ookusa	35° 13.8’ N	137° 17.1’ E	264.00	Log Pearson Type III	Talbot
Toyohashi	34° 46.6’ N	137° 22.1’ E	2.00	Log Pearson Type III	Talbot
Taguchi	35° 5.5’ N	137° 33.8’ E	466.00	Log Pearson Type III	Ishiguro

Tabel 4.5. The best fit distribution function and rainfall intensity method for Korea

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Daegu	35° 53’ 00’’ N	128° 37’ 00’’ E	57.60	Log Pearson Type III	Talbot
Andong	36° 34’ 00’’ N	128° 43’ 00’’ E	139.40	Log Pearson Type III	Sherman

Tabel 4.6. The best fit distribution function and rainfall intensity method for Malaysia

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Kg. Sg. Tua	03° 16' 20'' N	101° 41' 10'' E	-	Pearson Type III	Talbot
Empangan Genting Kelang	03° 09' 30'' N	101° 45' 00'' E	-	Log Pearson Type III	Talbot
JPS Ampang	03° 14' 10'' N	101° 45' 10'' E	-	Log Pearson Type III	Talbot

Tabel 4.7. The best fit distribution function and rainfall intensity method for Philippine

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Naia	14° 30' N	122° 00' E	32.00	Log Pearson Type III	Ishiguro
Baler	15° 46' N	121° 34' E	6.00	Log Pearson Type III	Ishiguro
Ambulong	14° 05' N	121° 03' E	10.00	Log Pearson Type III	Ishiguro
Puerto Princesa	09° 45' N	118° 44' E	16.00	Pearson Type III	Ishiguro
Daet	14° 07' N	122° 57' E	4.00	Log Pearson Type III	Ishiguro
Port Area	14° 35' N	122° 59' E	15.00	Log Pearson Type III	Ishiguro
Dagupan	16° 03' N	120° 20' E	2.00	Log Pearson Type III	Ishiguro
Baguio	16° 25' N	120° 33' E	1500.00	Log Pearson Type III	Ishiguro

Tabel 4.8. The best fit distribution function and rainfall intensity method for New Zealand

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Wellington (Auto)	41.286 S	174.767 E	125.00	Pearson Type III	Ishiguro
Kaitoke (Auto)	41.067 S	175.188 E	189.00	Log Pearson Type III	Ishiguro
Wainuiomata (Auto)	41.291 S	174.950 E	82.00	Log Pearson Type III	Ishiguro
Wellington (Manual)	41.286 S	174.767 E	125.00	Pearson Type III	Sherman
Kaitoke (Manual)	41.080 S	171.191 E	223.00	Pearson Type III	Sherman
Wainuiomata (Manual)	41.291 S	174.950 E	82.00	Log Pearson Type III	Talbot

Tabel 4.9 The best fit distribution function and rainfall intensity method for Vietnam

Station	Latitude	Longitude	Elevation (m)	Frequency Distribution	Intensity Formula
Ha Noi	21° 01' 00'' N	105° 48' 00'' E	-	Log Pearson Type III	Talbot
An Nhon	13° 54' 00'' N	109° 07' 00'' E	8.46	Log Pearson Type III	Ishiguro
Quy Nhon	13° 46' 00'' N	109° 13' 00'' E	-	Log Pearson Type III	Talbot

Table 4.10. Summary Results

Country	Frequency Distribution	Intensity Formula
Australia	Log Pearson Type III	Talbot + Sherman + Ishiguro
China	Log Pearson Type III	Sherman
Indonesia	Pearson Type III + Log Pearson Type III	Talbot
Japan	Log Pearson Type III	Talbot
Korea	Log Pearson Type III	Talbot + Sherman
Malaysia	Pearson Type III + Log Pearson Type III	Talbot
Philippine	Log Pearson Type III	Ishiguro
New Zealand	Pearson Type III + Log Pearson Type III	Talbot + Sherman + Ishiguro
Vietnam	Log Pearson Type III	Talbot + Ishiguro

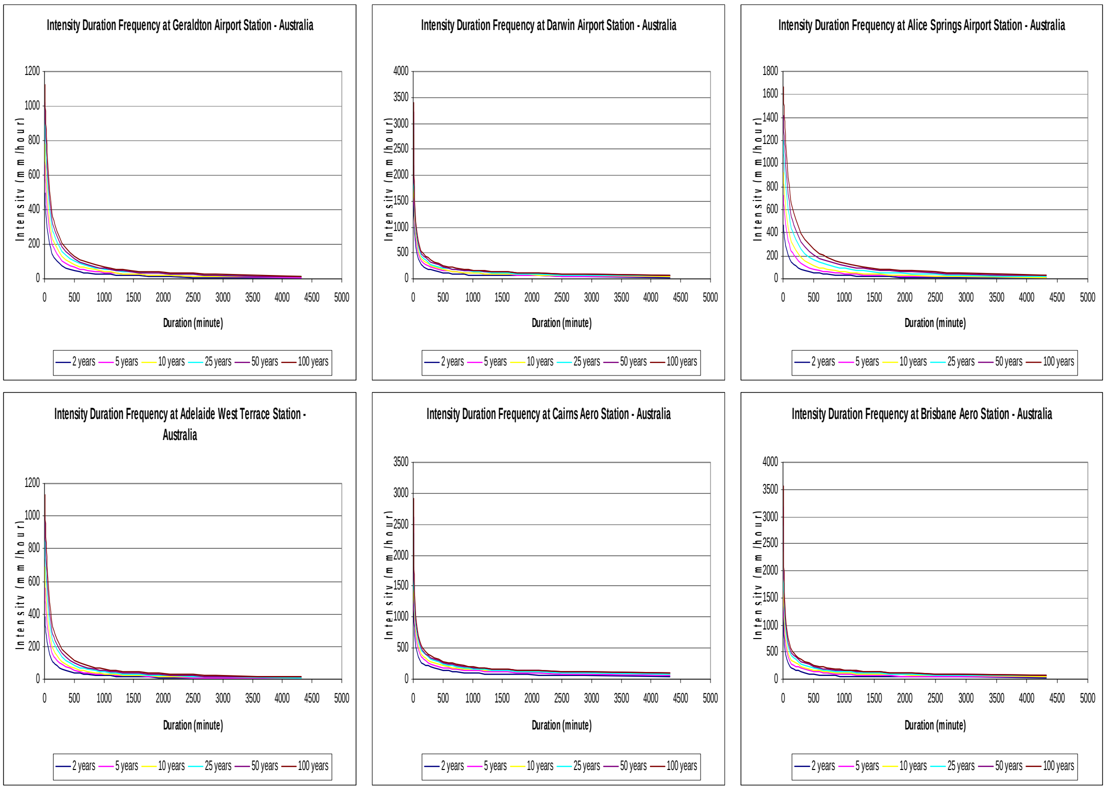


Figure 4.2 IDF for Australia

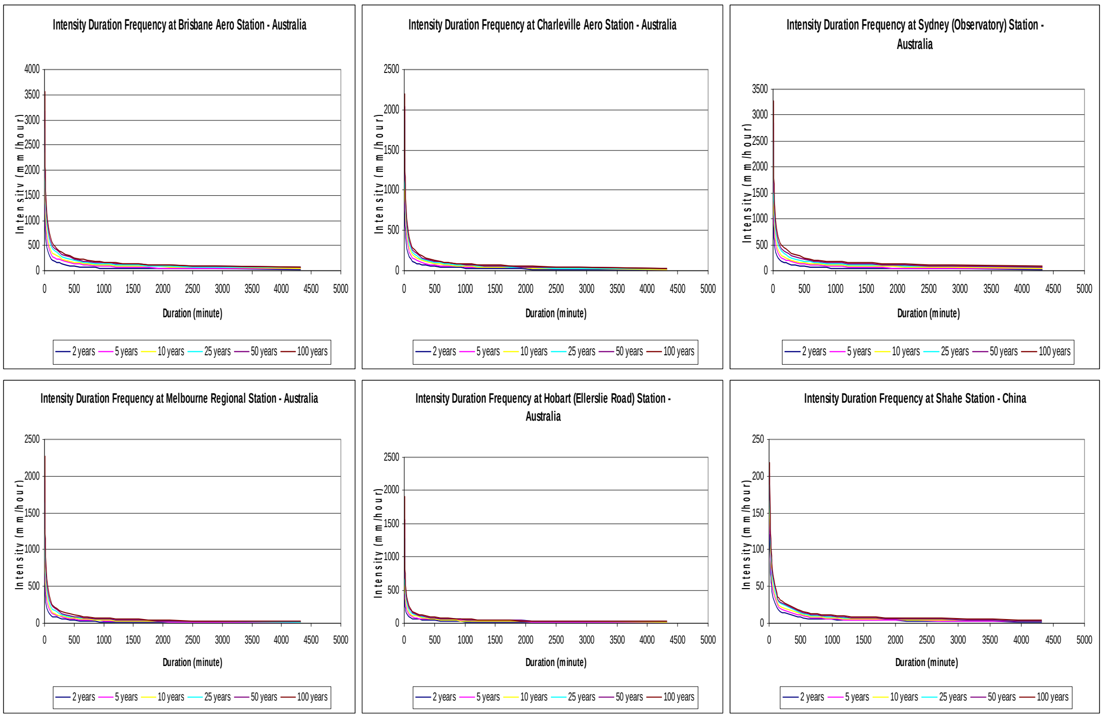


Figure 4.3 IDF for Australia and China

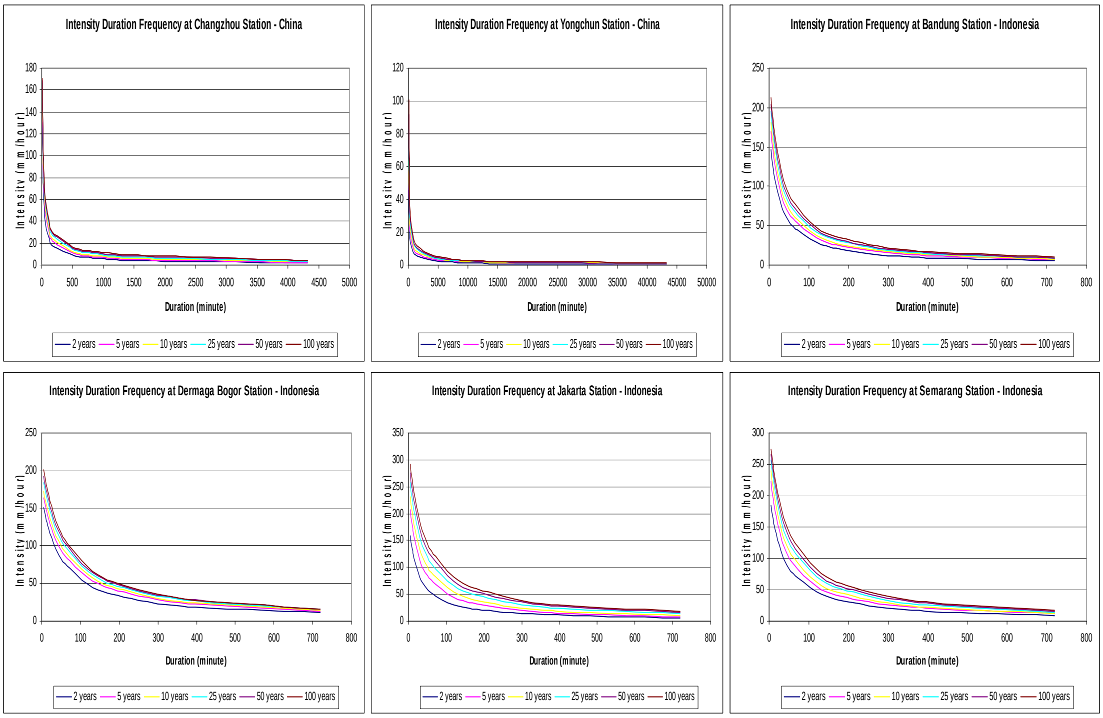


Figure 4.4 IDF for China and Indonesia

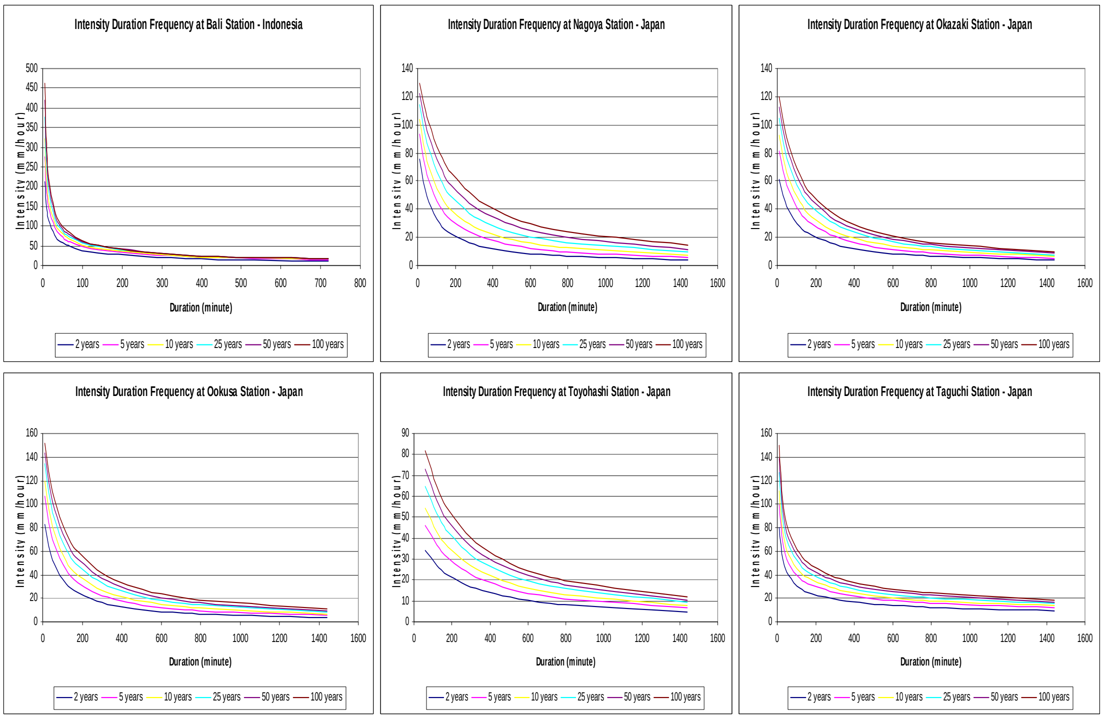


Figure 4.5 IDF for Indonesia and Japan

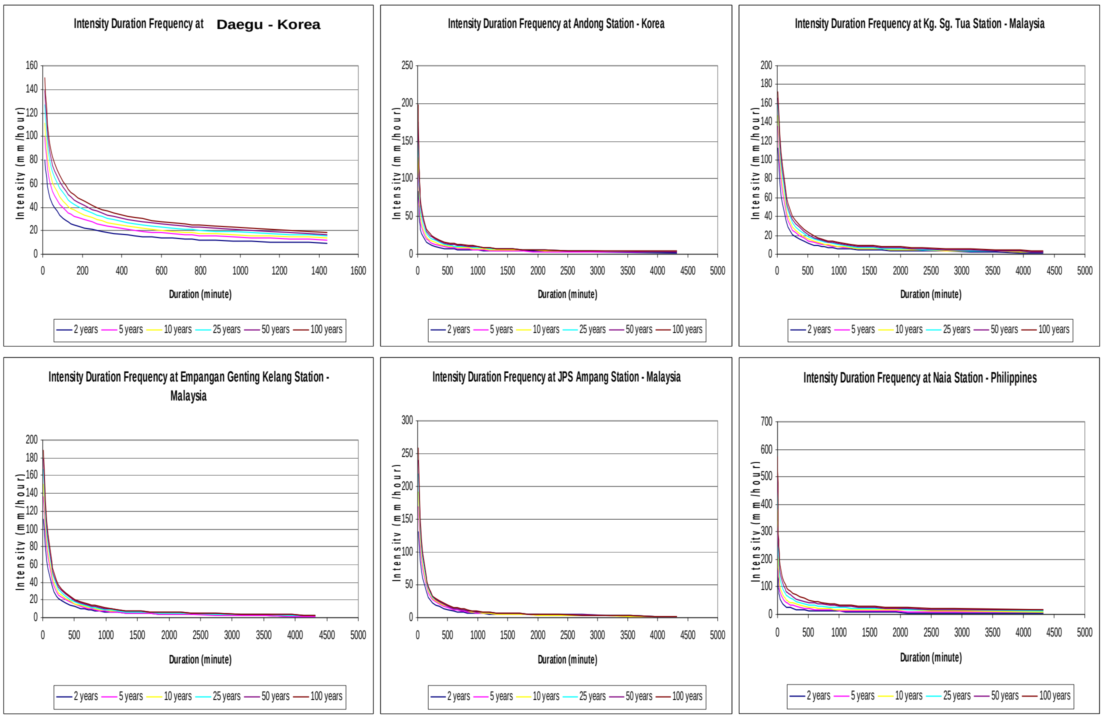


Figure 4.6 IDF for Korea, Malaysia and Philippines

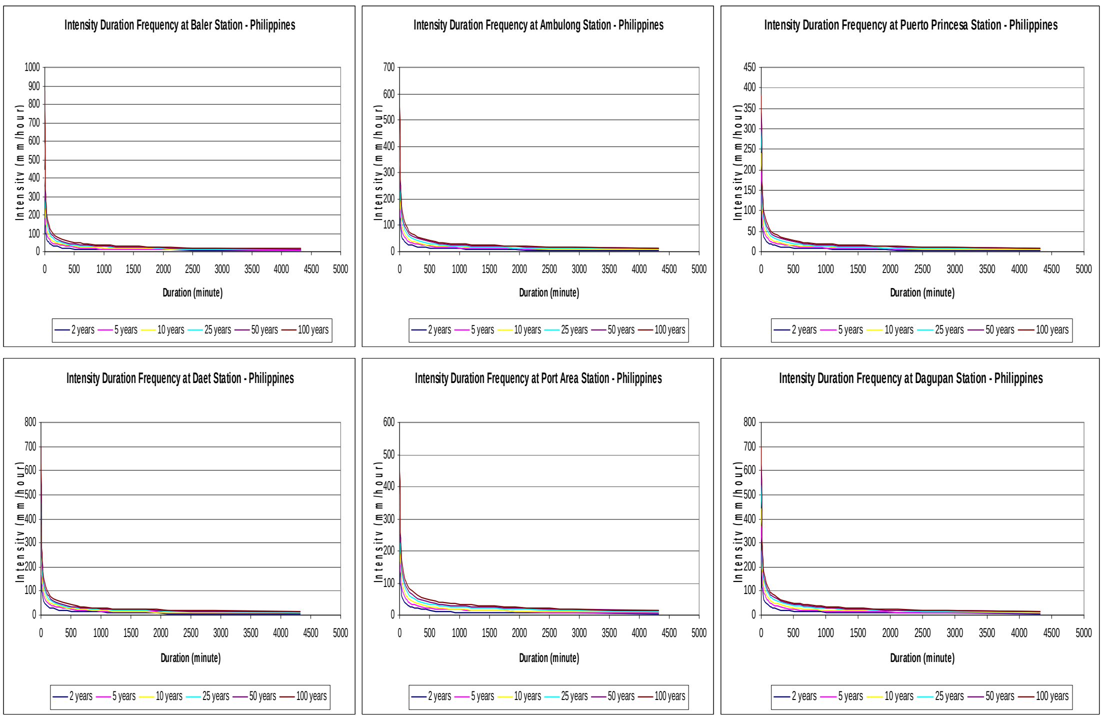


Figure 4.7 IDF for Philippines

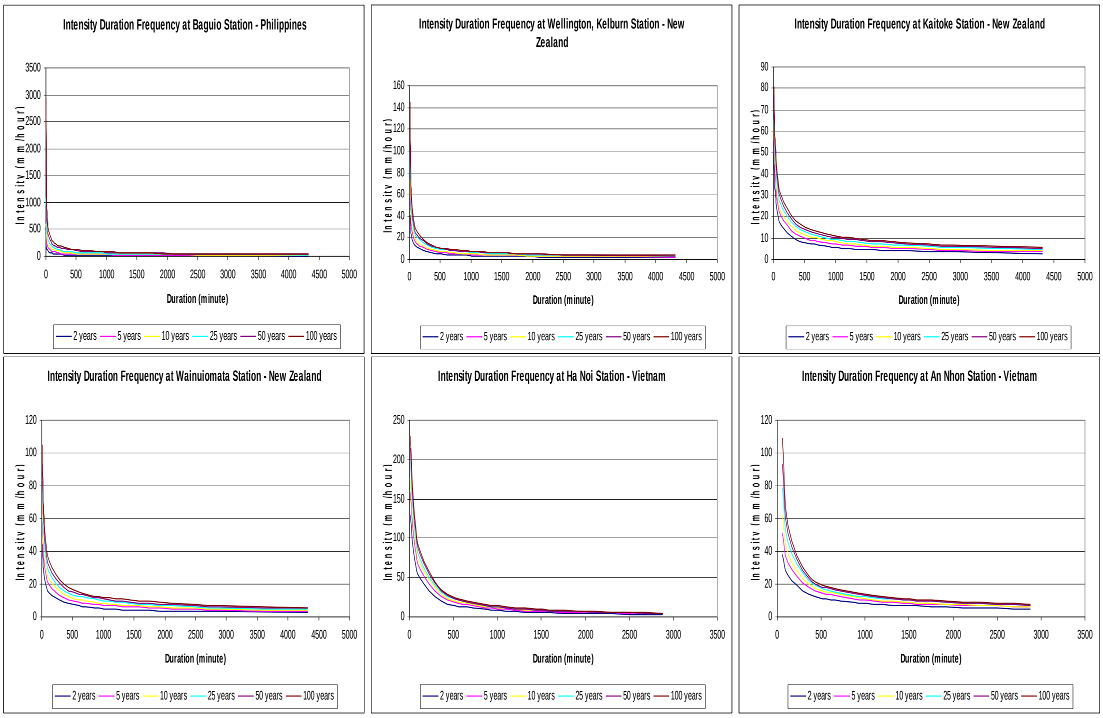


Figure 4.8 IDF for Phillipines, New Zealand and Vietnam

4.4 Data supplied

Annual maximum rainfall series from durations ranging from 5 minutes to over 15 days were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries to supply extreme rainfall data, have been listed in the preamble to this report, and were:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	2 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

The record lengths of each rainfall data series varied from a minimum of 6 years to over 90 years. Since it was assumed that each contributing country would have undertaken quality assurance checks before supplying data, no further error checking was undertaken, apart from a visual check of each rainfall series.

4.5 Acknowledgments

The support of the Research Institute for Water Resources – Indonesia in this work is acknowledged through its commitment in supporting involvement in the international science community and also for financial support from MEXT-Japan to attend the workshops of APFRIEND.

4.6 References

Chow, V.T.; Maidment, David R.; Mays, L.W. (1988), *Applied Hydrology*, McGraw-Hill, New York.

Departemen Pekerjaan Umum, (2000)., *Tata Cara Perhitungan Debit Banjir*. SNI, Revisi SNI 03-2415-1991

Hosking, J.R.M., Wallis, J.R. and Wood, E.F. (1985), *Estimation of the generalised extreme value distribution by the method of probability weighted moments*, 27, 251-261,

Hosking,J.R.M and Wallis,J.R., (1997)., *Regional Frequency Analysis*., Cambridge University Press.

Loebis, Joesron. (1988)., Perhitungan Deras Curah Hujan, J. Penelitian dan Pengembangan Pengairan, No. 10 Th. 3 – KW. II.

Madsen, H., Rasmussen, P.F. and Rosbjerg, D. (1997)., *Comparison of annual maximum series and partial duration series methods for modelling extreme hydrologic events*, Water Resour. Res., 33, 747-757.

Maidment, David R. (1993)., *Handbook of Hydrology*, McGraw-Hill, New York.

Phien, H.N. (1987), A *review of methods of parameter estimation for the extreme value type-1 distribution*, J. Hydrol., 90 251-268.

Ramachandra, R. and Hamed.K.H, (2000)., *Flood Frequency Analysis*. CRC Press LLC, N.W. Corporate Blvd., Boca Raton, Florida.

.

Chapter 5 Japan

Kaoru Takara and Le Minh Nhat

5.1 Introduction

The Intensity-Duration-Frequency (IDF) curves represent a given non-exceedence probability (or usually in terms of the return period in years) for the variation of the maximum annual rainfall intensity with the time interval length. Obviously, for a given return period, the IDF curves decrease with increasing time interval. Minor attention has been paid in the past to improve current techniques of data analysis. Actually, in most cases design practice is based on unproved or unrealistic assumptions concerning the structure of rainfall in space and time. The traditional method to construct IDF curves has three main steps. Based on the raw data, the first step is to obtain annual maximum intensity series for each time interval length. Then, for each time interval a statistical analysis has to be done to compute the quantiles for different return periods. Lastly, the IDF curves are usually determined by fitting a specified parametric equation for each return period to the quantiles estimates, using regression techniques.

This traditional methodology has an important problem: a large number of parameters are involved, which makes it non-parsimonious from the statistical point of view. Usually, for each time interval there are at least 2 parameters for the fitted distribution function, and two or three for each smoothing curve. Therefore, one of the main objectives of this work is to reduce the number of parameters to be estimated in order to increase their reliability. The other main objective is to reduce the estimation process to one single step. Some regularities in hydrological observations, such as scale invariance, has been detected on storm records in the past. Present study deals with the estimation of IDF curves using the scaling properties observed on data of extreme storm intensities with a few number of parameters.

Moreover, in some countries, there may exist a number of recording rainfall gauging stations operating for a time period sufficiently long to yield a reliable estimation of IDF relationships; in many other countries, especially in developing countries, however, these stations are either non-existent or their sample sizes are too small. Because daily precipitation data is the most accessible and abundant source of rainfall information, it seems natural, at least for the regions where data at higher time resolution are scarce, to develop and apply methods to derive the IDF characteristics of short-duration events from daily rainfall statistics. In this paper, the properties of time scale invariance of rainfall are investigated and applied to Intensity-Duration-Frequency (IDF) relationships. The hypothesis of simple scaling implies in direct and empirically verifiable relations among the moments of several orders of rainfall intensities in different durations. Using these relations, it is possible to analytically derive IDF relationships for short-duration rainfall from the statistical characteristics of daily data only.

5.2 Methodology

5.2.1 Traditional methods to establish IDF curves for precipitation

The rainfall intensity patterns for various return periods are required for designing hydraulic structures (dams, levees, drainage systems, bridges, etc.) or for flood mapping and zoning. The objective of the rainfall IDF curves is to estimate the maximum intensity of rainfall for any duration and return period. This frequency analysis uses annual or seasonal maximum series, or independent values above a high threshold selected for different durations. If each duration is treated separately, contradictions between rainfall estimates can occur. IDF analysis takes into account the different durations in a single study, and prevents curves from intersecting. The first relationship goes back as early as 1932 (Bernard 1932). The classical approach for building IDF curves has three steps (Chow *et al.* 1988). In the first step, a probability distribution function is fitted to each duration sample. In the second step, the quantiles of several return periods T are calculated using the estimated distribution function from step one. Lastly, the IDF curves are determined by fitting a parametric equation for each return period, using regression techniques between the quantile estimates and the duration. The disadvantages of this procedure are the need to have a large number of parameters, and the calculation of a regression based on dependent values (since the estimated quantiles come from the same observed series, but aggregated into different time scales). There are other more consistent approaches, using for example an extreme value distribution (e.g. Koutsoyiannis *et al.* 1998).

Probability distribution function

The first step is to fit a Probability Distribution Function (PDF) or Cumulative Distribution Function (CDF) to each group comprised of the data values for a specific duration.

Random hydrological variables that are extremes, such as maximum rainfall and floods, are often described by several extreme value (EV) distributions developed by Gumbel (1954).

The General Extreme Value (GEV) distribution function can be written as

$$F(x) = \exp\left\{-\left[1-\frac{k(x-\mu)}{\sigma}\right]^{1/k}\right\} \quad for\ k \neq 0 \qquad (1)$$

The EV1 (or Gumbel) distribution results when the k variable in equation (1) is zero

$$F(x) = \exp\left[-\exp(-\frac{x-\mu}{\sigma})\right] \quad for\ k = 0 \qquad (2)$$

where the location parameter μ and scale parameter σ to be calculated from data series based on L moment method.

Taking the inverse of the distribution function (2) for a non-exceedance probability q,

$$x_q = F^{-1}(q) = m - s[-\ln(-\ln(q)] \qquad (q=F(x_q)) \qquad (3)$$

It is possible to relate the annual maximum rainfall intensity for each time interval with the corresponding return period from the cumulative distribution function F. Given a return period T, its corresponding cumulative frequency q (or non-exceedance probability) will be:

$$q = 1-\frac{1}{T} \quad \text{or} \quad T = \frac{1}{1-q} \qquad (4)$$

Once a cumulative frequency is known, the T-years rainfall event (or quantile) is determined using chosen theoretical distribution function (e.g. EV1, GEV or Log-normal distributions). The EVI distributions that are commonly used in Japan for frequency analysis.

IDF estimates were computed using the EV1 distribution, because this method is currently used in practice. Estimates computed by the EV1 distribution were calculated to the observed data for all stations.

Transformation of the CDF into the IDF curves

In the second step, the rainfall intensities for each duration and a set of selected return periods (e.g. 5, 10, 20, 50,100 years, etc.) are calculated. This is done by using the probability distribution functions derived in the first step. Figure 5.1 shows the transformation of the CDF into the IDF curves.

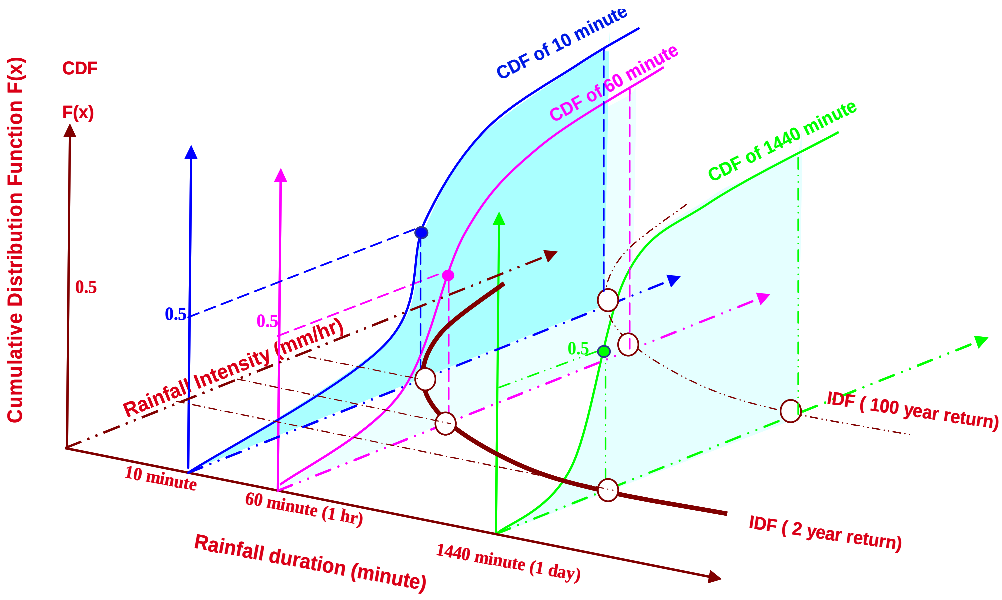


Figure 5.1 The transformation of the CDF into the IDF curves.

Fitting a specified parametric empirical IDF formulas

In the third step, the empirical formulas are used to construct the rainfall IDF curves. The least-square method is applied to determine the parameters of the empirical IDF equation that is used to represent intensity-duration relationships.

The IDF formulas are the empirical equations representing a relationship among maximum rainfall intensity (as dependant variable) and other parameters of interest such as rainfall duration and frequency (as independent variables). There are several commonly used functions found in the literature of hydrology applications (Chow *et al.(*1988); Takara (2005)), four basic forms of equations used to describe the rainfall intensity duration relationship are summarized as follows:

Talbot equation:

$$I = \frac{a}{d + b} \tag{5}$$

Bernard equation:

$$I = \frac{a}{d^c} \tag{6}$$

Kimijima equation:

$$I = \frac{a}{(d^c + b)} \tag{7}$$

Sherman equation:

$$I = \frac{a}{(d + b)^c} \tag{8}$$

where *I* is the rainfall intensity (mm/hour); *d* is the duration (hour); *a*, *b* and *c* are the constant parameters related to the metrological conditions.

The IDF curves for each station were obtained by using equations (5) to (8): Talbot, Bernard, Kimijima and Sherman. Least square method is applied to determine the parameters of four empirical IDF equations used to represent intensity-duration relationships. The value of parameter in the Rainfall IDF equations were chosen on the minimum of Root Mean Square Error (RMSE) between the IDF relationship produced by the frequency analysis and that simulated by the IDF equations. The RMSE was defined as

$$RMSE(d,T) = \sqrt{\frac{1}{m.n}\sum_{i=1}^{m}\sum_{j=1}^{n}(I_{i,j}(d,T)^* - I_{i,j}(d,T))^2} \qquad (9)$$

where *m* is the number of various rainfall duration, *n* is the number of various return periods (n=8, from 2-years to 200-year return), *I(d,T)** indicates the rainfall intensity of duration *d* and return period *T* estimated and the *I(d,T)* indicates the rainfall intensity derived by distribution for *d*-hour and *T*-year return .

5.2.2 The simple scaling method to establish intensity duration frequency curves.

Usually, for each time interval there are at least 2 parameters for the fitted distribution function, and two or three for each smoothing curve using the empirical formulas. Therefore, one of the main objectives of this work is to reduce the number of parameters to be estimated in order to increase their reliability.

The scaling or scale-invariant models enables us to transform hydrologic information from one temporal or spatial scale to another one, and thus, helping overcome the difficulty of inadequate hydrologic data. A natural process fulfills the simple scaling property if the underlying probability distribution of some physical measurements at one scale is identical to the distribution at another scale. The basic theoretical development of scaling has been investigated by many authors, including Gupta and Waymire (1990), Menabde *et al.* (1999), Nguyen *et al.* (2002) and Kuzuha *et al.* (2005). Rainfall intensity *I*(*d*) with duration d, exhibits a simple scale invariance behavior if

$$I(\lambda d) \overset{dist}{=} \lambda^H I(d) \qquad (10)$$

holds. The equality " $\overset{dist}{=}$ " refers to identical probability distributions in both sides of the equations; λ denotes a scale factor and *H* is a scaling exponent. From equation (10), it leads to a simple scaling law in a wide sense

$$E[\{I(\lambda d)\}^q] = \lambda^{qH} E[\{I(d)\}^q] \qquad (11)$$

where *E[.]* is the expected value operator and q is the moment order.

The random variable *I(d)* exhibits a simple scale invariance in a wide sense if Equation (11) holds. If *H* is a non-linear function of *q*, the *I(d)* is a general case of multi-scaling. Figure 5.2 shown the moments *E[.]* are plotted on the logarithmic chart versus the scale *λ* for different moment order *q*. The slope function of the order moment *K(q)* is plotted on the linear chart versus the moment order *q*. If the plotted results are on a straight line, the random variable shows simple scaling, while in other cases, the multi-scaling approach has to be considered.

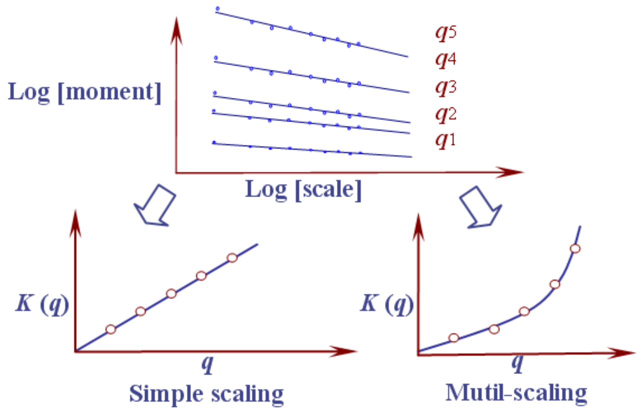


Figure 5.2 Simple and multiscaling in term of statistical moments. First step, moments of different orders q are plotted as function of scale in a log-log plot. From the slope, values of the function K(q) are obtained. If K(q) is linear, the process is simple scaling. If K(q) is non-linear, the process is multiscaling.

According to the scaling theory, the IDF formula can be derived (see Nhat *et al.* (2007) for more detail).

$$I(d,T) = \frac{\mu^* + \sigma^*[-\ln(-\ln(1-1/T))]}{d^{-H}} \qquad (12)$$
$$\text{With } \mu^* = \mu_{24}(\lambda d)^{-H}; \sigma^* = \sigma_{24}(\lambda d)^{-H}$$

where the μ_{24} and σ_{24} are parameters of 24 hour data series. It is worthwhile to note that the simple scaling hypothesis leads to the equality between the scale factor and the exponent in the expression relating rainfall intensity and duration.

The IDF relationship can be derived from 24 hours data series based on three parameters: scale exponent, the location and scale parameters of EV1 distribution.

5.3 Data supplied

Annual maximum rainfall series from durations ranging from 5 minutes to over 15 days were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries to supply extreme rainfall data, have been listed in the preamble to this report, and were:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	2 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

The record lengths of each rainfall data series varied from a minimum of 6 years to over 90 years.

5.4 Results and Discussion

5.4.1 Traditional methods to establish IDF curves for precipitation

The IDF curves for each station were constructed by using equations (2) to (5): Talbot, Bernard, Kimijima and Sherman. Least square method is applied to determine the parameter of four empirical IDF equations used to represent intensity-duration relationships. Table 5.1 shows the value of parameter in the rainfall IDF equations chosen on the minimum of RMSE at Nagoya station of Japan.

Table 5.1 The constant parameters of equations as IDF curves.

Year	Talbot		Bernard		Kimijima			Sherman		
return	*a*	*b*	*a*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
200	272.58	1.40	95.63	0.38	245.76	1.21	0.91	245.76	1.21	0.91
100	239.71	1.33	86.97	0.39	209.29	1.08	0.88	167.34	0.81	0.87
..50	206.97	1.24	78.26	0.40	174.25	0.95	0.85	136.15	0.77	0.72
25	174.33	1.14	69.47	0.41	140.84	0.80	0.81	108.57	0.73	0.57
10	131.22	0.97	57.54	0.43	99.53	0.57	0.74	77.34	0.66	0.36
5	98.27	0.80	48.01	0.45	70.56	0.37	0.68	57.21	0.61	0.20
3	73.35	0.64	40.32	0.48	50.34	0.20	0.62	43.81	0.57	0.09
2	52.58	0.47	33.27	0.52	34.65	0.03	0.55	32.26	0.54	0.00

a, b, c are the constant parameters.

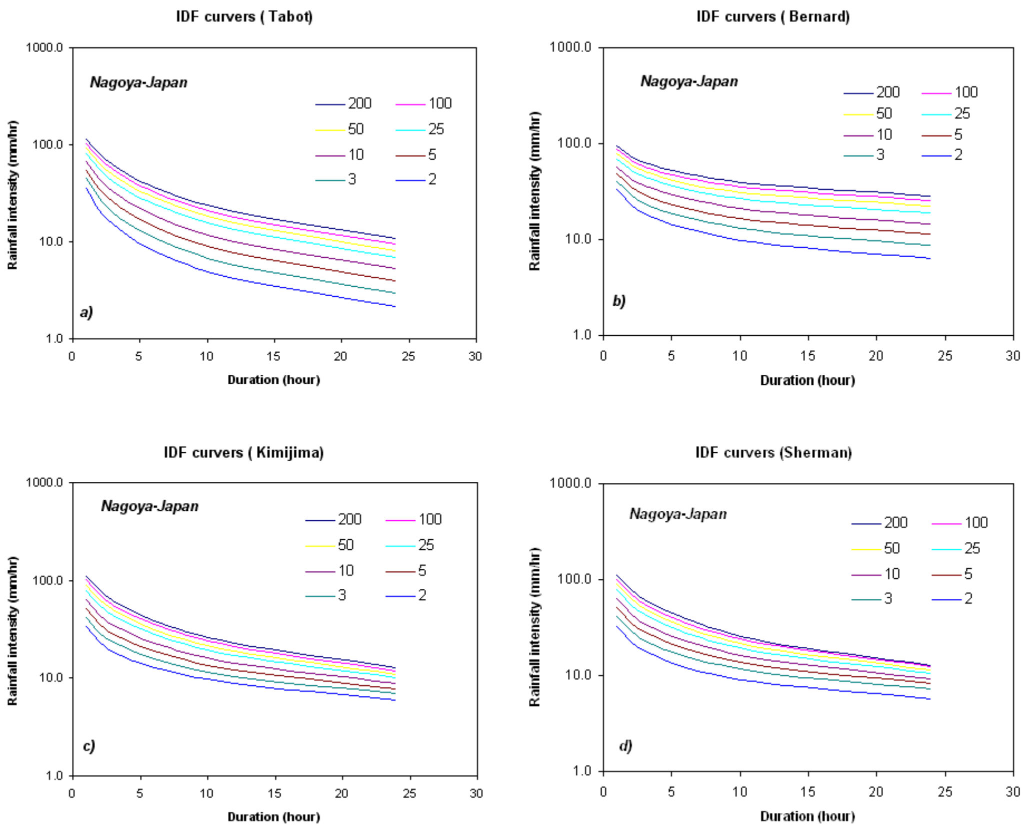


Figure 5.3 The rainfall Intensity-Duration-Frequency for Nagoya-Japan by a)Talbot, b)Bernard, c)Kimijima and d) Sherman empirical equations.

5.4.2 The simple scaling method to establish IDF curves.

Scale invariance properties of rainfall

The scaling properties of rainfall data were investigated by computing the five moment for each duration, and then by examining the log-log plots of the moments against their duration. Figure 5.4 shows the scaling exponents for the storm intervals and corresponding R^2 values for Nagoya stations used in the analysis. Figures 5.5 illustrates the relationship between the scaling exponents versus the order of moments for the Nagoya station.

The differences in the degree of steepness in the slopes for the short (10 min to 1 hr) and long (1 to 24 hr) duration storms indicate that two different scaling regimes exist for rainfall. This can be observed by a steeper slope found in short duration storms compared to long duration storms. The plots indicate that the relationships between moments and durations are linear having two different slopes with a breaking point at the 1 hour duration. This property perhaps suggests an existence of two different regimes with a transition in storm dynamics from high variability convective storms (less than 1 hour duration) to a smaller variability of frontal storms of longer duration than 1 hour.

The linearity in slope found in the moment versus log-durations plots illustrates that rainfall follows a simple scaling process. If the exponent is not a linear function of moment, then rainfall would follow a multi-scaling process The slopes of the moment versus log-duration plots define the *K(q)* coefficient shown in equation (11). The high correlation coefficients for each duration interval range from 0.982 to 1, indicating a strong validity of the simple scaling property of extreme rainfall.

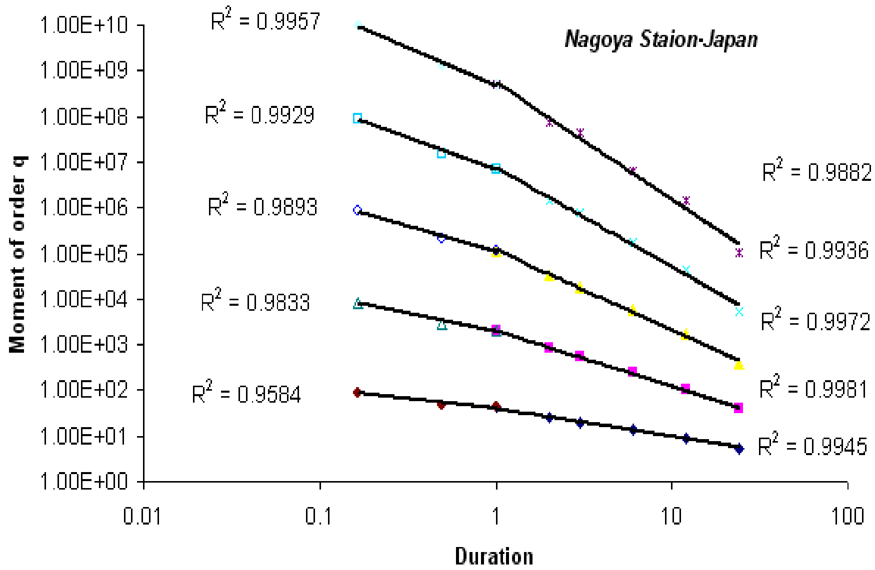


Figure 5.4 Log-log plot of moment versus duration for the Nagoya-Japan.

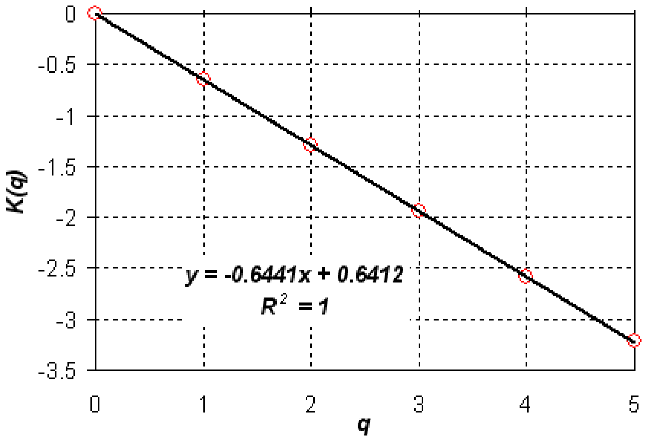


Figure 5.5 The scaling exponent versus order of moment for the Nagoya-Japan.

Estimation of Annual Extreme Rainfall

Figure 5.6 and 5.7 illustrate the scaled annual extreme and observed annual extreme rainfall versus probability for the Nagoya site. Figure 5.6 indicates that the scaled annual maximum estimates are similar to the observed. This result was typical for all stations analyzed in this paper. Figure 5.7 displays results for a 24 hr storm. The scaling procedure does well to predict the observed series.

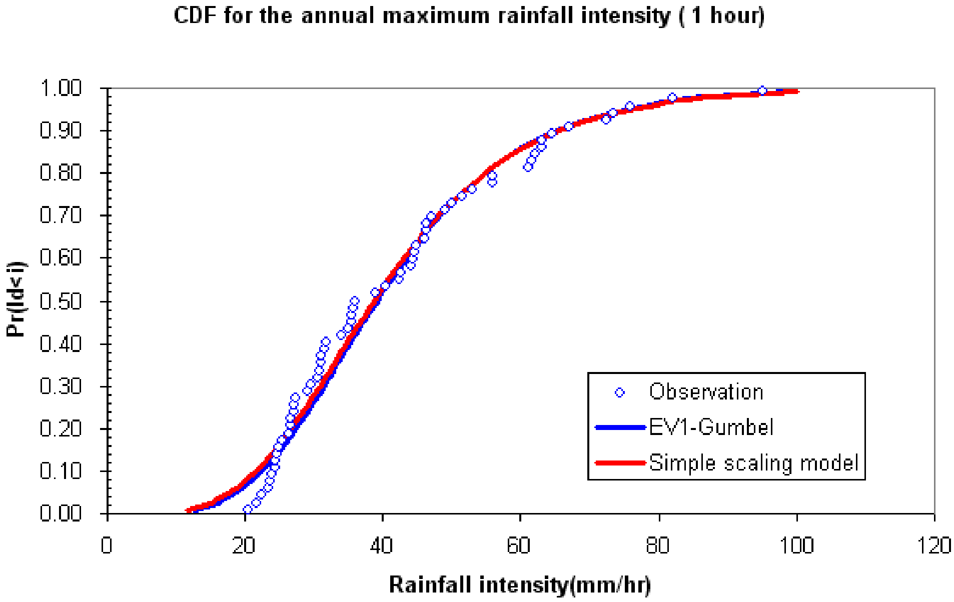


Figure 5.6 Quantile plots for Nagoya-Japan for 1 hour.

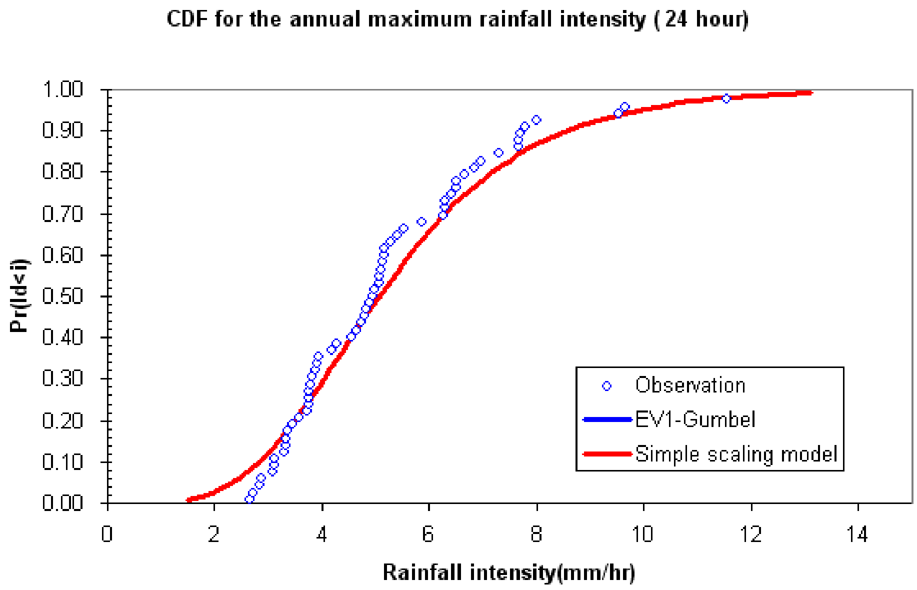


Figure 5.7 Quantile plots for Nagoya-Japan for 24 hour.

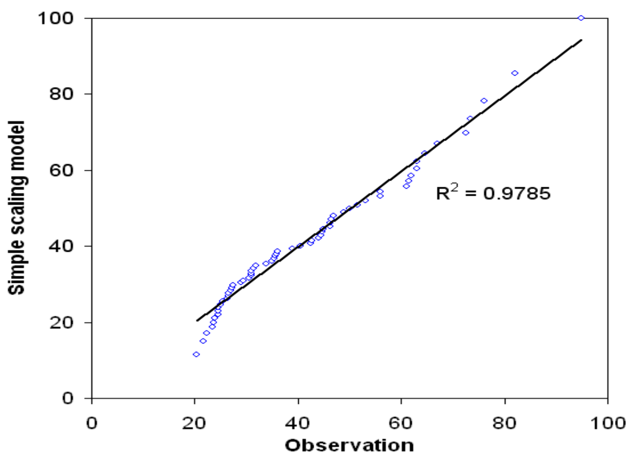


Figure 5.8 Estimated annual maximum versus observed for the 1 hr storms for Nagoya-Japan.

Figure 5.8 illustrates the plots of the scaled (estimated extreme rainfall) versus observed rainfall performed for the Nagoya site. The model performance variables (RMSE), and the best distribution which most accurately fits the observed data were performed for all sites and storm durations.

Estimation of IDF Rainfall Estimates

The graphical results of IDF estimates are shown in Figure 5.9 and 5.10 for the Nagoya station. It can be seen that the scaled estimates are relatively close to the observed estimates for short duration storms. For long duration storms, a greater discrepancy exists for all stations when the record lengths are greater than 40 years. Similar observations have been made for other stations used in this study.

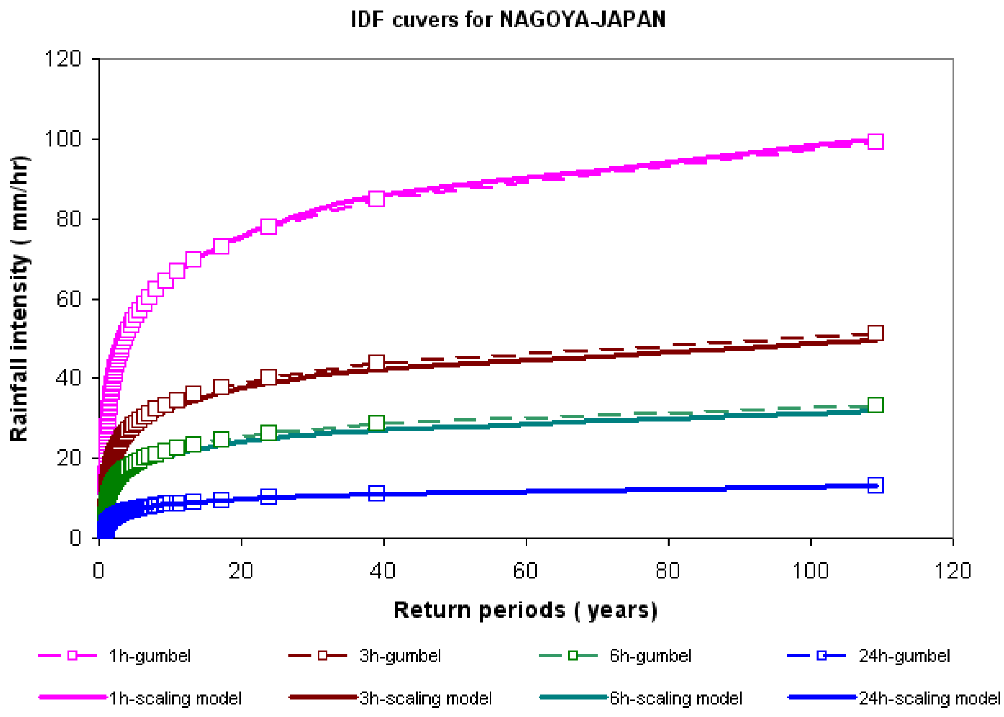


Figure 5.9 IDF Curves for short duration storm for Nagoya-Japan

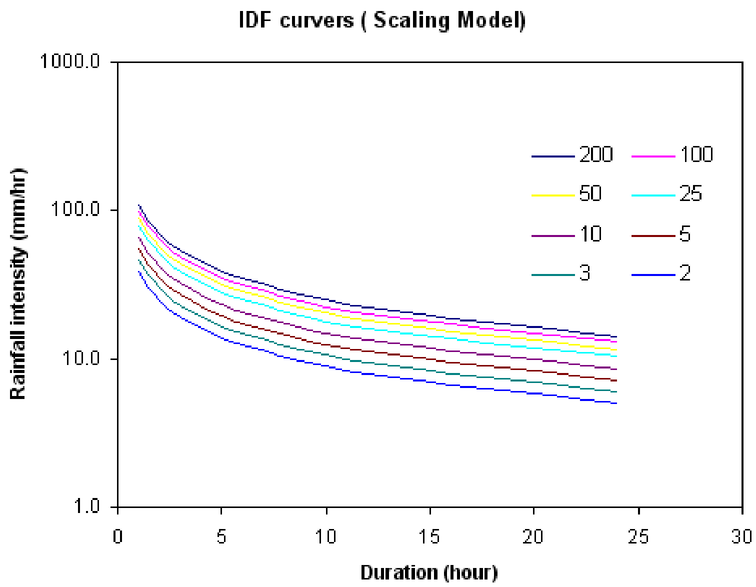


Figure 5.10 IDF Curves for short duration storm for Nagoya-Japan by scaling model.

The IDF curves of Nagoya station can be derived by using scaling model. Only three parameters need to estimate one set of the IDF curve.

$$I_{d,T} = \frac{33.48 + 14.21.[-\ln(-\ln(1-1/T)]}{d^{0.64}} \quad (12)$$

The IDF formulas (Table A5.1) and the IDF curves (Figures A5.1 to A5.10) for the Asia Pacific region by a scaling model are given in Appendicex 5.

5.4.3 Comparison of the methods to establish IDF curves.

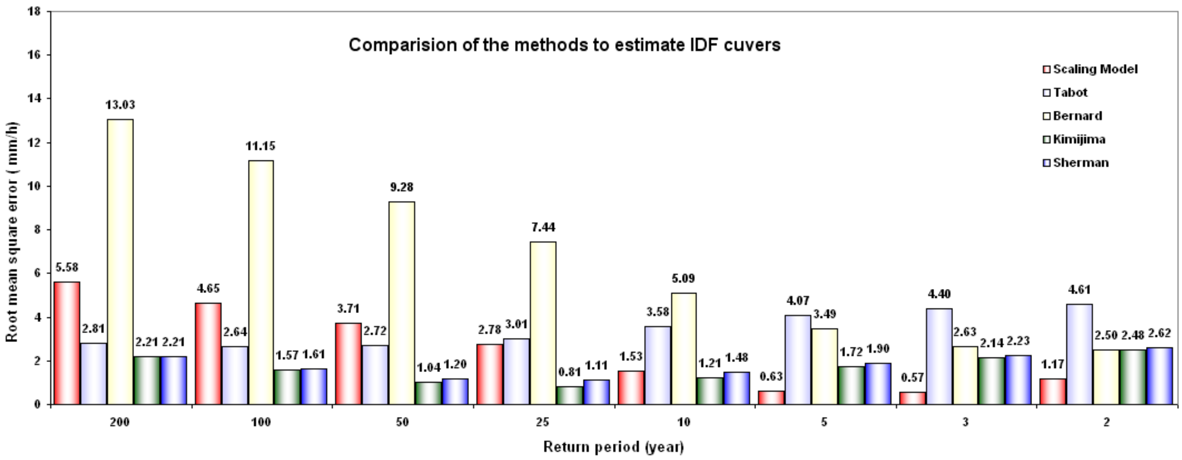


Figure 5.11 The RMSE computed for empirical functions and Scaling model.

The evaluation statistics, the RMSE were computed for the annual maximum rainfall estimated by four empirical equation and the Scaling model. For illustration, the values of the RMSE for Nagoya are shown in the Figure 5.11. All methods can be applicable for estimated IDF curves because maximum of RMSE is only 13.03 mm/hr for 200-year return rainfall estimation. For other stations, the RMSE were calculated in Figures A5.11 to A5.15 of Appendix 5.

For short-year return of less than 10 years, it can be clearly seen that scaling model produces have more accurate estimates than those values givens by four empirical method. For long years return RMSE values of Scaling Model are far lower than those for Bernard empirical equations and upper than three parameters equations (Kimijima and Sherman).

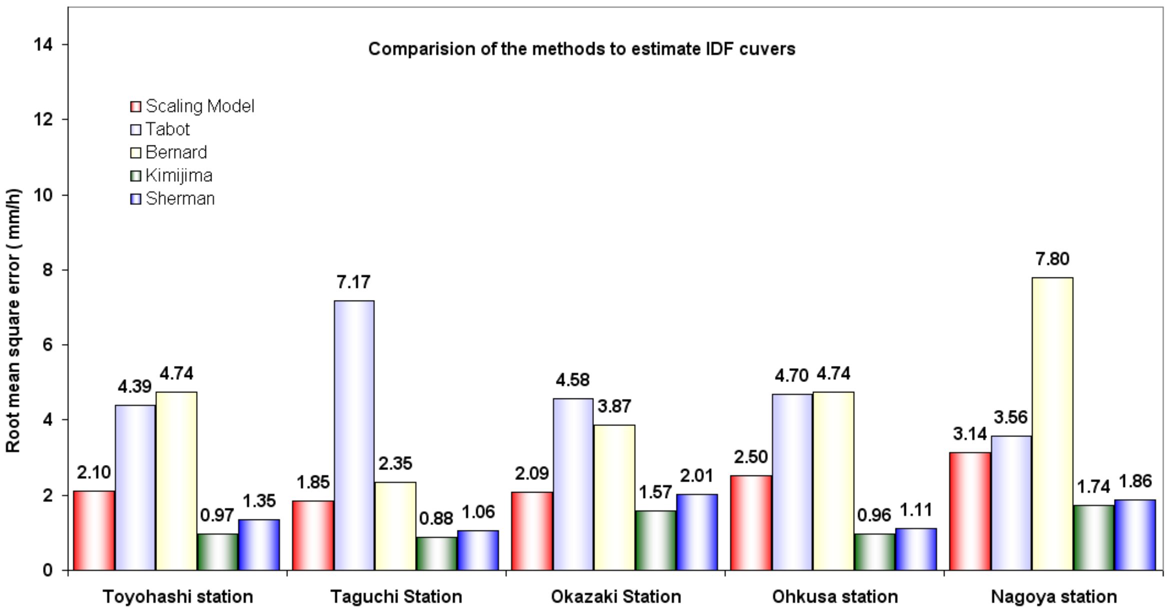


Figure 5.12 The RMSE computed for empirical functions and Scaling model.

The comparison statistics, the RMSE were computed for the five stations of Japan. For illustration, the values of the RMSE are shown in the Figure 5.12. It can be seen that scaling model produces have more accurate estimates than two empirical equation (two parameter methods: Talbot and Bernard), the goodness of equation is three parameters Kimijima equation.

5.5 Conclusion

The major findings of the present study can be summarized as follows: The properties of the time and space scale invariance of rainfall quantiles are examined in the Asia Pacific region. The results of this study show that rainfall follows a simple scaling process with two different scaling regimes: 10 minute to 1 hour and 1 hour to 24 hour. Results found from scaling estimates are very similar to the observed data. The benefit of using the principles of scaling is that it reduces the amount of parameters required to compute the quantiles.

If data is missing from a station, then the first order moment of the duration in question is the only parameter required to compute the quantiles. If that station belongs in a homogeneous region, then the regional *d* minute first order moment can be used to determine estimates. In practical applications, short duration storms and return periods less than 10 years are used to size drainage pipes for minor system analysis.

Results of this study are of significant practical importance because statistical rainfall inferences can be made from a higher aggregation model (ie. observed daily data) to a finer resolution model (ie. less than one hour, that might not have been observed). This is important since daily data are more widely available from standard rain gauge measurements, but data for short durations are often not available for the required site. The findings from this study can be further extended for other regional analysis.

5.6 Acknowledgments

Hydrological data used for the analysis were provided by the Aichi Prefectural Government, Japan and colleagues in the Technilal Sub-Committee (Chair: Dr. Trevor Daniell, Adelaid University, Australia) for Asian Pacific FRIEND (Flow Regimes from International, Experimental and Network Data) project of the UNESCO-IHP Regional Steering Committee for Southeast Asia and the Pacific (RSC-SEAP). The authors are very grateful for them, as well as for Dr. Yasuto Tachikawa (Kyoto University, Japan) and Dr. Guillermo Q. Tabios III (The University of Philippines) who gave useful suggestions to the authors.

5.7 References

Bernard, M. M. (1932): *Formulas for rainfall intensities of long duration.* Trans. ASCE, 96, 592-624.

Burlando, P. and Rosso, R. (1996): *Scaling and multiscaling models of depth-duration-frequency curves for storm precipitation*. Journal of Hydrology, 187, pp. 45-65.

Chow, V. T., Maidment, D. R. & Mays, L. W. (1988) *Applied Hydrology*. McGraw-Hill International Editions, New York, USA.

Gumbel, E. J. (1958): *Statistics of Extremes*, Columbia University Press, 375 p.

Gupta, V. K. and Waymire, E. (1990): *Multiscaling properties of spatial rainfall and river flow distributions.* Journal of Geophysical Research, 95(D3), pp. 1999-2009.

Kuzuha, Y., Komatsu, Y., Tomosugi, K. and Kishii, T. (2005): *Regional Flood Frequency Analysis, Scaling and PUB,* Journal Japan Soc. Hydrol. and Water Resources Vol. 18, No. 4, pp. 441-458.

Koutsoyiannis, D., Manetas, A. (1998): *A mathematical framework for studying rainfall intensity duration frequency relationships,* Journal of Hydrology, 206, pp.118–135.

Menabde, M., Seed, A. and Pegram, G. (1999): *A simple scaling model for extreme rainfall*. Water Resources Research, Vol. 35, No.1, pp. 335-339.

Nguyen, V. T. V, Nguyen, T.-D. and Ashkar, F. (2002): *Regional frequency analysis of extreme rainfalls*, Water Sci. Technol. 45(2), pp. 75–81.

Nhat, L. M., Tachikawa, Y. and Takara, K. (2006*): Establishment of Intensity-Duration-Frequency curves for precipitation in the monsoon area of Vietnam*, Annuals of Disas. Prev. Res. Inst., Kyoto Univ., No. 49B.

Nhat, L. M., Tachikawa, Y., Sayama, T., and Takaka, K. (2007): *A simple scaling characteristic of rainfall in time and space to derive intensity duration frequency relationships*, Annual Journal of Hydaulic Engineering, JSCE, Vol. 51, pp. 73-78.

Takara, K. (2005): *Report on data availability and IDF procedures: Situation in Japan.* IHP-VI technical Document in Hydrology No 5. Annex Japan country report.

5.8 Appendix Chapter 5 Results for Japan

Table A5.1 The IDF formulas curve for Asia Pacific region by scaling model

Country	Station	Latitude	Longitude	Elevation	IDF formulas
Japan	Nagoya	35° 10.0’	136° 57.9’	51.00	$I_{d,T} = \frac{33.48 + 14.21.[-\ln(-\ln(1-1/T)]}{d^{0.64}}$
	Okazaki	34° 55.1’	137° 11.6’	47.00	$I_{d,T} = \frac{31.01 + 10.63[-\ln(-\ln(1-1/T)]}{d^{0.627}}$
	Ohkusa	35° 13.8’	137° 17.1’	264.00	$I_{d,T} = \frac{36.08 + 12.40[-\ln(-\ln(1-1/T)]}{d^{0.644}}$
	Toyohashi	34° 46.6’	137° 22.1’	2.00	$I_{d,T} = \frac{33.82 + 11.80[-\ln(-\ln(1-1/T)]}{d^{0.619}}$
	Taguchi	35° 5.5’	137° 33.8’	466.00	$I_{d,T} = \frac{34.45 + 10.21[-\ln(-\ln(1-1/T)]}{d^{0.492}}$
Korea	Daegu	35° 53’ 00’’	128° 37’ 00’’	57.60	$I_{d,T} = \frac{29.12 + 11.65[-\ln(-\ln(1-1/T)]}{d^{0.638}}$
Australia	Geraldton airport	28.80	114.70	33.00	$I_{d,T} = \frac{168.85 + 65.67[-\ln(-\ln(1-1/T)]}{d^{0.704}}$
Malaysia	JPS Ampang	03° 14’ 10’’	101° 45’ 10’’	-	$I_{d,T} = \frac{65.63 + 9.91[-\ln(-\ln(1-1/T)]}{d^{0.852}}$
China	Yongchun	25° 32’	118° 28’	120.00	$I_{d,T} = \frac{36.21 + 13.36[-\ln(-\ln(1-1/T)]}{d^{0.674}}$
Philippine	Peurto	09° 45’	118° 44’	16.00	$I_{d,T} = \frac{29.71 + 10.94[-\ln(-\ln(1-1/T)]}{d^{0.6298}}$

** $I_{d,T}$: Rainfall intensity for d(hour) duration and T(years) returns periods.*

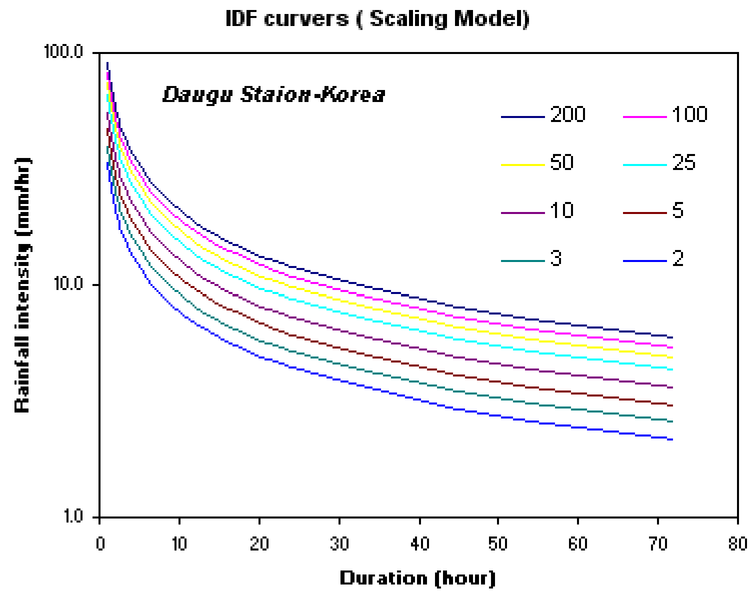


Figure A5.1 IDF Curves for short duration storm for Daugu-Korea by scaling model

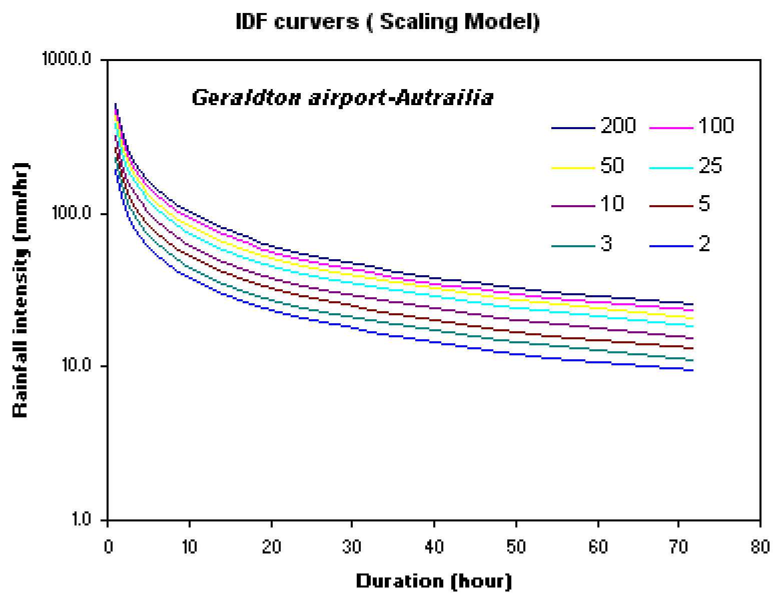


Figure A5.2 IDF Curves for short duration storm for Gealdton-Autralia by scaling model

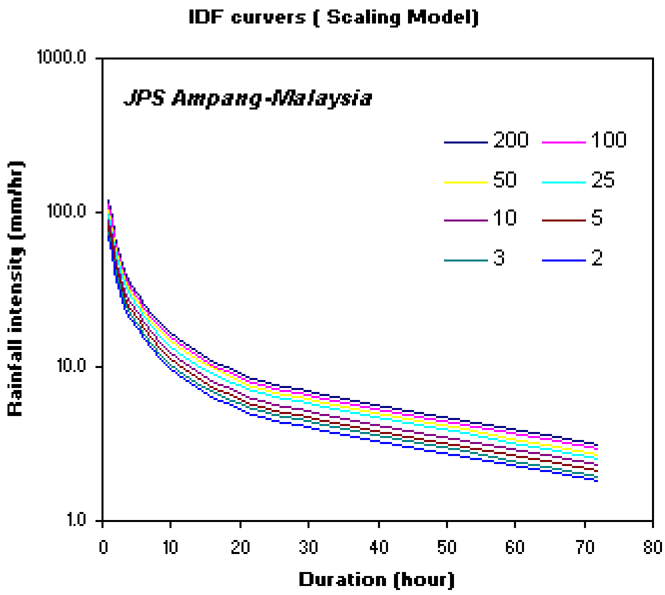


Figure A5.3 IDF Curves for short duration storm for JPS Ampang-Malaysia by scaling model

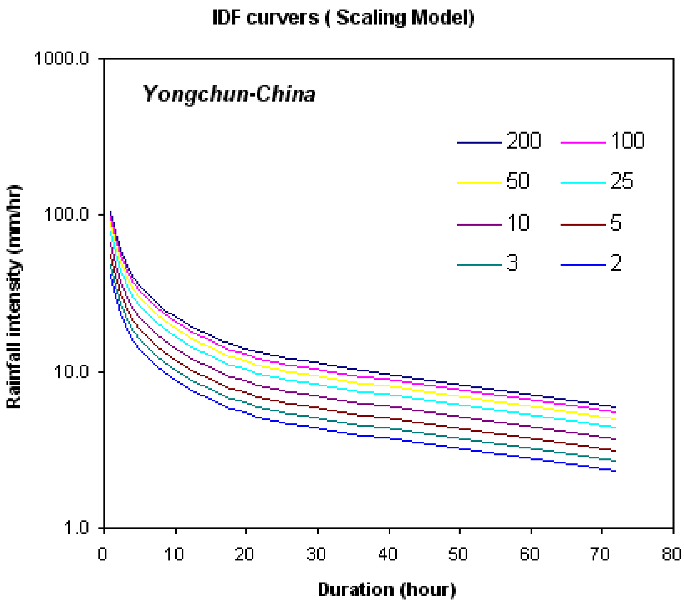


Figure A5.4 IDF Curves for short duration storm for Yongchun-China by scaling model

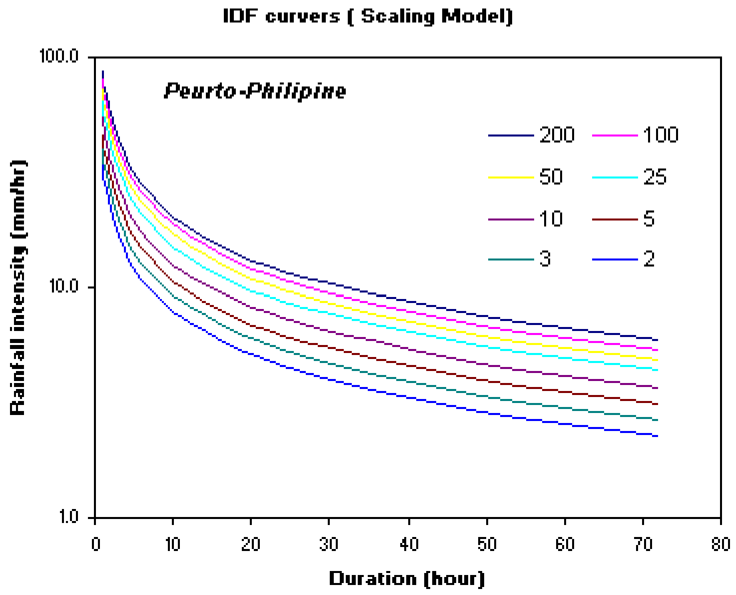


Figure A5.5 IDF Curves for short duration storm for Puerto Philipine by scaling model

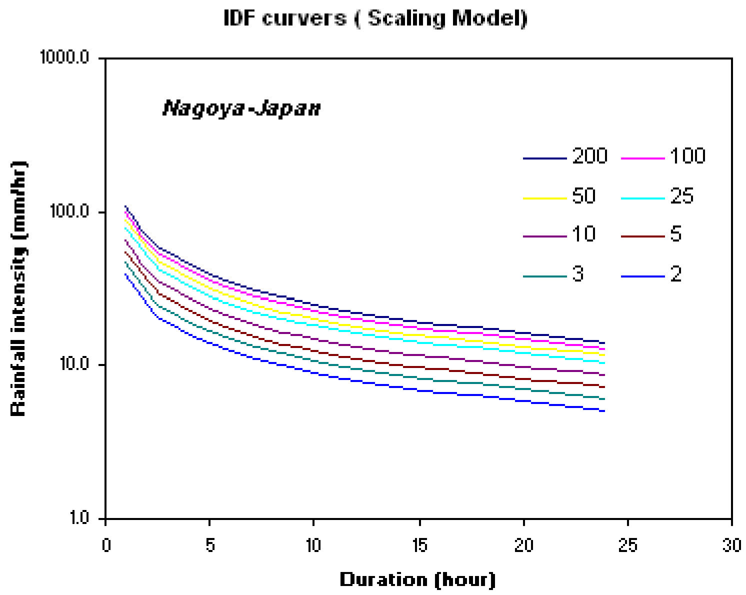


Figure A5.6 IDF Curves for short duration storm for Nagoya-Japan by scaling model

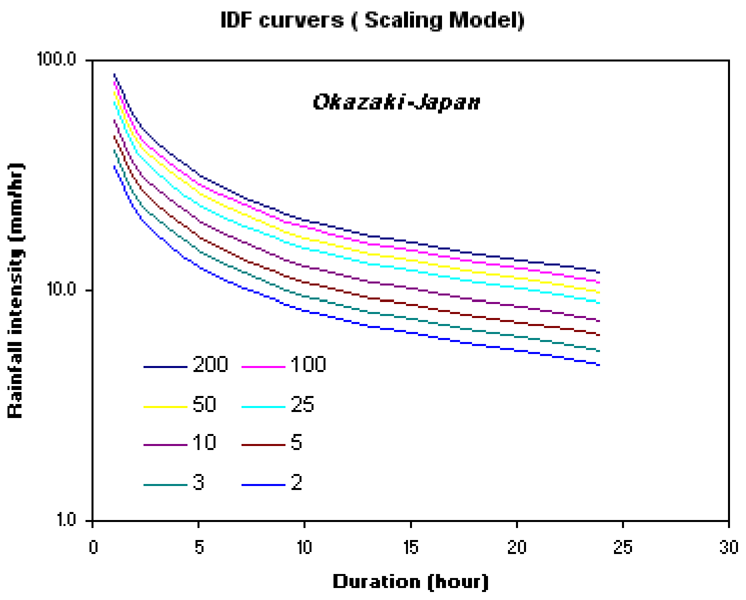


Figure A5.7 IDF Curves for short duration storm for Okazaki-Japan by scaling model

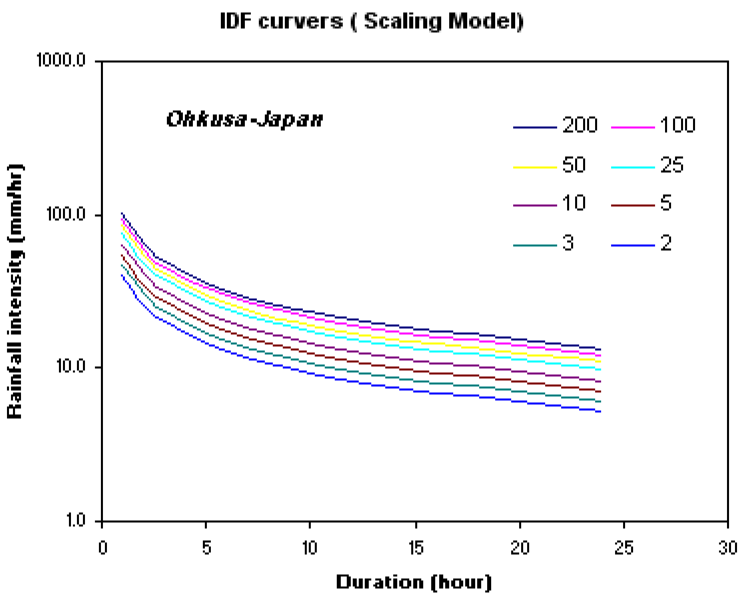


Figure A5.8 IDF Curves for short duration storm for Ohkusa-Japan by scaling model

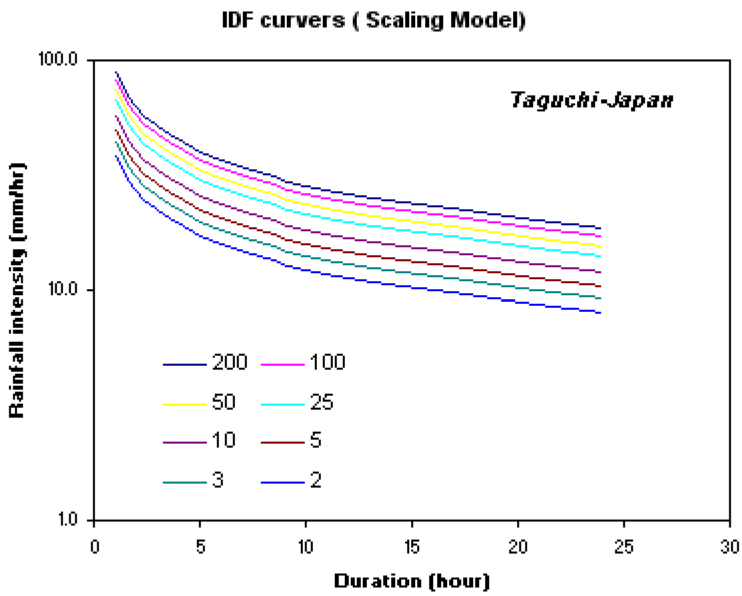


Figure A5.9 IDF Curves for short duration storm for Taguchi-Japan by scaling model

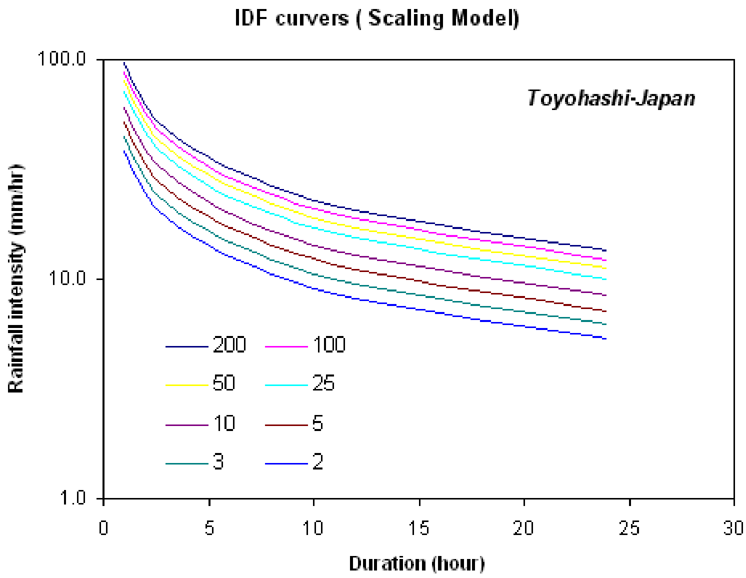


Figure A5.10 IDF Curves for short duration storm for Toyohashi-Japan by scaling model

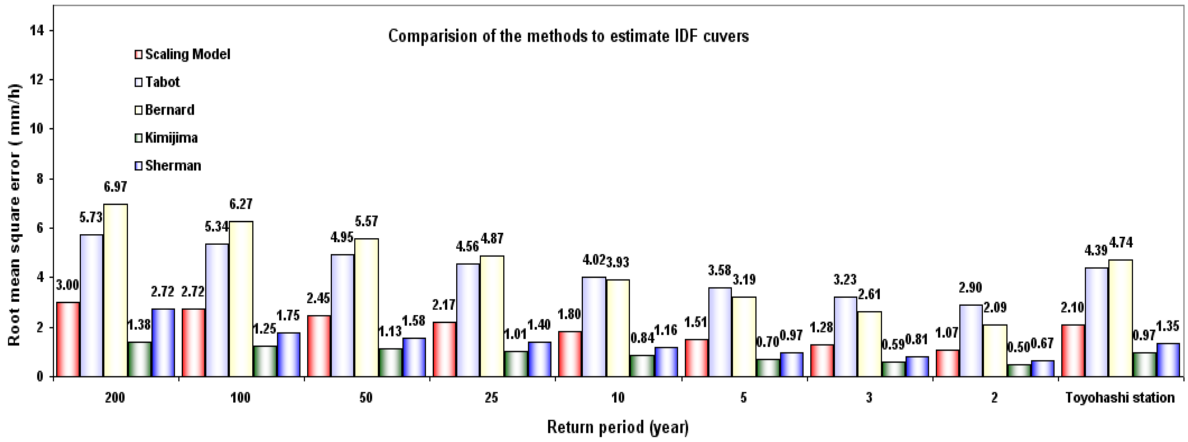


Figure A5.11 The RMSE computed for Toyohashi station- Japan.

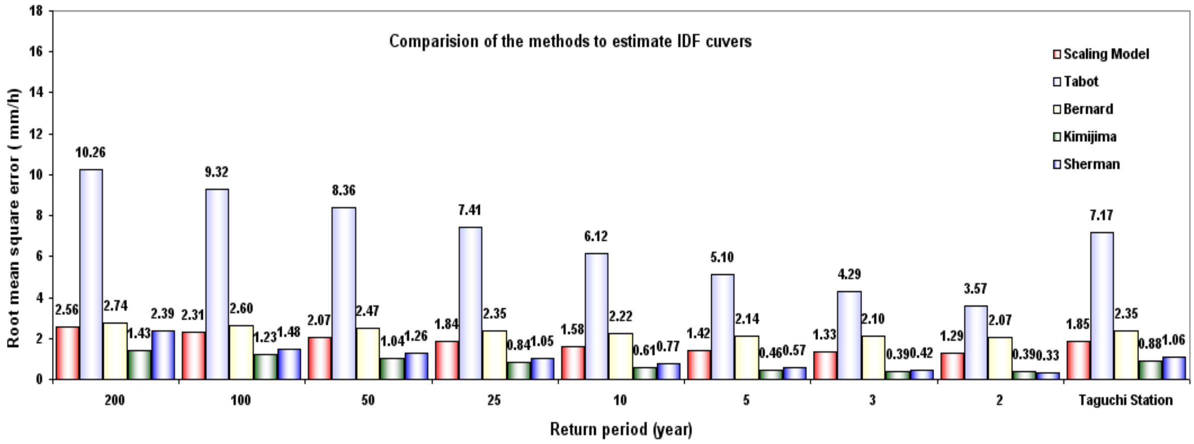


Figure A5.12 The RMSE computed for Taguchi station- Japan.

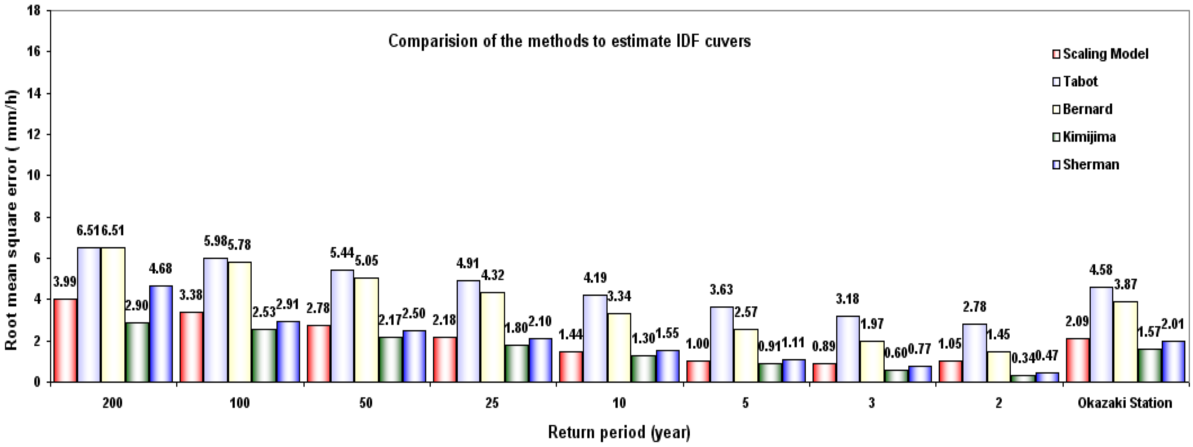


Figure A5.13 The RMSE computed for Ohkazaki station- Japan.

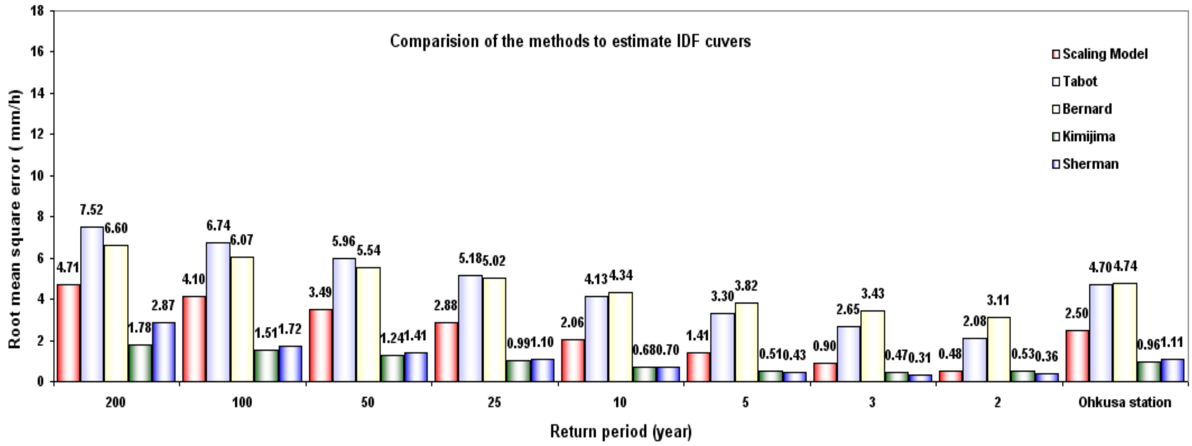


Figure A5.14 The RMSE computed for Ohkusha station- Japan.

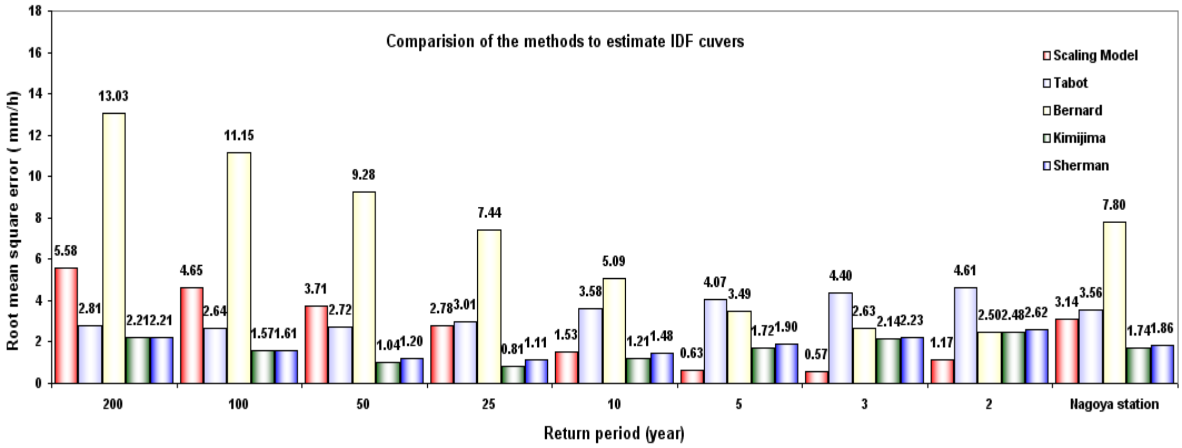


Figure A5.15 The RMSE computed for Nagoya station- Japan.

.

Chapter 6 Malaysia

Mohd Zaki M.Amin, Mohd Nor M.Desa and Zalina Mohd Daud

6.1 Introduction

Estimates of high intensity rainfall are very important in rainfall-runoff modeling with respect to water resources engineering, either for planning, designing and operating of water resources projects, or the protection of various engineering projects against floods. The rainfall intensity-duration-frequency (IDF) relationship is one of the most commonly used tools in determining design rainfall intensity. A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of rainfall data. An average recurrence interval (ARI) and annual exceedance probability (AEP) is attributed to the estimate. ARI is the average period between each exceedance and is associated with the partial duration series (PDS); nevertheless AEP is the probability that a particular level of rainfall will be exceeded in any particular year (at location and duration) and is derived using the annual maximum series data. This chapter briefly presents a method to be preferred in the estimation of design rainfall and construction of the rainfall IDF curves using the Partial Duration or Peak over Threshold Series (POT) and the Annual Maximum Series (AMS) for Malaysian data. The mathematical formulation is then presented to represent the constructed IDF curve.

6.2 Methodology

In Malaysia, the Department of Irrigation and Drainage Malaysia (DID), the government agency which looked into hydrological data collection and publication, has been motivated to publish Hydrological Procedure No. 1 (HP1) entitled “Estimation of the Design Rainstorm in Peninsular Malaysia” (Heiler, 1973; Mahmood et. al., 1982). The first edition of HP1, authored by Heiler (1973) was developed using a very minimum available data of 80 rainfall stations with records up to 1970. The second edition of HP1 authored by Mahmood, et al., (1982), had the benefit of more data from 210 rainfall stations with records extended to 1979/80. Out of the total number of rainfall stations used in the analysis, only 4 rainfall stations has more than 20 years record, 59 rainfall stations has less than 10 years records and the rest ranges from a 10 to 20 years record. The procedure provides an estimate of at-site design rainfall and the maps for accommodating design rainstorm of ungauged sites. The Gumbel distribution was used as the frequency distribution and the Gumbel paper was employed to draw the linear curve line to estimate the distribution’s parameters. Although HP1 was first published in 1973, it was reviewed and updated in 1983. However the main shortcoming of this reviewed procedure is the uncertainty of estimated design rainfall magnitude, particularly for high return periods or ARI (i.e. 50years and 100years). This uncertainty is identified to be highly contributed by the short records of data used in analysis.

To overcome this issue, the DID have embarked on a project of reviewing and updating the existing procedure in 2004 using more and longer periods of data with the main aim of enhancing and improving the accuracy of quantile estimations particularly at high return periods. Approximately 815 rainfall stations throughout Peninsular Malaysia were used in the mentioned exercise. The new estimates of design rainfall and IDF curves has been constructed from 188 auto-recording rainfall stations specifically for the duration of 0.25hour to 72hours.

The L-moments method which has been identified as a robust, most flexible and practical method was used for estimating the parameters and can easily accommodate the proposed models of AM data series or PD/POT data series.

Previous studies of the regional frequency analysis identified the Generalized Extreme Value (GEV) distribution is considered the most likely parent distribution for regional data of the entire Peninsular

Malaysia particularly for longer durations of more than 3 hours. Nevertheless, the Extreme Value Type 1 (EV1) distribution, which is special case of GEV distribution (κ=0) has been fitted to at-site data and statistical test has shown the EV1 can be considered to be a parent distribution; but the application of EV1 is only limited to AMS data. The 2P-Generalized Pareto (GPA) or Exponential distribution is used to accommodate the PD/POT data series for determining quantile estimations of 2, 5, 10, 20, 25, 50 and 100 years return period. Since relatively long and reliable PDS/POT records are available, it should yield more accurate estimates of extreme quantiles than the corresponding annual-maximum frequency analysis. The IDF values for ARI of 2, 5, 10, 20, 25, 50 and 100 years derived from the PD/POT series were adjusted into ARI of the AM series using the Langbein formula;

$$T_A = \frac{e^{1/T_P}}{e^{1/T_P} - 1} \quad (1)$$

where T_A is ARI of AM data series and T_P is PD/POT data series.

IDF relationship is a mathematical relationship between the rainfall intensity *i*, the duration *d*, and the return period *T* (or, equivalently, the annual frequency of exceedance, typically referred to as 'frequency' only). As stated by Koutsoyiannis et. al., (1998), the typical IDF relationship for a specific return period can be expressed in the form:

$$i = \frac{a(T)}{b(d)} \quad (2)$$

The function of *b(d)* is $b(d) = (d + \theta)^{\eta}$ where θ and η is parameter to be estimated ($\theta>0$, $0<\eta<1$). Even though the function *a(T)* could be completely determined from any probability distribution function of the maximum rainfall intensities *I(d)*; it was recognized by the oldest relationship (Bernard, 1932) as $a(T) = \lambda T^{\kappa}$. A generalized IDF relationship can be written in the form of

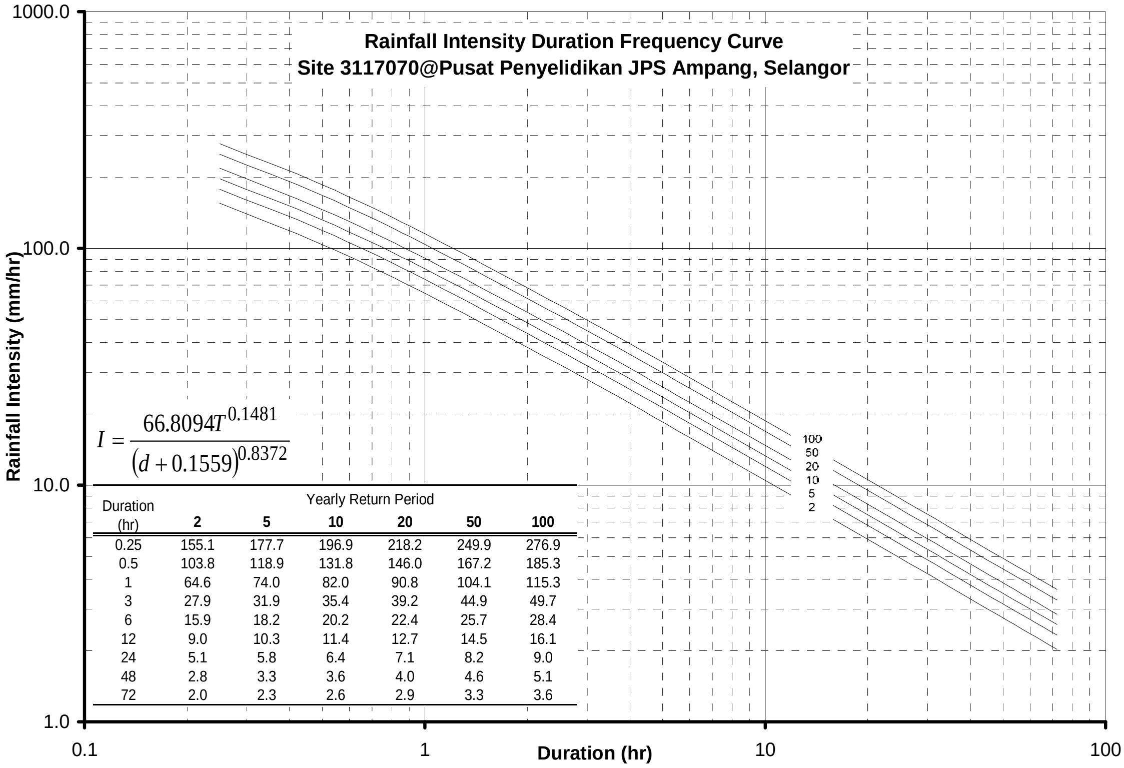
$$i = \frac{\lambda T^{\kappa}}{(d + \theta)^{\eta}} \quad (3)$$

where the parameters θ, η, λ and κ can be solved by means of the one-step least squared method using the embedded optimization procedure in MS Excel.

6.3 Data supplied

Annual maximum rainfall series for durations ranging from 5 minutes to over 15 days were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries supplying the extreme rainfall data have been listed in the preamble to this report. This particular section deals with only results of analysis being carried out using three Malasian raingauge data

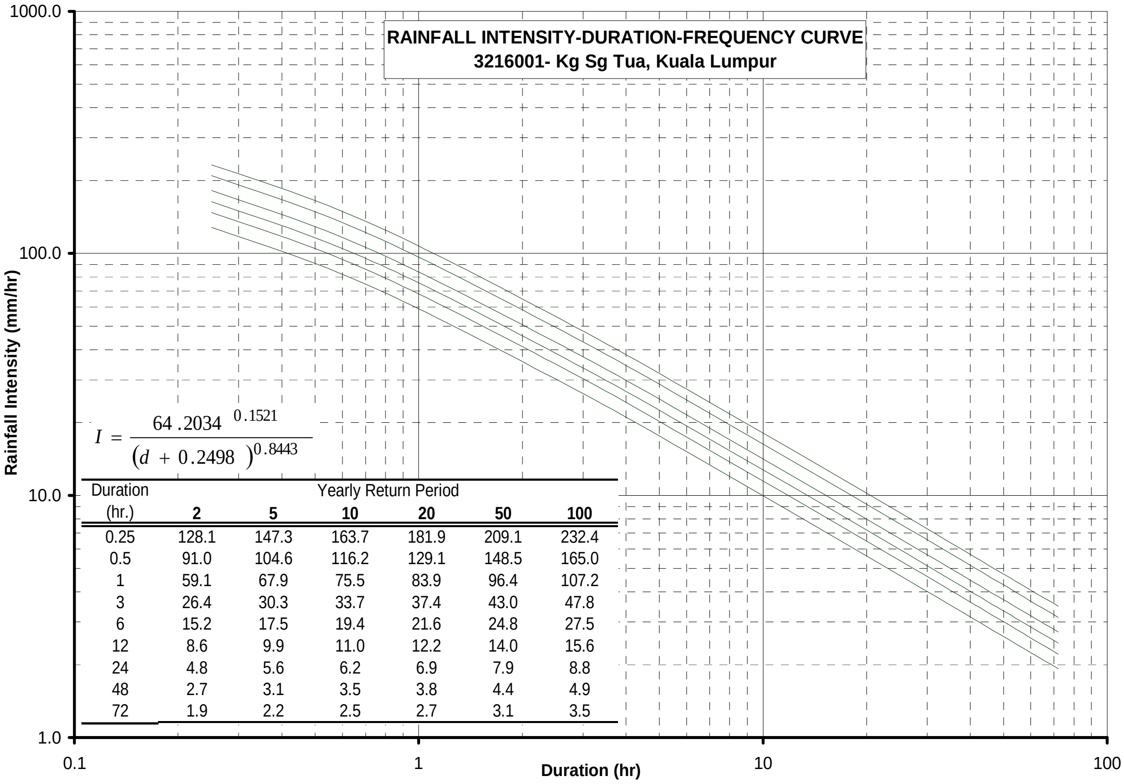
The final IDF curve and IDF formulation are shown in Figures 6.1, 6.2 and 6.3 for three rainfall stations.



$$I = \frac{66.8094T^{0.1481}}{(d+0.1559)^{0.8372}}$$

Duration (hr)	Yearly Return Period 2	5	10	20	50	100
0.25	155.1	177.7	196.9	218.2	249.9	276.9
0.5	103.8	118.9	131.8	146.0	167.2	185.3
1	64.6	74.0	82.0	90.8	104.1	115.3
3	27.9	31.9	35.4	39.2	44.9	49.7
6	15.9	18.2	20.2	22.4	25.7	28.4
12	9.0	10.3	11.4	12.7	14.5	16.1
24	5.1	5.8	6.4	7.1	8.2	9.0
48	2.8	3.3	3.6	4.0	4.6	5.1
72	2.0	2.3	2.6	2.9	3.3	3.6

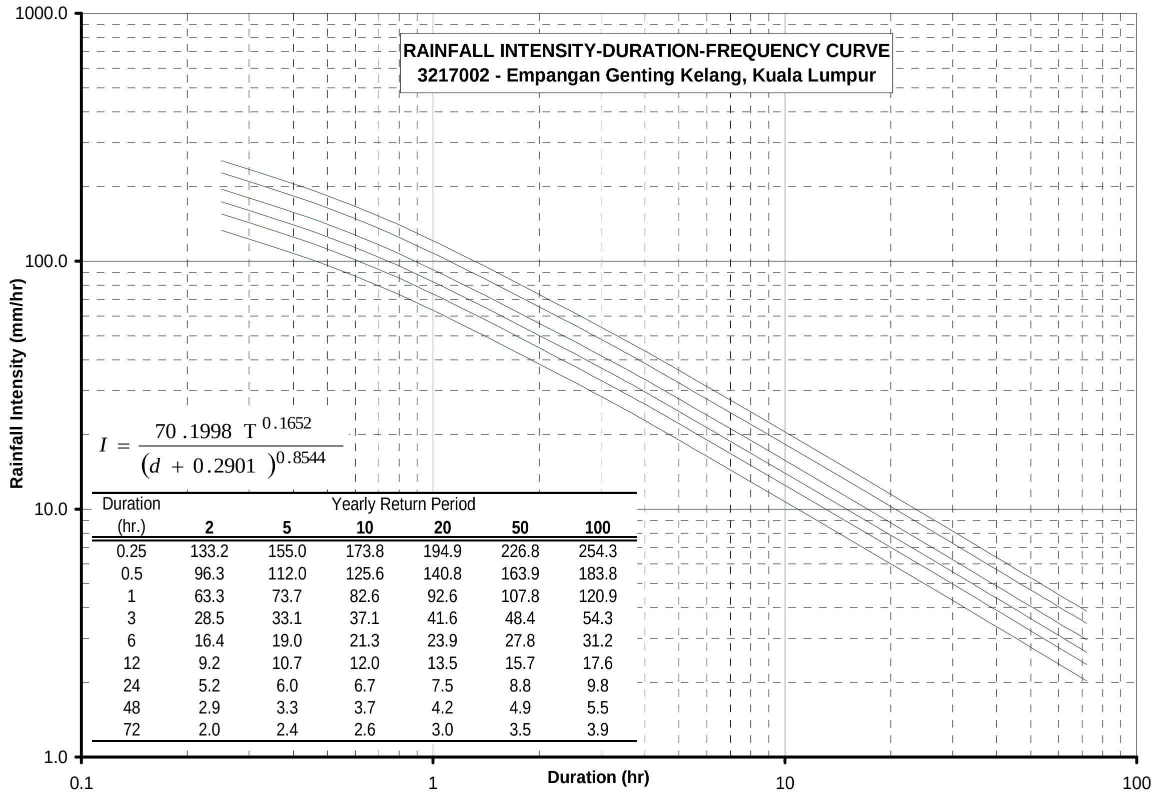
Figure 6.1 RIDF Curve of JP S, Ampang, Selangor, Malaysia



$$I = \frac{64.2034^{\;0.1521}}{(d+0.2498)^{0.8443}}$$

Duration (hr.)	Yearly Return Period 2	5	10	20	50	100
0.25	128.1	147.3	163.7	181.9	209.1	232.4
0.5	91.0	104.6	116.2	129.1	148.5	165.0
1	59.1	67.9	75.5	83.9	96.4	107.2
3	26.4	30.3	33.7	37.4	43.0	47.8
6	15.2	17.5	19.4	21.6	24.8	27.5
12	8.6	9.9	11.0	12.2	14.0	15.6
24	4.8	5.6	6.2	6.9	7.9	8.8
48	2.7	3.1	3.5	3.8	4.4	4.9
72	1.9	2.2	2.5	2.7	3.1	3.5

Figure 6.2 RIDF Curve of KG S Tua, Kuala Lumput, Malaysia



$$I = \frac{70.1998\ T^{0.1652}}{(d + 0.2901)^{0.8544}}$$

Duration (hr.)	Yearly Return Period 2	5	10	20	50	100
0.25	133.2	155.0	173.8	194.9	226.8	254.3
0.5	96.3	112.0	125.6	140.8	163.9	183.8
1	63.3	73.7	82.6	92.6	107.8	120.9
3	28.5	33.1	37.1	41.6	48.4	54.3
6	16.4	19.0	21.3	23.9	27.8	31.2
12	9.2	10.7	12.0	13.5	15.7	17.6
24	5.2	6.0	6.7	7.5	8.8	9.8
48	2.9	3.3	3.7	4.2	4.9	5.5
72	2.0	2.4	2.6	3.0	3.5	3.9

Figure 6.3 RIDF Curve of Empanga GK, Kuala Lumput, Malaysia

6.4 Acknowledgments

The authors would like to thank the Department of Irrigation and Drainage Malaysia for supplying the data concerned.

6.5 References

Amin, M.Z.M., Ishak, A.M., and M.N. Mohd Desa(2006). Developing A Low Return Period of Design Rainstorm using Generalized Pareto Distribution for an urban cathment area in Malaysia. Proc. of the 7th International Conference on Precipitation in Urban Areas, St. Moritz, Switzerland.

Amin, M.Z.M., and Shaaban, A.J., (2004). The rainfall Intensity-Duration-Frequency (IDF) relationship for ungauged sites in Peninsular Malaysia using a mathematical formulation. Proc. 1st. International Conference on Managing Rivers in the 21st Century, Penang, Malaysia, 251-258

Amin, M.Z.M., (2003). Design Rainstorm of Peninsular Malaysia: Regional Frequency Analysis Approach. Paper presented at International Conference on Water and Environment, 15-18 December 2003, Bhopal, Madhya Pradesh, India

Amin, M.Z.M., (2002). Regionalisation Approach in Design Rainstorm Estimation Based on L-Moments Theory in Peninsular Malaysia. Paper presented at International Conference on Urban Hydrology, 14-16 October 2002, Kuala Lumpur, Malaysia

Claps, P. & Vilanni, P., (2001). Using Rainfall and Runoff Peaks Over Threshold in the Analysis of Flood Generation Mechanisms. Proceedings of the 3rd EGS Plinius Conference, October 2001, Baja Sardinia, Italy.

Claps, P. & Laio, F., (2003). Peak over Threshold Analysis of Flood and Rainfall Frequency Curve. Proceedings of the ESF LESC Exploratory Workshop, October 24-25, Bologna, Italy

Daud, Z.M., 2001. Statistical modeling of extreme rainfall processes in Malaysia. Ph.D (Thesis), unpublished, Universiti Teknologi Malaysia.

Hosking, J.R.M., and Wallis, J.R. (1997). Regional frequency analysis: an approach based on L-moments. Cambridge University Press, New York, 224 pp.

Koutsoyiannis, D., Kozonis, D., Manetas, A., 1998. A Mathematical framework for studying rainfall intensity-duration-frequency relationship, Journal of Hydrology 206 (1998), 118-135.

Mahmood, M.D., Salleh, S., Leong, T.M, Teh, S.K., 1982. Hydrological Procedure No.1 - Estimation of design rainstorm in Peninsular Malaysia. Ministry of Agriculture Malaysia, Kuala Lumpur, 71 pp.

Chapter 7 New Zealand

Craig Thompson

7.1 Introduction

Investigations of extreme rainfalls by the scientific community in any country serves several purposes: (i) the estimation of extreme rainfalls for design purposes; (ii) the assessment of the rarity of observed rainfalls; and, (iii) comparison of methods to estimate design rainfalls. This report deals with the third purpose, and arises from an APFRIEND Workshop in Kuala Lumpur in June 2005, whereby the country representatives attending the workshop were asked to supply extreme rainfall data so that a comparison of the various methods used in estimating design rainfalls could be made. This chapter briefly presents a method used in the design rainfall estimation in New Zealand.

7,2 Methodology

Analysis of extreme rainfall events and estimation of their frequency are required in hydrometeorological practice. Procedures for the analysis of extremes are well established: there are two methods commonly used. The first uses annual maximum data, and is the highest recorded value in any given year, while the second method selects all data above a threshold without regard to the number of events within any given time period. An extreme-value analysis using the first method is used in this report.

For any statistical distribution of extremes,

$$Prob(X \leq x) = F(x),$$

where *F(x)* is the cumulative distribution function. However, in applying extreme value theory, it is more usual to express probability in terms of the annual exceedances, *aep*, given as

$$Prob(X \geq x) = 1 - F(x) = aep$$

The average recurrence interval (or return period), T_A, is simply 1/*aep*, and is the average interval in years containing at least once rainfall exceeding some magnitude.

However, in analysing annual maximum rainfalls for quantile estimation purposes, T_A is a convenient recurrence interval to use. For small recurrence intervals it is usual to note that T_A is not the *true* recurrence interval (WMO, 1983; Robson and Reed, 1999). This is due to measuring the extreme values in units of whole years, and because there may be more than one extreme rainfall event within a year which is greater in magnitude than the annual maxima from other years. The true recurrence interval is approximately 0.5 year smaller than T_A.

The analysis of annual maximum rainfalls in this report uses a Generalised Extreme Value (GEV) distribution, and more especially the EV1 of Gumbel distribution. The GEV is a distribution of three-parameters, ξ, α, and κ, where ξ and α are the (mode) location and dispersion (scale) parameters of the GEV and κ is the shape parameter of the distribution. Of the three parameters, κ is the most sensitive. For small amounts of data (less than about 30) it is known that the 3-parameter GEV often leads to unreliable quantile estimates (Martins and Stedinger, 2000; Rosbjerg and Madsen, 1995). This is due to the difficulty in reliably estimating the shape parameter with small amounts of data (Lu and Stedinger, 1992; NERC, 1975).

The EV1 or Gumbel distribution given by

$$P(X \le x) = F(x) = \exp(-\exp(-(x-\xi)/\alpha)),$$

is a 2-parameter GEV distribution with the shape parameter, *κ*, set to zero. This relation provides the probability that the specified *x* is never exceeded. Several methods are readily available to estimate the parameters of the distribution: in this report L-moments (Hosking and Wallis, 1997) are used to fit annual maximum series to each of the 45 sites. L-moments are modifications to the method of probability weighted moments. Both methods provide identical parameter estimators. In terms of L-moments, the parameters of the EV1 distribution are:

$$\alpha = \lambda_2 / \log(2)$$
$$\xi = \lambda_1 - \alpha\gamma$$

where λ_1 and λ_2 are the first and second L-moment and γ is Eulers constant. For the EV1 distribution, and for any given recurrence interval, T_A, the amount of rainfall or quantile estimate is given by

$$X_{T_A} = \xi - \alpha(\log_e(-\log_e(1-1/T_A))).$$

Variances of the EV1 parameters were determined from the method provided by Phien (1987), and Madsen et al. (1997).

Design rainfalls (or quantiles) for a range of durations and recurrence intervals were determined from the estimated parameters of the fitted Gumbel distributions. The variances associated with these quantiles are also computed using the method given by Phien (1987) and Madsen et al (1997). Examples of Depth – Duration – Frequency tables for each of the contributing countries are given below. The complete analysis for all 45 sites is contained in a spreadsheet accompanying this report.

7.3 Data supplied

Annual maximum rainfall series from durations ranging from 5 minutes to over 15 days were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries to supply extreme rainfall data, have been listed in the preamble to this report, and were:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	2 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

The record lengths of each rainfall data series varied from a minimum of 6 years to over 90 years. Apart from a visual check of each data series, no further error checks were made as it was assumed that each contributing country undertook quality assurance checks before supplying data. An apparent error was found for the Japanese site Toyohashi. It had an extreme value of 12402 for 1996, and was adjusted to 124.2.

Given in Table 7.1 are examples of the RIFD analyses for the various countries. Complete results of RIFD analyses for each country are given in Appendix 7.

Table 7.1 Examples of High Intensity Rainfall Analyses from Data supplied by Contributing Countries fitted to a Two-parameter Extreme-Value Type 1 (Gumbel) Distribution. The tables are in the form of Depth (mm) – Duration (minutes, hours or days) – Frequency (years). aep is the annual exceedance probability and is the inverse of the annual recurrence interval (ARI).

Australia – Adelaide (West Terrace)

ARI(y)	aep	6m	12m	18m	30m	60m	120m	180m	360m	720m	1440m	2880m	4320m
2	**0.50**	5.1	7.2	8.6	10.8	14.5	18.9	21.8	28.2	35.2	41.7	49.0	53.5
5	**0.20**	7.3	10.2	12.1	15.6	21.0	27.9	31.7	39.9	48.4	57.2	65.5	71.4
10	**0.10**	8.8	12.2	14.4	18.8	25.4	33.8	38.3	47.7	57.2	67.4	76.4	83.2
20	**0.05**	10.3	14.1	16.7	21.8	29.5	39.5	44.5	55.2	65.6	77.2	86.9	94.6
50	**0.02**	12.2	16.6	19.6	25.8	34.9	46.9	52.7	64.9	76.4	89.8	100.4	109.3

China – Chongzhou

ARI(y)	aep	10m	30m	60m	2h	3h	6h	9h	12h	1d	3d
2	**0.50**	17.1	31.3	38.3	45.8	53.5	78.2	86.5		101.3	125.4
5	**0.20**	20.4	39.1	48.1	55.6	63.5	97.6	112.2		131.4	163.0
10	**0.10**	22.5	44.3	54.5	62.1	70.1	110.4	129.2		151.3	187.9
20	**0.05**	24.6	49.2	60.7	68.3	76.5	122.8	145.5		170.4	211.8
50	**0.02**	27.3	55.6	68.7	76.4	84.7	138.7	166.6		195.2	242.7

Indonesia – Bogor

ARI(y)	aep	2m	10m	15m	30m	45m	60m	120m	180m	360m	720m
2	**0.50**	11.2	21.6	31.8	55.0	68.8	80.6	97.6	108.2	115.2	118.8
5	**0.20**	12.7	24.3	34.5	62.6	77.2	89.4	114.8	128.5	138.5	141.1
10	**0.10**	13.7	26.0	36.2	67.6	82.8	95.2	126.1	142.0	154.0	155.9
20	**0.05**	14.6	27.7	37.9	72.4	88.1	100.7	137.0	154.9	168.8	170.0
50	**0.02**	15.9	29.9	40.1	78.7	95.0	107.9	151.1	171.7	188.1	188.3

Japan – Taguchi

ARI(y)	aep	10m	30m	60m	120m	180m	6h	12h	24h
2	**0.50**	12.6	26.6	40.5	40.5	70.3	103.8	147.0	193.3
5	**0.20**	16.0	33.1	51.1	51.1	91.1	136.6	193.8	249.2
10	**0.10**	18.3	37.3	58.1	58.1	104.8	158.3	224.7	286.2
20	**0.05**	20.4	41.4	64.8	64.8	118.0	179.1	254.4	321.6
50	**0.02**	23.2	46.7	73.5	73.5	135.1	206.1	292.8	367.5

Korea – Daegu

ARI(y)	aep	10m	30m	1h	2h	3h	6h	9h	12h	15h	18h	24h	48h
2	**0.50**	11.7	22.9	32.6	44.1	51.3	65.2	74.2	81.4	87.7	93.6	105.4	122.6
5	**0.20**	15.9	31.7	44.6	60.1	70.0	89.4	102.5	112.6	122.0	130.2	147.0	169.6
10	**0.10**	18.7	37.6	52.5	70.6	82.5	105.4	121.2	133.2	144.6	154.5	174.5	200.7
20	**0.05**	21.5	43.2	60.1	80.7	94.4	120.7	139.1	153.0	166.4	177.8	200.8	230.5
50	**0.02**	25.0	50.4	69.9	93.8	109.8	140.6	162.3	178.7	194.5	208.0	235.0	269.1

Malaysia – Kg. Sg. Tua

ARI(y)	aep	15m	30m	60m	3h	6h	12h	24h	72h
2	**0.50**	28.9	40.7	57.9	77.6	87.0	93.2	103.1	144.3
5	**0.20**	36.6	49.2	72.4	95.8	106.2	115.9	127.6	174.4
10	**0.10**	41.7	54.9	82.0	107.8	119.0	131.0	143.8	194.3
20	**0.05**	46.6	60.3	91.3	119.3	131.2	145.4	159.3	213.4
50	**0.02**	52.9	67.3	103.2	134.3	147.0	164.1	179.5	238.1

New Zealand – Kelburn, Wellington

ARI(y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72hr
2	**0.50**	6.6	10.0	12.7	18.4	25.5	43.3	57.7	74.4	91.0	99.4
5	**0.20**	8.8	13.4	16.9	24.3	33.0	53.8	71.5	95.7	118.3	128.2
10	**0.10**	10.2	15.7	19.7	28.1	38.0	60.8	80.7	109.9	136.4	147.3
20	**0.05**	11.6	17.8	22.4	31.9	42.8	67.4	89.5	123.4	153.7	165.7
50	**0.02**	13.4	20.6	25.9	36.7	49.1	76.0	100.8	141.0	176.1	189.4

Philippines – Baguio

ARI(y)	aep	5m	10m	30m	60m	120m	150m	3h	6h	12h	1d	2d	3d
2	**0.50**	20.5	31.9	61.1	80.7	120.0	137.0	149.4	220.3	303.8	372.9	546.4	624.6
5	**0.20**	33.8	52.4	100.9	133.5	200.7	227.8	247.4	347.6	464.7	561.4	793.2	894.5
10	**0.10**	42.6	66.1	127.3	168.4	254.2	287.8	312.2	431.8	571.3	686.1	956.6	1073.2
20	**0.05**	51.0	79.1	152.6	202.0	305.4	345.5	374.4	512.7	673.5	805.8	1113.3	1244.6
50	**0.02**	61.9	96.0	185.3	245.4	371.7	420.1	455.0	617.3	805.8	960.7	1316.2	1466.5

Vietnam – Hanoi

ARI(y)	aep	10m	60m	2h	6h	12h	24h	1d	2d
2	**0.50**	23.7	63.4	59.1	85.2	117.6	148.0	121.7	177.0
5	**0.20**	27.6	89.8	92.1	115.8	154.8	179.9	149.7	232.3
10	**0.10**	30.1	107.3	113.9	136.0	179.4	201.1	168.3	268.9
20	**0.05**	32.6	124.1	134.8	155.5	203.0	221.4	186.1	304.0
50	**0.02**	35.7	145.8	161.9	180.6	233.6	247.6	209.2	349.5

7.4 Acknowledgments

The support of the National Institute of Water and Atmospheric Research in this preparing this chapter is acknowledged through its on-going commitment and involvement in the international science community.

7.5 References

Hosking, JRM and Wallis, JR, 1997*. Regional Frequency Analysis*. Cambridge University Press, Cambridge, 224 pp.

Phien, H.N. (1987), A *review of methods of parameter estimation for the extreme value type-1 distribution*, J. Hydrol., 90 251-268.

Madsen, H., Rasmussen, P.F. and Rosbjerg, D. (1997), *Comparison of annual maximum series and partial duration series methods for modelling extreme hydrologic events*, Water Resour. Res., 33, 747-757.

Lu L-H, and Stedinger, JR, 1992. *Variance of two- and three-parameter GEV/PWM quantile estimators: formulae, confidence intervals, and a comparison*, J. Hydrol., 138, 247 – 267.

Martins, ES, and Stedinger JR, 1995. *Generalised maximum-likelihood generalised extreme value quantile estimators for hydrologic data*, Water Resour. Res., 36, 737 – 744.

Natural Environmental Research Council (NERC), 1975. *Flood Studies Rep. Vol 1*. NERC, London, 550 pp.

Robson, AJ and Reed D, 1999. *Flood Estimation Handbook, Vol 3. Statistical procedures for flood frequency estimation*, Institute of Hydrology, Wallingford.

Rosbjerg, D, and Madsen, H, 1995. *Uncertainty measures of regional flood frequency estimators*, J. Hydrol., 167, 209 – 224.

World Meteorological Organization, (WMO) 1983. *Guide to Hydrological practices. Vol. II, Analysis, Forecasting and other Applications*. WMO – No. 168, Geneva.

7.6 Appendix 7 Complete Results of RIFD Analysis

Table A7.1 Parameters of EV1 for Australian Sites

	Parameters of an EV Type 1 Extreme Value Distribution for Australian Sites											
94029	**Hobart (Ellerslie Road)**											
	6m	**12m**	**18m**	**30m**	**60m**	**120m**	**180m**	**360m**	**720m**	**1440m**	**2880m**	**4320m**
α	2.03	2.74	3.20	3.61	3.81	4.60	5.82	9.06	13.81	19.23	23.93	24.97
ξ	3.35	5.02	6.29	8.06	10.83	15.12	18.66	25.66	35.25	45.03	52.95	57.55
var(α)	0.04	0.07	0.09	0.11	0.13	0.19	0.30	0.72	1.68	3.26	5.05	5.50
var(ξ)	0.05	0.09	0.12	0.16	0.18	0.26	0.41	0.99	2.31	4.48	6.94	7.56
86071	**Melbourne Regional Office**											
α	2.48	3.60	4.39	5.49	6.65	7.52	7.91	9.55	12.38	17.48	22.17	24.49
ξ	5.39	7.86	9.55	11.74	15.08	19.28	22.67	29.63	36.96	44.99	54.26	58.81
var(α)	0.04	0.09	0.14	0.21	0.31	0.40	0.44	0.65	1.09	2.17	3.49	4.26
var(ξ)	0.06	0.13	0.19	0.29	0.43	0.55	0.61	0.89	1.50	2.99	4.81	5.87
66062	**Sydney (Observatory Hill)**											
α	3.14	4.46	6.08	8.44	13.37	18.13	20.55	25.62	33.10	41.17	54.13	60.21
ξ	9.09	13.28	16.91	22.01	30.43	40.81	48.00	61.99	79.32	102.41	128.95	143.98
var(α)	0.09	0.18	0.33	0.64	1.61	2.96	3.81	5.92	9.88	15.29	26.42	32.69
var(ξ)	0.12	0.25	0.46	0.88	2.21	4.07	5.23	8.13	13.57	21.00	36.30	44.92
440223	**Charleville**											
α	2.70	3.85	4.92	5.76	7.47	9.98	11.15	14.17	17.61	19.17	26.12	28.60
ξ	6.98	10.76	13.50	16.95	21.50	26.22	30.21	38.44	46.40	55.71	66.69	72.08
var(α)	0.12	0.24	0.39	0.53	0.89	1.60	1.99	3.22	4.97	5.88	10.93	13.11
var(ξ)	0.16	0.32	0.53	0.73	1.22	2.18	2.72	4.40	6.79	8.04	14.94	17.92
40223	**Brisbane**											
α	3.83	6.16	7.84	9.79	14.39	18.02	20.05	24.63	33.40	48.25	63.77	73.57
ξ	10.53	15.94	20.67	27.06	34.89	44.83	52.36	68.31	86.53	110.04	135.11	154.45
var(α)	0.24	0.62	1.01	1.57	3.39	5.31	6.57	9.92	18.23	38.05	66.47	88.46
var(ξ)	0.33	0.85	1.37	2.14	4.63	7.26	8.98	13.55	24.92	52.01	90.85	120.91
31011	**Cairns**											
α	3.81	4.35	5.50	7.05	9.87	15.58	20.48	33.64	49.02	66.93	92.29	107.96
ξ	11.30	17.72	22.90	31.44	45.89	61.24	71.62	94.34	119.28	156.18	215.45	245.88
var(α)	0.20	0.26	0.41	0.68	1.32	3.30	5.70	15.38	32.65	60.85	115.71	158.34
var(ξ)	0.27	0.35	0.56	0.92	1.81	4.52	7.81	21.06	44.71	83.33	158.47	216.85
23000	**Adelaide (West Terrace)**											
α	2.01	2.65	3.11	4.22	5.78	7.90	8.72	10.38	11.66	13.60	14.55	15.78
ξ	4.32	6.21	7.44	9.28	12.36	16.05	18.64	24.37	30.94	36.76	43.67	47.73
var(α)	0.04	0.07	0.10	0.19	0.35	0.66	0.80	1.14	1.43	1.95	2.24	2.63
var(ξ)	0.06	0.10	0.14	0.26	0.48	0.90	1.10	1.56	1.97	2.68	3.07	3.61
15590	**Alice Springs**											
α	2.52	4.48	6.41	8.82	11.24	13.76	16.41	19.79	24.48	29.27	40.16	45.55
ξ	4.92	7.53	9.56	12.47	16.30	20.65	24.10	29.90	36.83	43.96	53.42	58.12
var(α)	0.10	0.33	0.67	1.27	2.06	3.10	4.40	6.40	9.79	14.00	26.37	33.91
var(ξ)	0.14	0.45	0.92	1.74	2.82	4.23	6.02	8.75	13.39	19.14	36.04	46.35
14015	**Darwin**											
α	3.61	4.45	5.05	6.52	11.56	15.70	17.76	24.25	31.34	43.71	57.76	67.53
ξ	15.51	23.28	30.31	41.56	54.63	65.57	73.12	85.27	98.71	119.50	158.74	187.37
var(α)	0.23	0.35	0.45	0.76	2.38	4.39	5.61	10.46	17.48	34.00	59.36	81.12
var(ξ)	0.32	0.48	0.62	1.03	3.24	5.99	7.66	14.28	23.86	46.42	81.05	110.76
8051	**Geraldton**											
α	1.83	2.96	3.40	4.54	6.76	9.10	10.77	13.52	16.36	16.66	17.23	19.17
ξ	5.34	8.29	10.29	13.09	16.72	21.15	24.44	30.48	36.93	43.24	49.30	54.45
var(α)	0.06	0.15	0.20	0.35	0.78	1.41	1.98	3.11	4.56	4.73	5.06	6.26
var(ξ)	0.08	0.20	0.27	0.48	1.06	1.93	2.70	4.25	6.23	6.46	6.91	8.55

Table A7.2 Depth-duration-frequency for Australian Sites

Depth (mm)-duration(minutes/hours)-frequency(years) for Australian Sites

ARI (y)	6m	12m	18m	30m	60m	120m	180m	360m	720m	1440m	2880m	4320m
94029	**Hobart (Ellerslie Road)**											
2	4.1	6.0	7.5	9.4	12.2	16.8	20.8	29.0	40.3	52.1	61.7	66.7
5	6.4	9.1	11.1	13.5	16.5	22.0	27.4	39.3	56.0	73.9	88.8	95.0
10	7.9	11.2	13.5	16.2	19.4	25.5	31.8	46.0	66.3	88.3	106.8	113.7
20	9.4	13.1	15.8	18.8	22.2	28.8	35.9	52.6	76.3	102.1	124.0	131.7
50	11.3	15.7	18.8	22.1	25.7	33.1	41.4	61.0	89.1	120.1	146.3	155.0
86071	**Melbourne Regional Office**											
2	6.3	9.2	11.2	13.8	17.5	22.0	25.6	33.1	41.5	51.4	62.4	67.8
5	9.1	13.3	16.1	20.0	25.1	30.6	34.5	44.0	55.5	71.2	87.5	95.5
10	11.0	16.0	19.4	24.1	30.0	36.2	40.5	51.1	64.8	84.3	104.2	113.9
20	12.8	18.5	22.6	28.0	34.8	41.6	46.2	58.0	73.7	96.9	120.1	131.6
50	15.1	21.9	26.7	33.2	41.0	48.6	53.5	66.9	85.3	113.2	140.8	154.4
66062	**Sydney (Observatory Hill)**											
2	10.2	14.9	19.1	25.1	35.3	47.5	55.5	71.4	91.4	117.5	148.8	166.0
5	13.8	20.0	26.0	34.7	50.5	68.0	78.8	100.4	129.0	164.2	210.1	234.3
10	16.2	23.3	30.6	41.0	60.5	81.6	94.2	119.6	153.8	195.1	250.8	279.5
20	18.4	26.5	35.0	47.1	70.1	94.7	109.0	138.1	177.6	224.7	289.7	322.8
50	21.3	30.7	40.7	54.9	82.6	111.5	128.2	162.0	208.5	263.1	340.1	378.9
44021	**Charleville**											
2	8.0	12.2	15.3	19.1	24.2	29.9	34.3	43.6	52.9	62.7	76.3	82.6
5	11.0	16.5	20.9	25.6	32.7	41.2	46.9	59.7	72.8	84.5	105.9	115.0
10	13.1	19.4	24.6	29.9	38.3	48.7	55.3	70.3	86.0	98.8	125.5	136.4
20	15.0	22.2	28.1	34.1	43.7	55.9	63.3	80.5	98.7	112.6	144.3	157.0
50	17.5	25.8	32.7	39.4	50.7	65.2	73.7	93.7	115.1	130.5	168.6	183.7
40223	**Brisbane**											
2	11.9	18.2	23.5	30.6	40.2	51.4	59.7	77.3	98.8	127.7	158.5	181.4
5	16.3	25.2	32.4	41.7	56.5	71.9	82.4	105.3	136.6	182.4	230.8	264.8
10	19.1	29.8	38.3	49.1	67.3	85.4	97.5	123.7	161.7	218.6	278.6	320.0
20	21.9	34.2	44.0	56.1	77.6	98.4	111.9	141.5	185.7	253.4	324.5	373.0
50	25.5	40.0	51.3	65.3	91.0	115.2	130.6	164.4	216.8	298.3	383.9	441.5
31011	**Cairns**											
2	12.7	19.3	24.9	34.0	49.5	66.9	79.1	106.7	137.3	180.7	249.3	285.5
5	17.0	24.2	31.1	42.0	60.7	84.6	102.3	144.8	192.8	256.6	353.9	407.8
10	19.9	27.5	35.3	47.3	68.1	96.3	117.7	170.1	229.6	306.8	423.1	488.8
20	22.6	30.6	39.2	52.4	75.2	107.5	132.5	194.3	264.9	355.0	489.6	566.5
50	26.2	34.7	44.3	58.9	84.4	122.0	151.5	225.6	310.6	417.3	575.6	667.1
23000	**Adelaide (West Terrace)**											
2	5.1	7.2	8.6	10.8	14.5	18.9	21.8	28.2	35.2	41.7	49.0	53.5
5	7.3	10.2	12.1	15.6	21.0	27.9	31.7	39.9	48.4	57.2	65.5	71.4
10	8.8	12.2	14.4	18.8	25.4	33.8	38.3	47.7	57.2	67.4	76.4	83.2
20	10.3	14.1	16.7	21.8	29.5	39.5	44.5	55.2	65.6	77.2	86.9	94.6
50	12.2	16.6	19.6	25.8	34.9	46.9	52.7	64.9	76.4	89.8	100.4	109.3
15590	**Alice Springs**											
2	5.8	9.2	11.9	15.7	20.4	25.7	30.1	37.2	45.8	54.7	68.1	74.8
5	8.7	14.3	19.2	25.7	33.2	41.3	48.7	59.6	73.5	87.9	113.7	126.4
10	10.6	17.6	24.0	32.3	41.6	51.6	61.0	74.4	91.9	109.8	143.8	160.6
20	12.4	20.8	28.6	38.7	49.7	61.5	72.9	88.7	109.5	130.9	172.7	193.4
50	14.8	25.0	34.6	46.9	60.1	74.4	88.1	107.1	132.3	158.2	210.1	235.9
14015	**Darwin**											
2	16.8	24.9	32.2	43.9	58.9	71.3	79.6	94.2	110.2	135.5	179.9	212.1
5	20.9	29.9	37.9	51.3	72.0	89.1	99.8	121.6	145.7	185.1	245.4	288.7
10	23.6	33.3	41.7	56.2	80.6	100.9	113.1	139.8	169.2	217.9	288.7	339.3
20	26.2	36.5	45.3	60.9	89.0	112.2	125.9	157.3	191.8	249.3	330.3	387.9
50	29.6	40.6	50.0	67.0	99.7	126.8	142.4	179.9	221.0	290.1	384.1	450.9
8051	**Geraldton**											
2	6.0	9.4	11.5	14.8	19.2	24.5	28.4	35.4	42.9	49.3	55.6	61.5
5	8.1	12.7	15.4	19.9	26.9	34.8	40.6	50.8	61.5	68.2	75.1	83.2
10	9.5	15.0	18.0	23.3	31.9	41.6	48.7	60.9	73.8	80.7	88.1	97.6
20	10.8	17.1	20.4	26.6	36.8	48.2	56.4	70.6	85.5	92.7	100.5	111.4
50	12.5	19.9	23.6	30.8	43.1	56.7	66.5	83.2	100.8	108.2	116.5	129.2

Table A7.3 Parameters of EV1 for Chinese Sites

	Parameters of an EV Type 1 Extreme Value Distribution for Chinese Sites												
	Yongchun												
	10m	**30m**	**60m**	**2h**	**3h**	**6h**	**9h**	**12h**	**1d**	**3d**	**7d**	**15d**	**30d**
α			11.39		18.56	21.93		28.36	37.27	60.73	61.80	69.60	83.40
ξ			43.05		60.24	73.74		93.13	102.09	154.29	201.11	288.27	409.50
var(α)			2.21		5.87	8.19		13.70	23.66	62.83	65.08	82.52	118.51
var(ξ)			3.02		8.02	11.19		18.72	32.32	85.84	88.91	112.73	161.90
	Shahe												
α	4.29	7.65	8.14	7.87	9.70	13.57		16.36	26.32	34.82			
ξ	14.38	27.56	36.67	43.15	47.36	60.39		64.98	81.40	105.68			
var(α)	0.70	2.22	2.51	2.35	3.57	6.98		10.15	26.27	45.96			
var(ξ)	0.94	2.99	3.38	3.16	4.80	9.40		13.66	35.36	61.86			
	Chongzhou												
α	2.88	6.88	8.60	8.67	8.85	17.12	22.64		26.58	33.19			
ξ	16.04	28.78	35.15	42.59	50.21	71.91	78.22		91.51	113.21			
var(α)	0.32	1.80	2.80	2.85	2.97	11.11	19.43		26.78	41.75			
var(ξ)	0.42	2.42	3.77	3.83	3.99	14.95	26.16		36.04	56.20			

Table A7.4 Depth-duration-frequency for Chinese Sites

		Depth (mm)-duration(minutes/hours)-frequency(years) for Chinese Sites											
	Yonchun												
ARI(y)	**10m**	**30m**	**60m**	**2h**	**3h**	**6h**	**9h**	**12h**	**1d**	**3d**	**7d**	**15d**	**30d**
2			47.2		67.0	81.8		103.5	115.7	176.5	223.8	313.8	440.1
5			60.1		88.1	106.6		135.7	158.0	245.4	293.8	392.7	534.6
10			68.7		102.0	123.1		156.9	186.0	291.0	340.2	444.9	597.2
20			76.9		115.4	138.9		177.4	212.8	334.7	384.7	495.0	657.2
50			87.5		132.7	159.3		203.8	247.5	391.2	442.3	559.8	734.9
	Shahe												
2	16.0	30.4	39.6	46.0	50.9	65.4		71.0	91.0	118.4			
5	20.8	39.0	48.9	55.0	61.9	80.8		89.5	120.9	157.9			
10	24.0	44.8	55.0	60.9	69.2	90.9		101.8	140.6	184.0			
20	27.1	50.3	60.8	66.5	76.2	100.7		113.6	159.6	209.1			
50	31.1	57.4	68.4	73.9	85.2	113.4		128.8	184.1	241.5			
	Chongzhou												
2	17.1	31.3	38.3	45.8	53.5	78.2	86.5		101.3	125.4			
5	20.4	39.1	48.1	55.6	63.5	97.6	112.2		131.4	163.0			
10	22.5	44.3	54.5	62.1	70.1	110.4	129.2		151.3	187.9			
20	24.6	49.2	60.7	68.3	76.5	122.8	145.5		170.4	211.8			
50	27.3	55.6	68.7	76.4	84.7	138.7	166.6		195.2	242.7			

Table A7.5 Parameters of EV1 for Indonesian Sites

	Parameters of an EV Type 1 Extreme Value Distribution for Indonesian Sites									
	Bandung									
	2m	**10m**	**15m**	**30m**	**45m**	**60m**	**120m**	**180m**	**360m**	**720m**
α	2.89	3.07	3.88	18.87	4.76	6.17	8.70	10.53	12.92	13.46
ξ	11.97	16.68	22.00	37.47	41.70	47.49	54.69	56.51	62.91	68.55
var(α)	0.18	0.82	1.31	7.70	1.98	0.82	1.64	2.39	3.61	3.91
var(ξ)	0.25	1.07	1.71	10.48	2.58	1.12	2.23	3.26	4.91	5.33
	Bogor									
α	1.33	2.35	2.35	6.68	7.39	7.71	15.13	17.96	20.62	19.67
ξ	10.70	20.73	30.93	52.59	66.13	77.81	92.08	101.58	107.61	111.61
var(α)	0.15	0.48	0.48	3.90	4.77	5.19	20.00	28.19	37.12	33.78
var(ξ)	0.20	0.63	0.63	5.07	6.20	6.75	26.00	36.65	48.27	43.92
	Bali									
α	4.63	5.34	6.77	8.95	9.86	12.84	15.61		19.91	36.79
ξ	11.76	19.39	26.20	41.82	48.56	54.96	65.00		85.09	99.51
var(α)	1.87	2.49	4.01	7.00	8.50	14.40	21.28		34.60	118.20
var(ξ)	2.44	3.24	5.21	9.10	11.05	18.73	27.67		45.00	153.70
	Jakarta									
α	4.84	7.19	9.50	13.70	17.31	19.52	24.12	26.36	31.23	34.10
ξ	10.71	17.94	22.72	34.14	37.83	46.39	54.06	56.38	59.88	61.86
var(α)	0.64	1.96	3.42	5.17	11.36	10.49	16.02	19.13	27.80	32.01
var(ξ)	0.87	2.64	4.60	7.01	15.30	14.22	21.72	25.94	37.67	43.40
	Semarang									
α	4.01	4.72	3.73	7.82	10.77	14.57	20.07	23.54	24.20	24.29
ξ	14.89	22.23	30.70	48.13	57.85	69.04	94.32	98.02	99.95	100.08
var(α)	1.40	1.95	1.21	5.34	10.12	18.55	35.18	48.38	51.14	51.54
var(ξ)	1.82	2.53	1.58	6.94	13.16	24.12	45.75	62.91	66.51	67.02

Table A7.6 Depth-duration-frequency for Indonesian Sites

		Depth (mm)-duration(minutes/hours)-frequency(years) for Indonesian Sites								
	Bandung									
ARI (y)	**2m**	**10m**	**15m**	**30m**	**45m**	**60m**	**120m**	**180m**	**360m**	**720m**
2	13.0	17.8	23.4	44.4	43.4	49.8	57.9	60.4	67.6	73.5
5	16.3	21.3	27.8	65.8	48.8	56.7	67.7	72.3	82.3	88.7
10	18.5	23.6	30.7	79.9	52.4	61.4	74.3	80.2	92.0	98.8
20	20.5	25.8	33.5	93.5	55.8	65.8	80.5	87.8	101.3	108.5
50	23.2	28.6	37.1	111.1	60.3	71.6	88.7	97.6	113.3	121.1
	Bogor									
2	11.2	21.6	31.8	55.0	68.8	80.6	97.6	108.2	115.2	118.8
5	12.7	24.3	34.5	62.6	77.2	89.4	114.8	128.5	138.5	141.1
10	13.7	26.0	36.2	67.6	82.8	95.2	126.1	142.0	154.0	155.9
20	14.6	27.7	37.9	72.4	88.1	100.7	137.0	154.9	168.8	170.0
50	15.9	29.9	40.1	78.7	95.0	107.9	151.1	171.7	188.1	188.3
	Bali									
2	13.5	21.3	28.7	45.1	52.2	59.7	70.7		92.4	113.0
5	18.7	27.4	36.4	55.2	63.3	74.2	88.4		114.9	154.7
10	22.2	31.4	41.4	62.0	70.7	83.9	100.1		129.9	182.3
20	25.5	35.2	46.3	68.4	77.8	93.1	111.4		144.2	208.8
50	29.8	40.2	52.6	76.7	87.0	105.1	125.9		162.8	243.1
	Jakarta									
2	12.5	20.6	26.2	39.2	44.2	53.5	62.9	66.0	71.3	74.4
5	18.0	28.7	37.0	54.7	63.8	75.7	90.2	95.9	106.7	113.0
10	21.6	34.1	44.1	65.0	76.8	90.3	108.3	115.7	130.2	138.6
20	25.1	39.3	50.9	74.8	89.3	104.4	125.7	134.7	152.6	163.1
50	29.6	46.0	59.8	87.6	105.4	122.5	148.2	159.2	181.7	194.9
	Semarang									
2	16.4	24.0	32.1	51.0	61.8	74.4	101.7	106.6	108.8	109.0
5	20.9	29.3	36.3	59.9	74.0	90.9	124.4	133.3	136.2	136.5
10	23.9	32.8	39.1	65.7	82.1	101.8	139.5	151.0	154.4	154.7
20	26.8	36.2	41.8	71.3	89.8	112.3	153.9	167.9	171.8	172.2
50	30.5	40.6	45.2	78.6	99.9	125.9	172.6	189.8	194.4	194.9

Table A7.7 Parameters of EV1 for Japanese Sites

	Parameters of an EV Type 1 Distribution for Japanese Sites							
	ToyohashiSS							
	10m	30m	60m	120m	180m	6h	12h	24h
α	3.08	7.05	11.21	16.24	19.87	25.31	34.56	39.33
ξ	11.49	22.49	32.95	46.53	55.62	75.91	95.10	113.67
var(α)	0.11	0.59	1.48	3.11	4.95	8.02	14.96	19.37
var(ξ)	0.15	0.80	2.03	4.26	6.78	10.99	20.51	26.55
	Taguchi							
α	2.99	5.69	9.33	9.33	18.33	28.91	41.22	49.27
ξ	11.54	24.54	37.13	37.13	63.58	93.25	131.94	175.27
var(α)	0.18	0.65	1.74	1.74	6.40	15.92	32.37	46.26
var(ξ)	0.24	0.88	2.37	2.37	8.74	21.72	44.16	63.10
	Okazaki							
α	3.31	6.98	12.06	17.36	20.31	24.49	29.33	34.64
ξ	10.43	20.02	28.30	39.27	48.37	64.16	81.66	101.27
var(α)	0.18	0.81	2.43	5.03	6.88	8.58	12.31	17.18
var(ξ)	0.25	1.11	3.32	6.87	9.40	11.74	16.85	23.51
	Ohkusa							
α	4.21	8.44	11.91	18.45	23.37	29.68	32.90	37.94
ξ	13.61	27.15	36.94	46.86	53.77	68.36	90.90	112.15
var(α)	0.37	1.50	2.99	7.16	11.49	18.54	22.79	30.29
var(ξ)	0.51	2.04	4.07	9.76	15.66	25.25	31.04	41.27
	Nagoya							
α	2.98	7.67	13.79	20.10	23.91	27.55	35.00	44.43
ξ	13.15	23.13	34.06	44.55	51.89	70.28	85.46	105.23
var(α)	0.12	0.89	2.54	6.11	8.65	10.14	16.37	26.37
var(ξ)	0.16	1.22	3.48	8.36	11.83	13.89	22.42	36.12

Table A7.8 Depth-duration-frequency for Japanese Sites

	Depth (mm)-duration(minutes/hours)-frequency(years) for Japanese Sites							
	ToyohashiSS							
ARI (y)	**10m**	**30m**	**60m**	**120m**	**180m**	**6h**	**12h**	**24h**
2	12.6	25.1	37.1	52.5	62.9	85.2	107.8	128.1
5	16.1	33.1	49.8	70.9	85.4	113.9	146.9	172.7
10	18.4	38.4	58.2	83.1	100.3	132.9	172.9	202.2
20	20.6	43.4	66.3	94.8	114.6	151.1	197.7	230.5
50	23.5	50.0	76.7	109.9	133.2	174.7	229.9	267.1
	Taguchi							
2	12.6	26.6	40.5	40.5	70.3	103.8	147.0	193.3
5	16.0	33.1	51.1	51.1	91.1	136.6	193.8	249.2
10	18.3	37.3	58.1	58.1	104.8	158.3	224.7	286.2
20	20.4	41.4	64.8	64.8	118.0	179.1	254.4	321.6
50	23.2	46.7	73.5	73.5	135.1	206.1	292.8	367.5
	Okazaki							
2	11.6	22.6	32.7	45.6	55.8	73.1	92.4	114.0
5	15.4	30.5	46.4	65.3	78.8	100.9	125.7	153.2
10	17.9	35.7	55.4	78.3	94.1	119.3	147.7	179.2
20	20.3	40.8	64.1	90.8	108.7	136.9	168.8	204.2
50	23.3	47.3	75.4	107.0	127.6	159.7	196.1	236.5
	Ohkusa							
2	15.2	30.2	41.3	53.6	62.3	79.2	103.0	126.1
5	19.9	39.8	54.8	74.5	88.8	112.9	140.3	169.1
10	23.1	46.1	63.8	88.4	106.4	135.1	164.9	197.5
20	26.1	52.2	72.3	101.7	123.2	156.5	188.6	224.8
50	30.1	60.1	83.4	118.8	145.0	184.2	219.3	260.2
	Nagoya							
2	14.2	25.9	39.1	51.9	60.7	80.4	98.3	121.5
5	17.6	34.6	54.7	74.7	87.8	111.6	138.0	171.9
10	19.9	40.4	65.1	89.8	105.7	132.3	164.2	205.2
20	22.0	45.9	75.0	104.3	122.9	152.1	189.4	237.2
50	24.8	53.0	87.9	123.0	145.2	177.8	222.0	278.6

Table A7.9 Parameters of EV1 for Korean Sites

	Parameters of an EV Type 1 Extreme Value Distribution for Korean Sites													
	Andong													
	10m	**30m**	**1h**	**2h**	**3h**	**4h**	**6h**	**9h**	**12h**	**15h**	**18h**	**24h**	**48h**	**72h**
α	3.50	6.43	8.28	9.53	10.06	10.32	10.52	11.52	14.77			19.72	34.21	38.60
ξ	11.31	18.93	25.04	34.85	42.02	49.41	53.20	62.31	72.25			83.31	104.88	111.04
var(α)	0.31	1.03	1.71	2.27	2.53	2.66	2.76	3.32	5.44			9.71	29.22	37.21
var(ξ)	0.41	1.40	2.33	3.08	3.43	3.61	3.76	4.50	7.40			13.18	39.69	50.54
	Daegu													
α	3.76	7.76	10.54	14.06	16.53		21.34	24.93	27.52	30.21	32.36	36.64	41.44	
ξ	10.29	20.10	28.76	38.97	45.25		57.34	65.08	71.27	76.64	81.70	92.00	107.41	
var(α)	0.13	0.55	1.01	1.80	2.49		4.15	5.67	6.91	8.32	9.55	12.24	15.66	
var(ξ)	0.18	0.75	1.39	2.48	3.42		5.71	7.78	9.49	11.44	13.12	16.82	21.52	

Table A7.10 Depth-duration-frequency for Korean Sites

		Depth (mm)-duration(minutes/hours)-frequency(years) and Variances (mm^2) for Korean Sites												
	Andong													
ARI (y)	**10m**	**30m**	**1h**	**2h**	**3h**	**4h**	**6h**	**9h**	**12h**	**15h**	**18h**	**24h**	**48h**	**72h**
2	12.6	21.3	28.1	38.3	45.7	53.2	57.1	66.5	77.7			90.5	117.4	125.2
5	16.6	28.6	37.5	49.1	57.1	64.9	69.0	79.6	94.4			112.9	156.2	168.9
10	19.2	33.4	43.7	56.3	64.7	72.6	76.9	88.2	105.5			127.7	181.9	197.9
20	21.7	38.0	49.6	63.1	71.9	80.1	84.5	96.5	116.1			141.9	206.5	225.7
50	25.0	44.0	57.3	72.0	81.3	89.7	94.3	107.3	129.9			160.2	238.4	261.7
	Daegu													
2	11.7	22.9	32.6	44.1	51.3		65.2	74.2	81.4	87.7	93.6	105.4	122.6	
5	15.9	31.7	44.6	60.1	70.0		89.4	102.5	112.6	122.0	130.2	147.0	169.6	
10	18.7	37.6	52.5	70.6	82.5		105.4	121.2	133.2	144.6	154.5	174.5	200.7	
20	21.5	43.2	60.1	80.7	94.4		120.7	139.1	153.0	166.4	177.8	200.8	230.5	
50	25.0	50.4	69.9	93.8	109.8		140.6	162.3	178.7	194.5	208.0	235.0	269.1	

Table A7.11 Parameters of EV1 for Malaysian Sites

	Parameters of an EV Type 1 Distribution for Malaysian Sites							
3217002	**Empangen Genting Kelan**							
	15m	**30m**	**60m**	**3h**	**6h**	**12h**	**24h**	**72h**
α	6.09	8.40	12.18	16.82	18.16	19.84	20.51	29.62
ξ	27.41	38.52	53.11	73.86	79.89	82.65	93.58	131.01
var(α)	1.02	1.94	4.08	7.78	9.08	10.83	11.58	24.16
var(ξ)	1.39	2.63	5.53	10.56	12.32	14.69	15.71	32.75
3216001	**Kg. Sg. Tua**							
α	6.76	7.51	12.81	16.04	16.96	20.03	21.61	26.53
ξ	26.46	37.97	53.21	71.70	80.80	85.90	95.17	134.56
var(α)	1.22	1.50	4.37	6.85	7.66	10.68	12.43	18.74
var(ξ)	1.65	2.04	5.93	9.29	10.39	14.49	16.86	25.42
3117070	**JPS Ampang**							
α	9.24	11.24	13.38	14.18	12.39	12.68	14.82	25.61
ξ	30.88	43.57	58.33	78.84	85.76	91.88	105.49	137.07
var(α)	2.07	3.06	4.34	4.87	3.71	3.89	5.32	15.88
var(ξ)	2.81	4.16	5.89	6.61	5.05	5.29	7.23	21.58

Table A7.12 Depth-duration-frequency for Malaysian Sites

	Depth (mm)-duration(minutes/hours)-frequency(years) for Malaysian Sites							
3217002	**Empangen Genting Kelan**							
ARI (y)	**15m**	**30m**	**60m**	**3h**	**6h**	**12h**	**24h**	**72h**
2	29.6	41.6	57.6	80.0	86.5	89.9	101.1	141.9
5	36.6	51.1	71.4	99.1	107.1	112.4	124.3	175.4
10	41.1	57.4	80.5	111.7	120.8	127.3	139.7	197.7
20	45.5	63.5	89.3	123.8	133.8	141.6	154.5	219.0
50	51.2	71.3	100.6	139.5	150.8	160.0	173.6	246.6
3216001	**Kg. Sg. Tua**							
2	28.9	40.7	57.9	77.6	87.0	93.2	103.1	144.3
5	36.6	49.2	72.4	95.8	106.2	115.9	127.6	174.4
10	41.7	54.9	82.0	107.8	119.0	131.0	143.8	194.3
20	46.6	60.3	91.3	119.3	131.2	145.4	159.3	213.4
50	52.9	67.3	103.2	134.3	147.0	164.1	179.5	238.1
3117070	**JPS Ampang**							
2	34.3	47.7	63.2	84.0	90.3	96.5	110.9	146.5
5	44.7	60.4	78.4	100.1	104.3	110.9	127.7	175.5
10	51.7	68.9	88.4	110.7	113.6	120.4	138.9	194.7
20	58.3	77.0	98.1	120.9	122.5	129.5	149.5	213.1
50	66.9	87.4	110.5	134.2	134.1	141.4	163.3	237.0

Table A7.13 Parameters of EV1 for New Zealand Sites

	Parameters of an EV Type 1 Extreme Value Distribution for New Zealand Sites									
E14272	**Kelburn, Wellington (Manual)**									
	10m	**20m**	**30m**	**60m**	**2h**	**6h**	**12h**	**24h**	**48h**	**72hr**
α								18.47	25.15	25.62
ξ								66.72	85.54	94.01
var(α)								3.60	6.68	6.93
var(ξ)								4.94	9.16	9.51
E15011	**Kaitoke (Manual)**									
α								31.23	43.10	45.06
ξ								102.97	133.63	139.72
var(α)								38.80	86.79	94.88
var(ξ)								52.16	116.09	126.91
E14294	**Wainuiomata (Manual)**									
α								47.80	65.73	74.04
ξ								114.36	153.83	173.11
var(α)								18.16	34.34	43.58
var(ξ)								24.98	47.22	59.92
E14272	**Kelburn, Wellington (Automatic)**									
α	1.94	3.02	3.73	5.17	6.67	9.25	12.20	18.85	24.09	25.46
ξ	5.85	8.86	11.31	16.50	23.05	39.94	53.24	67.45	82.17	90.05
var(α)	0.05	0.11	0.17	0.33	0.56	1.07	1.86	4.45	7.27	8.12
var(ξ)	0.06	0.16	0.24	0.46	0.76	1.47	2.55	6.10	9.96	11.13
E15021	**Kaitoke (Automatic)**									
α	1.66	2.30	3.22	4.02	5.56	15.74	25.38	31.88	39.23	38.32
ξ	7.23	10.67	13.27	19.69	29.32	54.96	77.39	100.71	124.23	138.72
var(α)	0.07	0.14	0.27	0.42	0.80	6.38	16.60	26.19	39.66	37.83
var(ξ)	0.10	0.18	0.36	0.57	1.08	8.67	22.54	35.56	53.84	51.36
E14296	**Wainuiomata (Automatic)**									
α	2.17	2.59	2.96	3.91	6.52	17.57	28.76	40.45	52.87	57.89
ξ	6.01	8.94	11.34	15.43	22.29	47.22	70.71	98.00	130.37	150.82
var(α)	0.19	0.27	0.35	0.61	1.69	12.28	32.90	65.12	111.20	133.35
var(ξ)	0.25	0.36	0.47	0.82	2.28	16.50	44.23	87.53	149.47	179.25

Table A7.14 Depth-duration-frequency for New Zealand Sites

	Depth (mm)-duration(minutes/hours)-frequency(years) for New Zealand Sites									
E14272	**Kelburn, Wellington (Manual)**									
ARI (y)	**10m**	**20m**	**30m**	**60m**	**2h**	**6h**	**12h**	**24h**	**48h**	**72hr**
2								73.5	94.8	103.4
5								94.4	123.3	132.4
10								108.3	142.1	151.7
20								121.6	160.2	170.1
50								138.8	183.7	194.0
E15011	**Kaitoke (Manual)**									
2								114.4	149.4	156.2
5								149.8	198.3	207.3
10								173.2	230.6	241.1
20								195.7	261.6	273.6
50								224.8	301.8	315.5
E14294	**Wainuioimata (Manual)**									
2								131.9	177.9	200.2
5								186.1	252.4	284.2
10								221.9	301.7	339.7
20								256.3	349.1	393.0
50								300.9	410.3	462.0
E14272	**Kelburn, Wellington (Automatic)**									
2	6.6	10.0	12.7	18.4	25.5	43.3	57.7	74.4	91.0	99.4
5	8.8	13.4	16.9	24.3	33.0	53.8	71.5	95.7	118.3	128.2
10	10.2	15.7	19.7	28.1	38.0	60.8	80.7	109.9	136.4	147.3
20	11.6	17.8	22.4	31.9	42.8	67.4	89.5	123.4	153.7	165.7
50	13.4	20.6	25.9	36.7	49.1	76.0	100.8	141.0	176.1	189.4
E15021	**Kaitoke (Automatic)**									
2	7.8	11.5	14.5	21.2	31.4	60.7	86.7	112.4	138.6	152.8
5	9.7	14.1	18.1	25.7	37.7	78.6	115.5	148.5	183.1	196.2
10	11.0	15.8	20.5	28.7	41.8	90.4	134.5	172.5	212.5	224.9
20	12.2	17.5	22.8	31.6	45.8	101.7	152.8	195.4	240.8	252.5
50	13.7	19.6	25.8	35.4	51.0	116.4	176.4	225.1	277.3	288.2
E14296	**Wainuiomata (Automatic)**									
2	6.8	9.9	12.4	16.9	24.7	53.7	81.3	112.8	149.7	172.0
5	9.3	12.8	15.8	21.3	32.1	73.6	113.8	158.7	209.7	237.7
10	10.9	14.8	18.0	24.2	37.0	86.8	135.4	189.0	249.3	281.1
20	12.5	16.6	20.1	27.0	41.7	99.4	156.1	218.2	287.4	322.8
50	14.5	19.1	22.9	30.7	47.7	115.8	182.9	255.8	336.6	376.7

Table A7.15 Parameters of EV1 for Philippines Sites

	Parameters of an EV Type 1 Extreme Value Distribution for Philippines Sites																
	Ambulong																
	5m	**10m**	**15m**	**20m**	**30m**	**45m**	**60m**	**80m**	**100m**	**120m**	**150m**	**3h**	**6h**	**12h**	**1d**	**2d**	**3d**
α	5.63	7.87	9.51	10.83	13.75	17.20	19.41	22.06	25.14	27.26	30.42	33.01	44.63	54.77	63.74	91.10	99.95
ξ	11.85	18.25	23.72	28.81	35.82	42.14	46.75	53.15	57.74	62.24	67.31	71.64	91.55	114.92	135.57	184.01	207.33
var(α)	0.84	1.65	2.41	3.12	5.04	7.87	10.03	12.96	16.83	19.79	24.63	29.02	53.03	79.85	108.15	220.93	265.93
var(ξ)	1.15	2.24	3.27	4.24	6.83	10.68	13.61	17.58	22.83	26.85	33.42	39.37	71.95	108.34	146.73	299.76	360.81
	Baguio																
α	11.71	18.15	23.46	27.75	35.12	42.12	46.57	55.97	66.68	71.20	80.06	86.42	112.31	141.98	166.26	217.74	238.14
ξ	16.22	25.20	32.59	38.80	48.24	56.99	63.65	74.82	80.37	93.94	107.67	117.75	179.10	251.76	312.01	466.61	537.29
var(α)	3.91	9.39	15.68	21.95	35.16	50.58	61.82	89.30	126.77	144.50	182.74	212.91	359.60	574.66	787.97	1351.51	1616.68
var(ξ)	5.30	12.73	21.25	29.74	47.64	68.54	83.77	121.00	171.77	195.80	247.60	288.49	487.24	778.64	1067.68	1831.25	2190.55
	Baler																
α	5.69	8.20	9.93	11.61	15.34	18.63	20.73	23.69	27.03	30.37	35.06	39.51	52.69	63.68	48.30	60.35	68.88
ξ	14.87	21.62	27.44	31.89	38.74	46.92	53.54	63.14	71.66	78.22	86.67	92.63	119.69	144.97	176.85	237.45	271.45
var(α)	0.81	1.68	2.46	3.37	5.88	8.67	10.73	14.01	18.24	23.04	30.68	38.97	69.32	101.26	58.24	90.93	118.46
var(ξ)	1.10	2.28	3.34	4.58	7.98	11.77	14.58	19.03	24.78	31.29	41.68	52.94	94.17	137.55	79.12	123.51	160.92
	Daet																
α	5.33	6.99	8.69	10.34	10.57	12.77	14.90	18.58	21.95	25.94	30.51	32.32	40.03	53.15	66.93	80.17	85.04
ξ	12.97	19.99	25.67	31.11	40.34	47.21	52.43	60.28	65.71	70.39	77.63	84.04	112.24	144.35	171.73	236.11	260.50
var(α)	0.78	1.34	2.08	2.94	3.08	4.49	6.11	9.51	13.26	18.52	25.63	28.76	44.11	77.77	123.34	176.95	199.08
var(ξ)	1.06	1.82	2.82	3.99	4.17	6.09	8.28	12.89	17.98	25.12	34.75	39.00	59.81	105.45	167.24	239.93	269.94
	Dagupan																
α	6.62	23.53	11.79	13.75	17.40	20.78	23.26	26.98	30.52	33.24	37.15	40.91	52.15	62.12	69.32	124.66	144.23
ξ	14.48	24.24	28.22	33.19	40.86	48.54	53.30	61.16	68.53	74.07	81.27	87.70	115.74	143.96	164.86	237.86	276.33
var(α)	1.21	15.25	3.83	5.21	8.34	11.89	14.90	20.05	25.64	30.42	37.99	46.09	74.87	106.23	132.31	427.84	572.69
var(ξ)	1.64	20.67	5.19	7.06	11.31	16.12	20.20	27.18	34.76	41.25	51.51	62.49	101.52	144.04	179.40	580.11	776.52
	Naia																
α	4.86	7.65	10.20	11.92	15.50	19.08	21.90	24.80	28.08	30.97	34.73	37.98	50.77	62.07	74.65	100.60	114.40
ξ	12.16	18.88	24.24	29.24	35.78	42.23	46.31	52.93	58.35	61.71	67.23	72.01	93.57	116.68	125.21	173.39	205.07
var(α)	0.63	1.56	2.77	3.78	6.39	9.69	12.77	16.38	20.98	25.54	32.11	38.39	68.63	102.55	148.35	269.39	348.38
var(ξ)	0.85	2.11	3.76	5.13	8.68	13.15	17.33	22.22	28.47	34.65	43.56	52.09	93.11	139.14	201.28	365.50	472.68
	Peurto																
α	2.96	4.77	6.10	6.98	8.44	9.77	10.76	12.81	14.23	15.61	17.45	18.90	24.99	30.57	35.00	55.23	63.56
ξ	8.06	12.27	15.63	18.43	22.80	27.61	30.60	35.09	40.41	44.04	48.64	53.02	69.75	85.15	96.68	130.40	148.08
var(α)	0.24	0.63	1.02	1.34	1.96	2.63	3.19	4.52	5.58	6.71	8.38	9.84	17.19	25.73	33.73	83.99	111.21
var(ξ)	0.33	0.85	1.39	1.82	2.66	3.56	4.32	6.12	7.56	9.09	11.36	13.34	23.31	34.89	45.73	113.88	150.79
	Port Area																
α	4.51	6.97	9.17	10.56	13.91	16.54	18.36	21.83	24.43	26.52	29.73	32.99	45.69	57.07	67.49	97.55	123.29
ξ	12.77	19.12	24.62	28.77	36.16	44.03	50.45	57.49	63.70	68.29	72.96	76.78	96.19	118.43	133.54	183.74	222.61
var(α)	0.60	1.44	2.48	3.30	5.72	8.08	9.96	14.09	17.64	20.78	26.12	32.16	61.71	96.26	134.62	281.26	449.24
var(ξ)	0.81	1.94	3.36	4.46	7.74	10.94	13.48	19.07	23.89	28.14	35.37	43.55	83.55	130.33	182.27	380.82	608.25

Table A7.16 Depth-duration-frequency for Philippines Sites

		Depth (mm)-duration(minutes/hours)-frequency(years) for Philippines Sites														
	Ambulong															
ARI (y)	5m	10m	15m	20m	30m	45m	60m	80m	100m	120m	150m	3h	6h	12h	1d	2d	3d
2	13.9	21.1	27.2	32.8	40.9	48.4	53.9	61.2	67.0	72.2	78.5	83.7	107.9	135.0	158.9	217.4	244.0
5	20.3	30.1	38.0	45.1	56.4	67.9	75.9	86.2	95.5	103.1	112.9	121.2	158.5	197.1	231.2	320.7	357.2
10	24.5	36.0	45.1	53.2	66.8	80.8	90.4	102.8	114.3	123.6	135.8	145.9	192.0	238.2	279.0	389.0	432.3
20	28.6	41.6	52.0	61.0	76.7	93.2	104.4	118.7	132.4	143.2	157.7	169.7	224.1	277.6	324.9	454.6	504.2
50	33.8	49.0	60.8	71.1	89.5	109.3	122.5	139.2	155.8	168.6	186.0	200.5	265.7	328.6	384.3	539.5	597.3
	Baguio															
2	20.5	31.9	41.2	49.0	61.1	72.4	80.7	95.3	104.8	120.0	137.0	149.4	220.3	303.8	372.9	546.4	624.6
5	33.8	52.4	67.8	80.4	100.9	120.2	133.5	158.8	180.4	200.7	227.8	247.4	347.6	464.7	561.4	793.2	894.5
10	42.6	66.1	85.4	101.2	127.3	151.8	168.4	200.8	230.4	254.2	287.8	312.2	431.8	571.3	686.1	956.6	1073.2
20	51.0	79.1	102.3	121.2	152.6	182.1	202.0	241.1	278.4	305.4	345.5	374.4	512.7	673.5	805.8	1113.3	1244.6
50	61.9	96.0	124.1	147.1	185.3	221.4	245.4	293.2	340.6	371.7	420.1	455.0	617.3	805.8	960.7	1316.2	1466.5
	Baler															
2	17.0	24.6	31.1	36.1	44.4	53.7	61.1	71.8	81.6	89.3	99.5	107.1	139.0	168.3	194.6	259.6	296.7
5	23.4	33.9	42.3	49.3	61.8	74.9	84.6	98.7	112.2	123.8	139.3	151.9	198.7	240.5	249.3	328.0	374.8
10	27.7	40.1	49.8	58.0	73.3	88.8	100.2	116.4	132.5	146.6	165.6	181.5	238.3	288.3	285.5	373.3	426.5
20	31.8	46.0	56.9	66.4	84.3	102.3	115.1	133.5	151.9	168.4	190.8	210.0	276.2	334.1	320.3	416.7	476.0
50	37.1	53.6	66.2	77.2	98.6	119.6	134.4	155.6	177.1	196.7	223.5	246.8	325.3	393.5	365.3	472.9	540.2
	Daet															
2	14.9	22.5	28.9	34.9	44.2	51.9	57.9	67.1	73.8	79.9	88.8	95.9	126.9	163.8	196.3	265.5	291.7
5	21.0	30.5	38.7	46.6	56.2	66.4	74.8	88.2	98.6	109.3	123.4	132.5	172.3	224.1	272.1	356.4	388.0
10	25.0	35.7	45.2	54.4	64.1	76.0	86.0	102.1	115.1	128.8	146.3	156.8	202.3	264.0	322.4	416.5	451.9
20	28.8	40.7	51.5	61.8	71.7	85.1	96.7	115.5	130.9	147.4	168.2	180.0	231.1	302.2	370.5	474.2	513.1
50	33.8	47.2	59.6	71.5	81.6	97.0	110.6	132.8	151.4	171.6	196.7	210.2	268.4	351.7	432.9	548.9	592.3
	Dagupan															
2	16.9	32.9	32.5	38.2	47.2	56.2	61.8	71.1	79.7	86.3	94.9	102.7	134.9	166.7	190.3	283.5	329.2
5	24.4	59.5	45.9	53.8	67.0	79.7	88.2	101.6	114.3	123.9	137.0	149.1	194.0	237.1	268.8	424.8	492.7
10	29.4	77.2	54.8	64.1	80.0	95.3	105.6	121.9	137.2	148.9	164.9	179.8	233.1	283.7	320.9	518.4	600.9
20	34.1	94.1	63.2	74.0	92.6	110.3	122.4	141.3	159.2	172.8	191.6	209.2	270.6	328.5	370.8	608.1	704.7
50	40.3	116.1	74.2	86.9	108.8	129.6	144.1	166.5	187.6	203.8	226.2	247.3	319.2	386.3	435.4	724.3	839.1
	Naia															
2	13.9	21.7	28.0	33.6	41.5	49.2	54.3	62.0	68.6	73.1	80.0	85.9	112.2	139.4	152.6	210.3	247.0
5	19.4	30.3	39.5	47.1	59.0	70.9	79.2	90.1	100.5	108.2	119.3	129.0	169.7	209.8	237.2	324.3	376.7
10	23.1	36.1	47.2	56.0	70.7	85.2	95.6	108.7	121.5	131.4	145.4	157.5	207.8	256.4	293.2	399.8	462.5
20	26.6	41.6	54.5	64.6	81.8	98.9	111.4	126.6	141.7	153.7	170.4	184.8	244.4	301.0	346.9	472.2	544.9
50	31.1	48.7	64.0	75.7	96.3	116.7	131.8	149.7	167.9	182.6	202.7	220.2	291.7	358.9	416.5	565.9	651.4
	Peurto															
2	9.1	14.0	17.9	21.0	25.9	31.2	34.5	39.8	45.6	49.8	55.0	59.9	78.9	96.4	109.5	150.6	171.4
5	12.5	19.4	24.8	28.9	35.5	42.3	46.7	54.3	61.8	67.4	74.8	81.4	107.2	131.0	149.2	213.2	243.4
10	14.7	23.0	29.4	34.1	41.8	49.6	54.8	63.9	72.4	79.2	87.9	95.6	126.0	153.9	175.4	254.7	291.1
20	16.8	26.4	33.7	39.2	47.9	56.6	62.6	73.1	82.7	90.4	100.5	109.2	144.0	176.0	200.6	294.4	336.9
50	19.6	30.9	39.4	45.7	55.7	65.7	72.6	85.1	95.9	104.9	116.7	126.8	167.3	204.4	233.2	345.9	396.1
	Port Area															
2	14.4	21.7	28.0	32.6	41.3	50.1	57.2	65.5	72.7	78.0	83.9	88.9	112.9	139.3	158.3	219.5	267.8
5	19.5	29.6	38.4	44.6	57.0	68.8	78.0	90.2	100.4	108.1	117.5	126.3	164.7	204.0	234.8	330.1	407.5
10	22.9	34.8	45.2	52.5	67.5	81.2	91.8	106.6	118.7	128.0	139.9	151.0	199.0	246.9	285.4	403.3	500.1
20	26.2	39.8	51.8	60.1	77.5	93.1	105.0	122.3	136.3	147.0	161.3	174.8	231.9	287.9	334.0	473.5	588.8
50	30.4	46.3	60.4	70.0	90.4	108.5	122.1	142.7	159.0	171.8	189.0	205.5	274.5	341.1	396.9	564.4	703.7

Table A7.17 Parameters of EV1 for Vietnamese Sites

	Parameters of an EV Type 1 Distribution for Vietnamese Sites							
	Annhon							
	10m	**60m**	**2h**	**6h**	**12h**	**24h**	**1d**	**2d**
α		11.93	12.34	17.86	30.87	47.99	44.18	51.67
ξ		30.96	51.26	66.14	90.08	139.63	120.20	182.74
var(α)		22.03	23.54	49.33	147.49	356.42	301.96	413.08
var(ξ)		27.38	29.27	61.32	183.34	443.03	375.34	513.46
	Hanoi							
α	3.39	23.31	29.07	27.01	32.81	28.17	24.75	48.78
ξ	22.47	54.84	48.49	75.26	105.61	137.68	112.58	159.13
var(α)	1.13	53.26	82.79	71.48	105.46	77.78	60.05	170.72
var(ξ)	1.46	68.75	106.88	92.27	136.15	100.41	77.52	224.40
	Quynhon							
α		10.12	15.18	23.49	28.10	39.60	41.16	36.95
ξ		32.89	45.91	71.31	92.13	111.16	89.28	148.47
var(α)		15.84	35.64	85.36	122.17	242.68	262.09	211.29
var(ξ)		19.69	44.30	106.10	151.86	301.65	325.78	262.63

Table A7.18 Depth-duration-frequency for Vietnamese Sites

	Depth (mm)-duration(minutes/hours)-frequency(years) for Vietnamese Sites							
	Annhon							
ARI (y)	**10m**	**60m**	**2h**	**6h**	**12h**	**24h**	**1d**	**2d**
2		35.3	55.8	72.7	101.4	157.2	136.4	201.7
5		48.9	69.8	92.9	136.4	211.6	186.5	260.2
10		57.8	79.0	106.3	159.6	247.6	219.6	299.0
20		66.4	87.9	119.2	181.8	282.2	251.4	336.2
50		77.5	99.4	135.8	210.5	326.9	292.6	384.3
	Hanoi							
2	23.7	63.4	59.1	85.2	117.6	148.0	121.7	177.0
5	27.6	89.8	92.1	115.8	154.8	179.9	149.7	232.3
10	30.1	107.3	113.9	136.0	179.4	201.1	168.3	268.9
20	32.6	124.1	134.8	155.5	203.0	221.4	186.1	304.0
50	35.7	145.8	161.9	180.6	233.6	247.6	209.2	349.5
	Quynhon							
2		36.6	51.5	79.9	102.4	125.7	104.4	162.0
5		48.1	68.7	106.5	134.3	170.6	151.0	203.9
10		55.7	80.1	124.2	155.4	200.3	181.9	231.6
20		62.9	91.0	141.1	175.6	228.8	211.5	258.2
50		72.4	105.1	163.0	201.8	265.7	249.9	292.7

Chapter 8 Republic of Korea

Hong-Kee Jee, Woon-Ki Yeo, Joong-Hoon Kim and Soontak Lee

8.1 Introduction

The FARD (Frequency Analysis of Rainfall Data) program which was developed by NIDP (National Institute for Disaster Prevention) of MOGAHA (Ministry of Government Administration and Home Affairs) in Korea is used in frequency analysis of rainfall for the estimation of design rainfalls in Korea. This program consists of test of randomness, parameter estimation of probability distribution functions, goodness of fit tests and finally estimation of probable rainfall.

In this chapter, frequency analysis was carried out using FARD program for rainfall data of Daegu, Busan and Andong station in Korea as well as 40 stations of AP FRIEND regions in 8 countries.

8.2 Methodology

The process of FARD program is shown as Figure 8.1 for frequency analysis. First of all, FARD program computes basic statistics such as the mean, standard deviation, coefficient of variation and coefficient of skewness from collected annual maximum series. It tests randomness of rainfall data to make sure that the data are random variables. After preliminary test, FARD program is applied to analyze probability distributions in order of parameter estimation, validity check and goodness of fit test. Then best fit distribution is finally selected from which probable rainfalls are estimated.

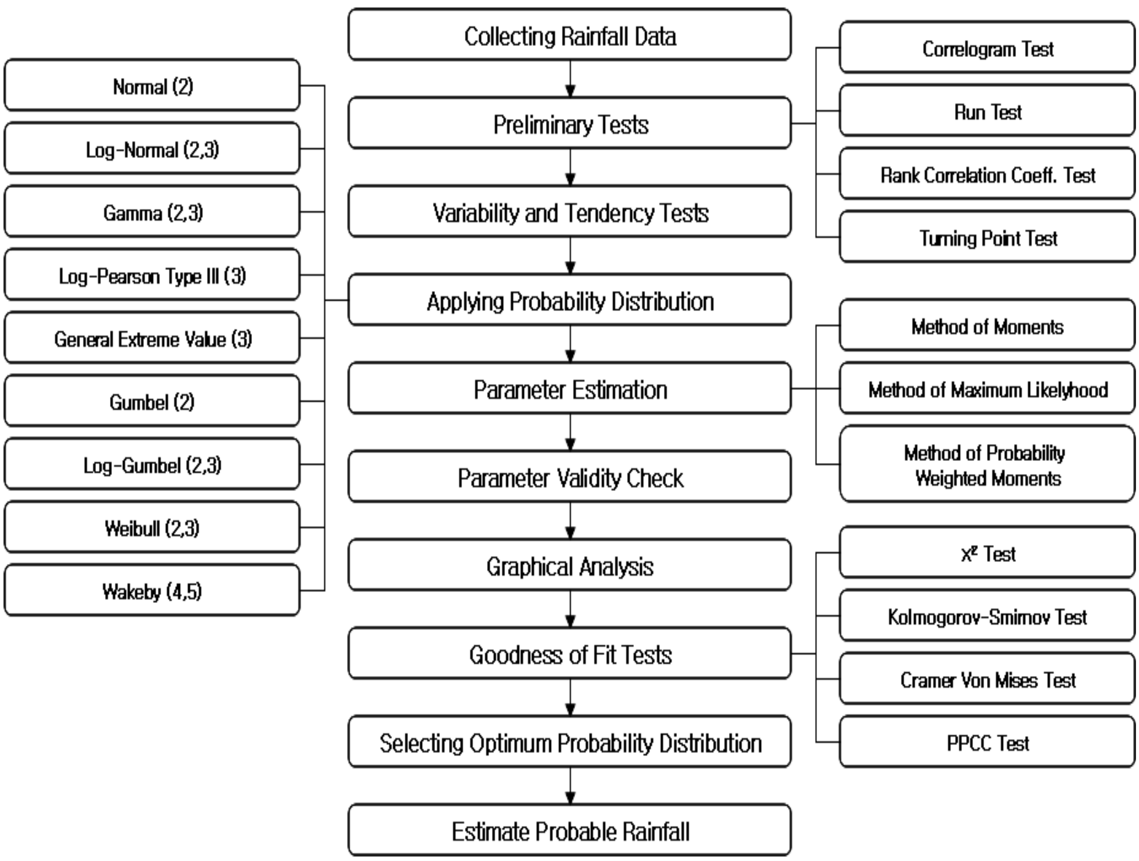


Figure 8.1 Process of Frequency Analysis of Rainfall Data by FARD program

8.3 Data supplied

Annual maximum rainfall series were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries supplied extreme rainfall data were as follows;

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	3 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

Additional 1 more site was supplemented to already supplied 2 sites of Republic of Korea. The maximum series of rainfall data from 10 minutes to 72 hours were used in analyses for 3 sites of Daegu, Busan and Andong in Korea.

8.4 Results of Analysis

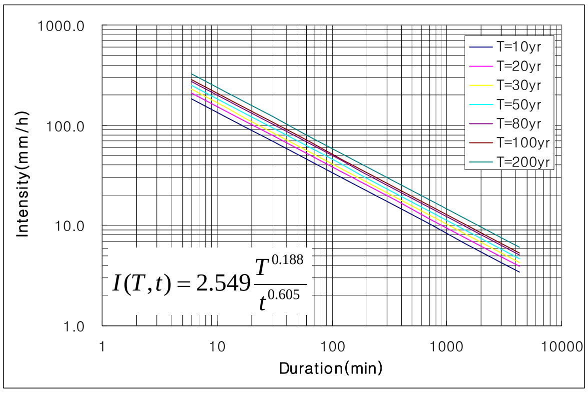
As results of frequency analysis, Gumbel distribution was selected as the best fit probability distribution with estimation of parameters by the method of probability weighted moments for every stations in Korea(Republic of) with return period of 10, 20, 30, 50, 80, 100 and 200 years.

Gumbel for Sydney and Log-Normal for Melbourne In Australia, Gamma for Yongcuan and Gumbel for Changzhou in China, GEV for Bandung and Gumbel for Bogor in Indonesia, Log-Normal for Nagoya and Ohkusa in Japan, Gamma for Empangan genting kelang and JPS ampang in Malaysia, Log-Normal for Wellington, Kelburn and Kaitoke in New Zealand, Log-Normal for Naia and Gamma for Baler in Philippines and Gumbel for Ha noi and An Nhon in Vietnam were selected as the best fit probability distributions with estimation of parameters by method of probability weighted moments for every stations with return period of 10, 20, 30, 50, 80, 100 and 200 years.

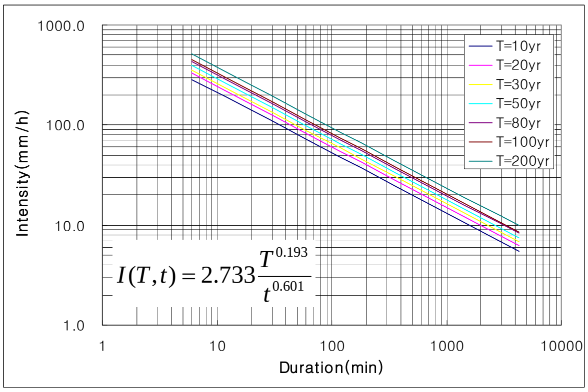
The equation (1) below, is generally used in Korea to determine rainfall IDF (intensity-duration-frequency) relationship.

$$I(T,t) = k\frac{T^x}{t^n} \tag{1}$$

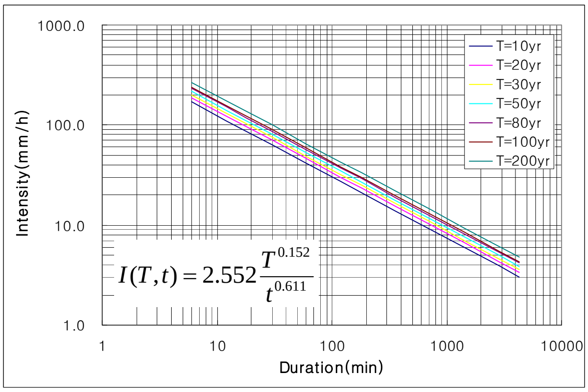
Results for the best fit distributions obtained by FARD program are shown in Figure 8.2(a)~(c) from Korean rainfall analyses and in Figures 8.3~8.10 from other APFRIEND region's rainfall data.



(a) IDF Curve for Daegu by Gumbel

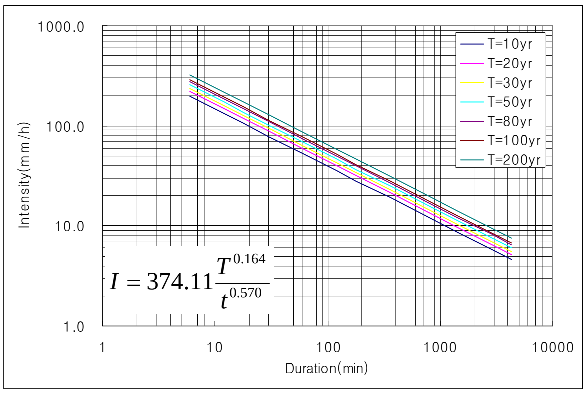


(b) IDF Curve for Busan by Gumbel

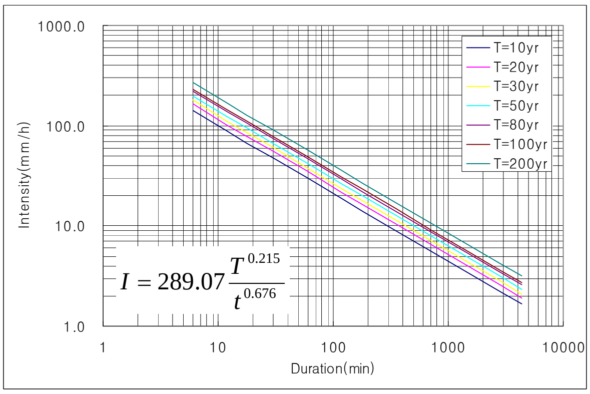


(c) IDF Curve for Andong by Gumbel

Figure 8.2 The IDF Curves for Korea

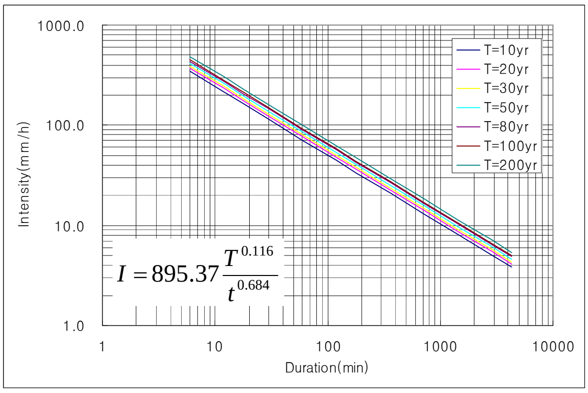


(a) IDF Curve for Sydney by Gumbel

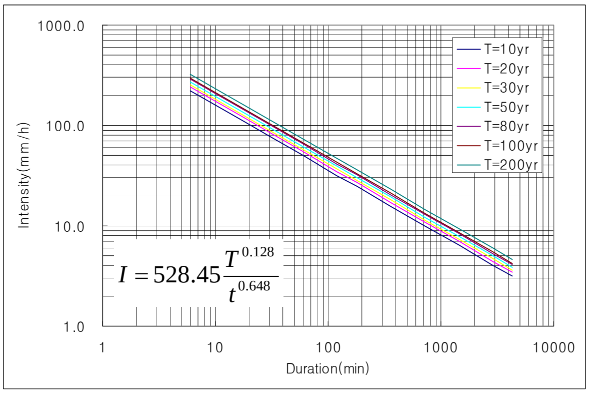


(b) IDF Curve for Melbourne by Log-Normal

Figure 8.3 The IDF Curves for Australia

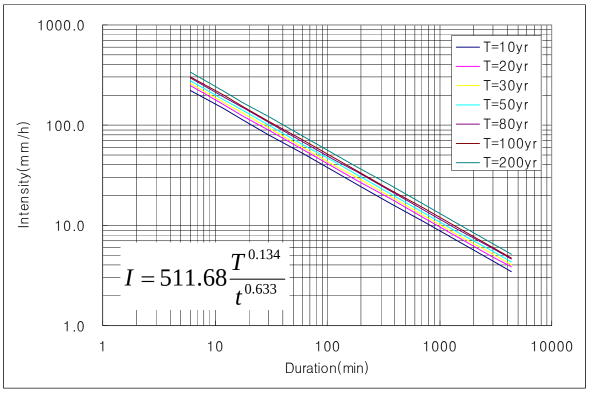


(a) IDF Curve for Yongcuan by Gamma

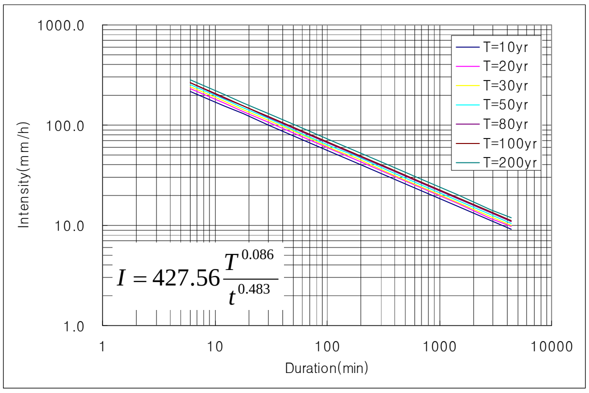


(b) IDF Curve for Changzhou by Gumbel

Figure 8.4 The IDF Curves for China

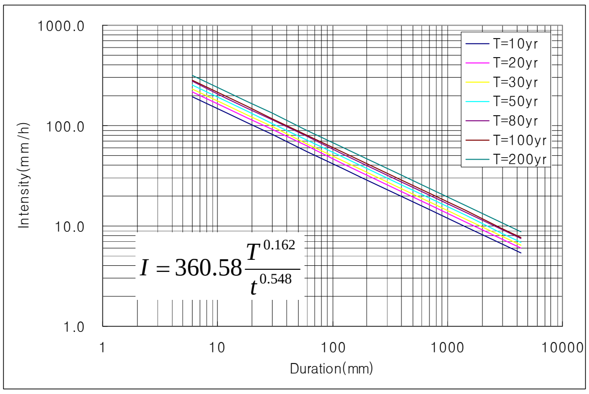


(a) IDF Curve for Bandung by GEV

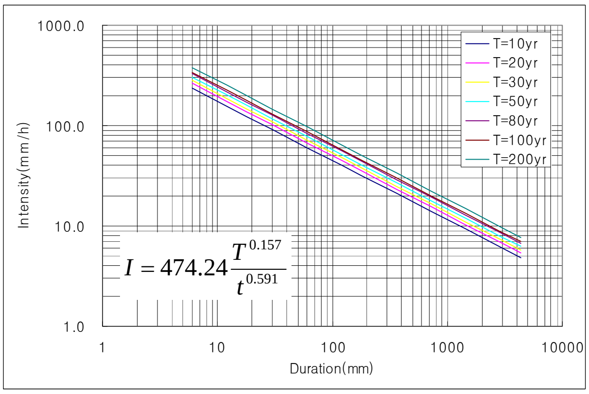


(b) IDF Curve for Bogor by Gumbel

Figure 8.5 The IDF Curves for Indonesia

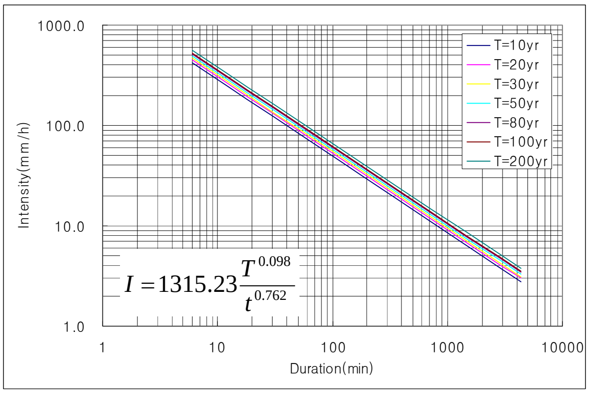


(a) IDF Curve for Nagoya by Log-Normal

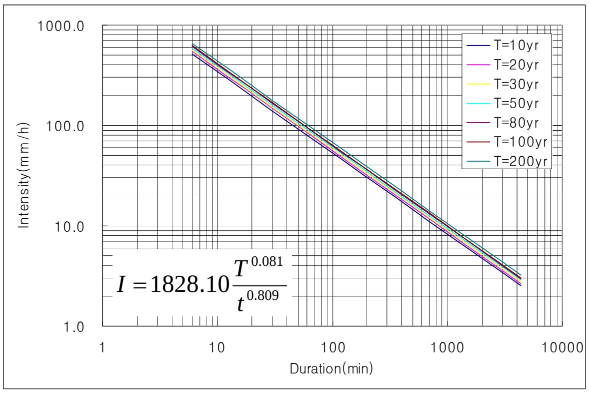


(b) IDF Curve for Ohkusa by Log-Normal

Figure 8.6 The IDF Curves for Japan

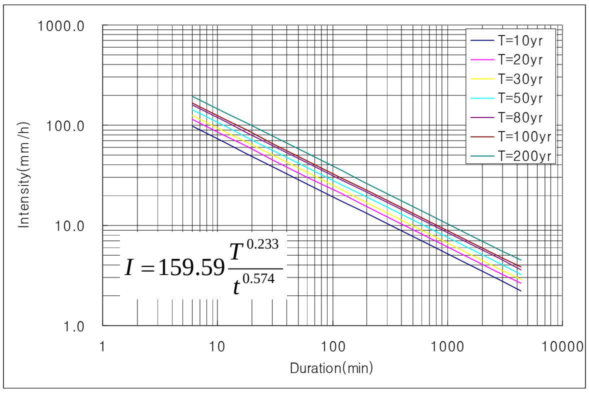


(a) IDF Curve for Empangan genting kelang by Gamma

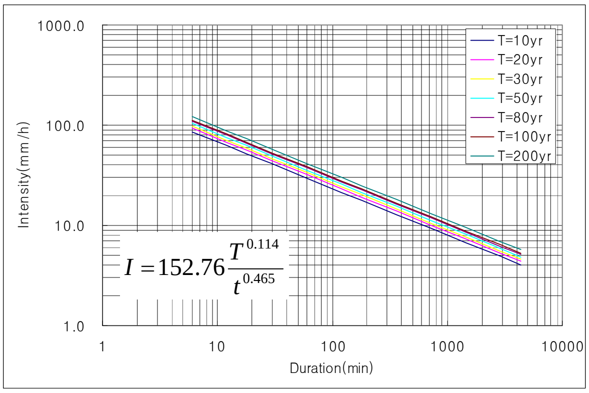


(b) IDF Curve for JPS ampang by Gamma

Figure 8.7 The IDF Curves for Malaysia

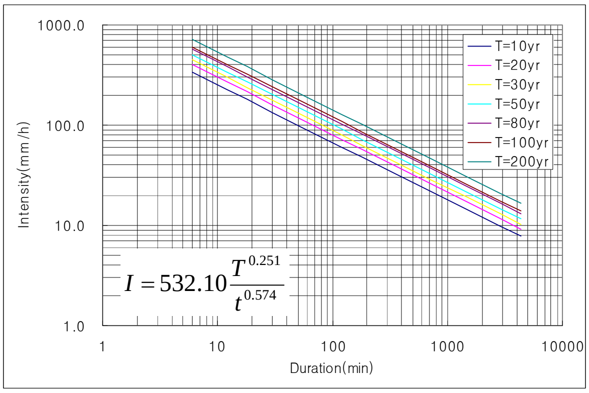


(a) IDF Curve for Wellington, Kelburn by Log-Normal

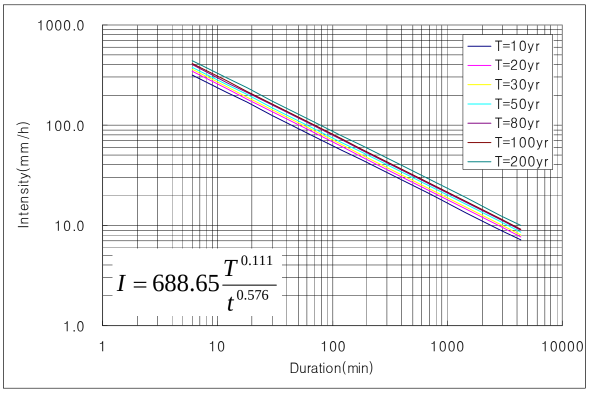


(b) IDF Curve for Kaitoke by Log-Normal

Figure 8.8 The IDF Curves for New Zealand

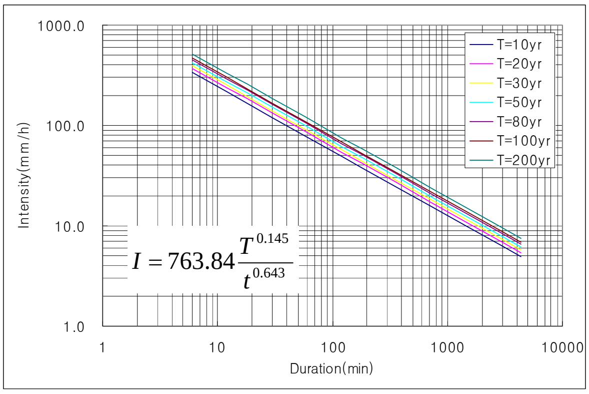


(a) IDF Curve for Naia by Log-Normal

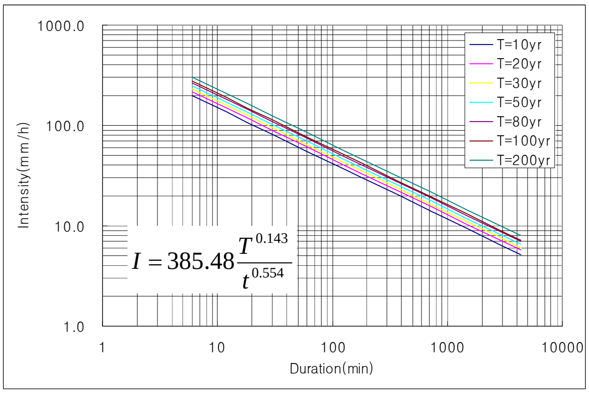


(b) IDF Curve for Baler by Gamma

Figure 8.9 The IDF Curves for Philippines



(a) IDF Curve for Ha noi by Gumbel



(b) IDF Curve for An Nhon by Gumbel

Figure 8.10 The IDF Curves for Vietnam

8.5 Acknowledgments

The support of KMA (Korea Meteorological Administration), Nakdong River Flood Control Office of MOCT (Ministry of Construction and Transportation) and NIDP of MOGAHA is acknowledged through their commitment in providing rainfall data and FARD program.

8.6 References

Korea Meteorological Administration (1916~2006), *Annual Climatological Report*, Seoul, Korea

Ministry of Construction and Transportation (1962~2006), *Annual Hydrological Report on Korea*, Seoul, Korea

Korea Water Resources Association (2004), *Statistical Analysis of Rainfall by FARD9(Frequency Analysis of Rainfall Data)*, 12th Hydro-Engineering Workshop Report, Seoul, Korea

National Institute for Disaster Prevention(NIDP) of Ministry of Government Administration and Home Affairs (MOGAHA) (1998), *Development of Program for Frequency Analysis of Rainfall Data(FARD)*, Research Report NIDP-97-09, Seoul, Korea.

Chapter 9 Philippines

Guillermo Q. Tabios III

9.1 Introduction

This report illustrates how the various countries involved in this project perform their rainfall intensity-frequency-duration (RIDF) analysis. In the Philippines, the National Water Resources Board (formerly National Water Resources Council) published in 1977 through 1981 the first comprehensive RIDF analysis for 12 regions in the Philippines. The RIDF analysis were performed for individual rainfall stations and the 3-parameter gamma (also called Pearson type III) probability distribution was used in the analysis. In 1981, the Philippine Atmospheric, Geophysical and Astronomic Services Administration (PAGASA) published RIDF curves for about 50 gaging stations in the Philippines using the extreme value Type 1 (EV-1, also called Gumbel) probability distribution. The latest RIDF analysis of Philippines rainfall data was published by the Flood Control and Sabo Engineering Center (FCSEC) of the Department of Public Works and Highways (DPWH) in 2003 for 1-day rainfall of selected gaging stations in the Philippines using either the EV-1 or 3-parameter gamma probability distribution. These manuals were specifically written to assist engineers at DPWH. This chapter illustrates RIDF analysis using the 3-parameter gamma or Pearson Type III probability distribution and the fitting of a parametric function to smoothen the RIDF curves. The gamma distribution being a 3-parameter distribution is more versatile model than the EV-1 or Gumbel distribution being only 2-parameter distributions.

9.2 Methodology

For a given rainfall station, the RIDF analysis involves two steps. First is to fit the 3-parameter gamma or Pearson type III probability distribution function to the annual maxima series for a particular duration (e.g., 10 min, 30 min or 1 hour duration) to estimate the rainfall quantiles at different frequencies or return periods. The estimated rainfall quantiles constitute the historical RIDF curve. Second is to fit a parametric function to these historical RIDF curves at different frequencies and durations to constitute the smoothen or station-specific RIDF curves.

The gamma or Pearson type III probability distribution function is given by:

$$f(x) = \frac{1}{|\alpha|\Gamma(\lambda)} \left[\frac{x - x_0}{\alpha} \right]^{\lambda - 1} \exp\left[-\frac{x - x_0}{\alpha} \right]$$

where x_0 is the location parameter, α is the scale parameter and λ is the shape parameter and $\Gamma(\lambda)$ is the gamma function of λ. The parameters of the distribution are estimated by maximum likelihood method

The parametric function fitted to the historical RIDF curves is given by:

$$i_{T,D} = \frac{a_1 \bullet T^{a_2} \bullet \exp[SDe^2/2]}{D^{a_3}}$$

where $i_{T,D}$ is the calculated rainfall intensity (in mm per hour) at return period T (in recurrence interval in years) and duration D (in hours); $[a_1, a_2, a_3]$ are model coefficients; and, SDe is the standard deviation of the model residuals (model error term). The equation as written above is to corrected for bias (underestimation of predicted value) due to the use of logarithmic transformation in the nonlinear least squares parameter estimation.

9.3 Data supplied

Annual maxima rainfall data at various durations were provided by the participating countries in this project. For this chapter, thirteen (13) rainfall stations were selected to illustrate the above RIDF analysis methodology. These stations are as follows:

1. Changzhou, CHINA
2. Yongchun, CHINA
3. Bandung, West Java, INDONESIA
4. Jakarta, Metropolitan City, INDONESIA
5. Daegu, KOREA
6. Andong, KOREA
7. NAIA, Manila, PHILIPPINES
8. Puerto Princesa, Palawan, PHILIPPINES
9. Ha Noi, VIETNAM
10. Wellington, Kelburn, NEW ZEALAND
11. Wainuiomata, NEW ZEALAND
12. Toyohashi, JAPAN
13. Ohkusa, JAPAN

9.4 Results of RIDF Analysis

Results of RIDF analysis are given in Figures 9.1 through 9.13 below in the order of the stations (names) listed above. In these figures, the rainfall quantiles obtained from raw historical data are also plotted with the RIDF parametric (smoothened) curves to indicate the goodness-of-fit between the parametric functions to the raw data. The plots are for exceedance probabilities of 1, 2, 40, 80 and 90 percent corresponding to return periods (RP) or average recurrence intervals of 100, 50, 25, 1.25 and 1.11 years. respectively. It may be noted that RIDF parametric function tend to fit well the rainfall quantiles at durations of 0.5 to 5 hours. Also, generally, the parametric function overestimates the rainfall quantiles at durations less 0.5 hours and durations greater than 5 hours except for Changzhou station (Figure 9.1) where the rainfall quantiles are underestimated at durations greater than 10 hours.

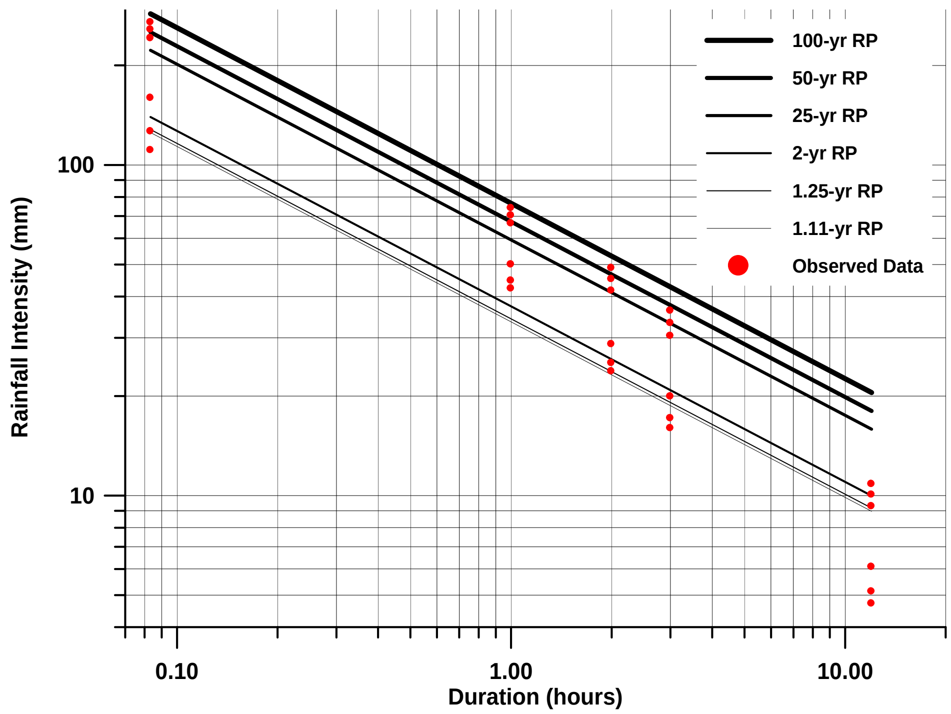


Figure 9.1 RIDF curve of Changzhou, CHINA.

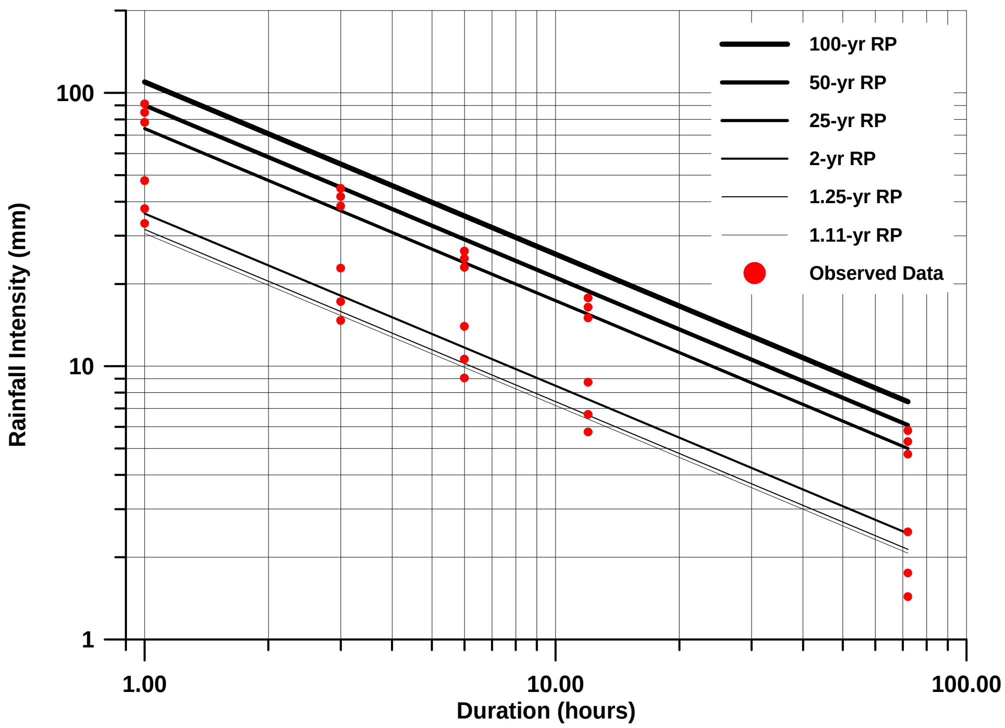


Figure 9.2 RIDF curve of Yongchun, CHINA.

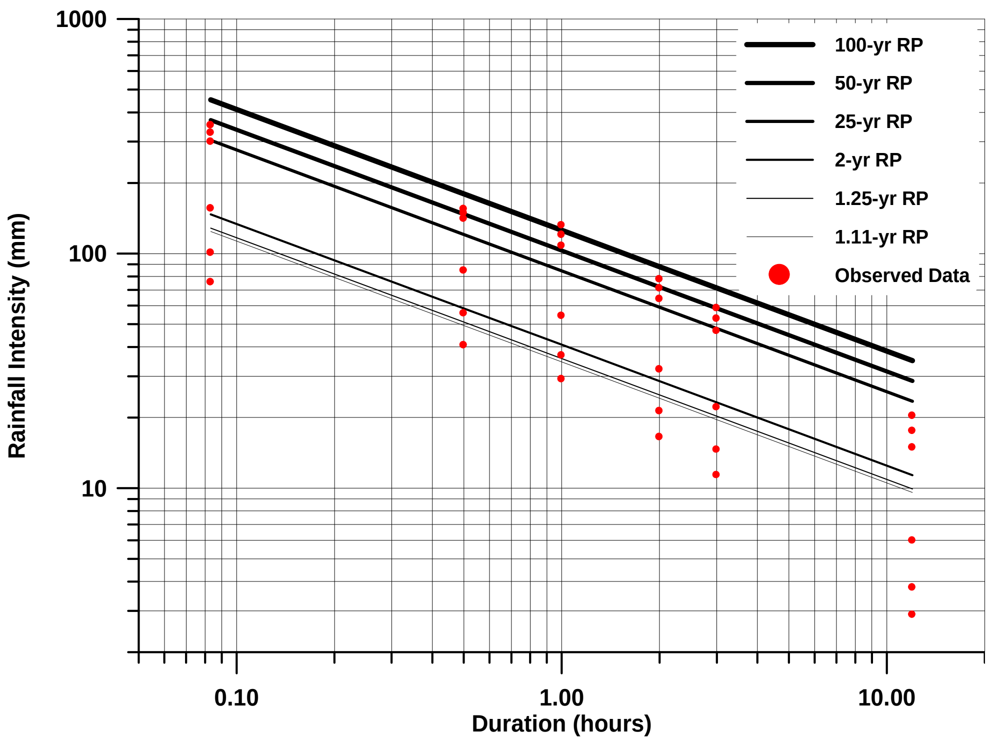


Figure 9.3 RIDF curve of Bandung, INDONESIA.

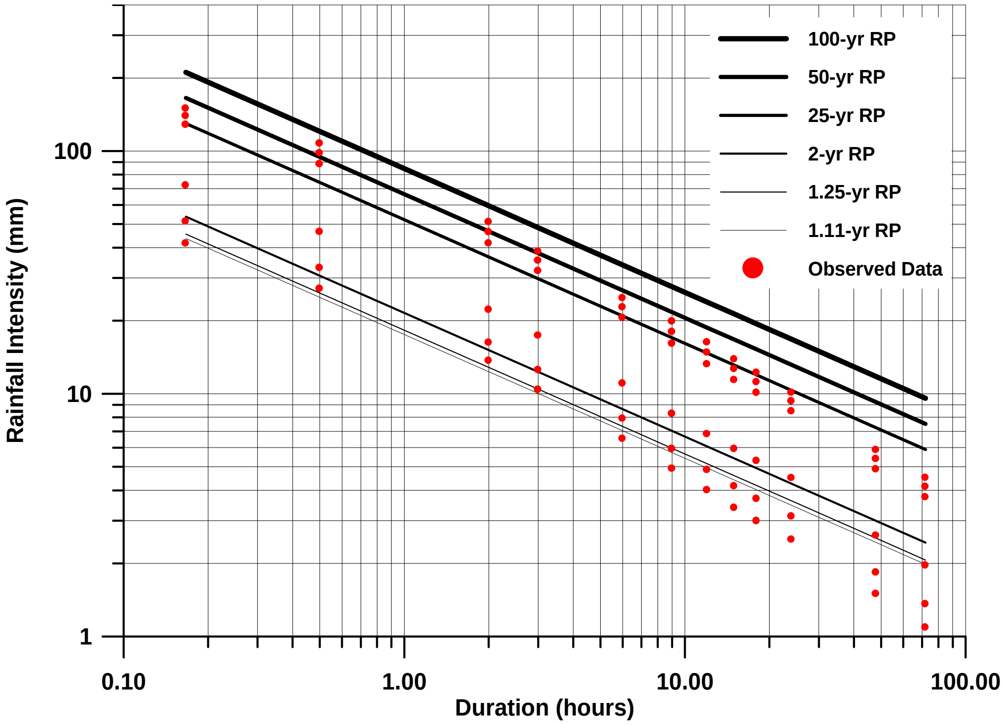


Figure 9.4 RIDF curve of Jakarta, INDONESIA.

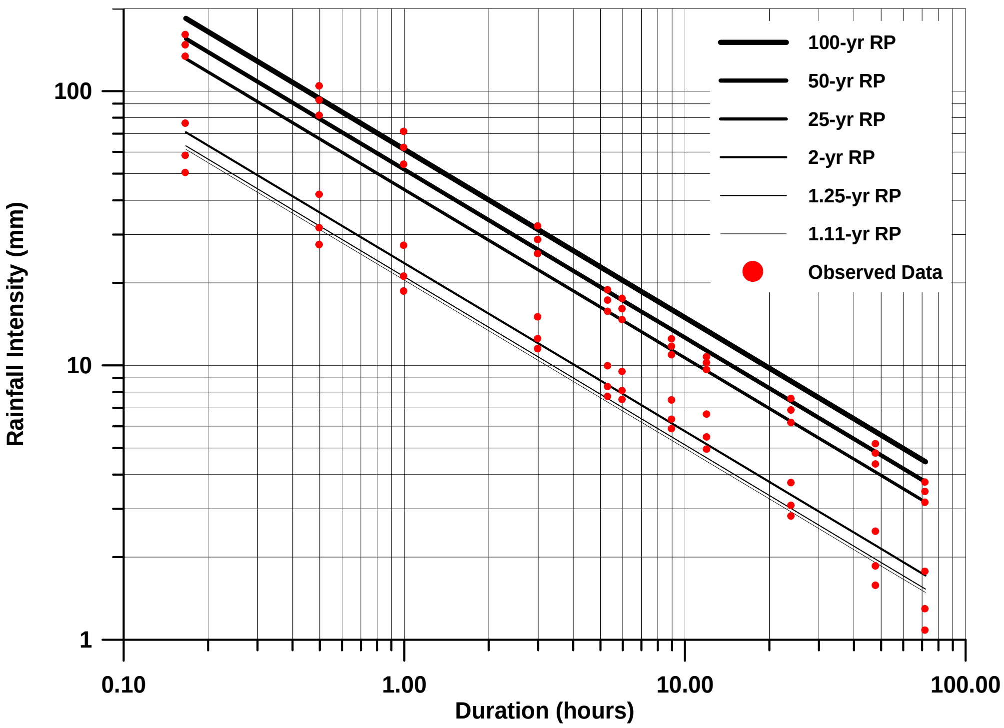


Figure 9.5 RIDF curve of Daegu, KOREA.

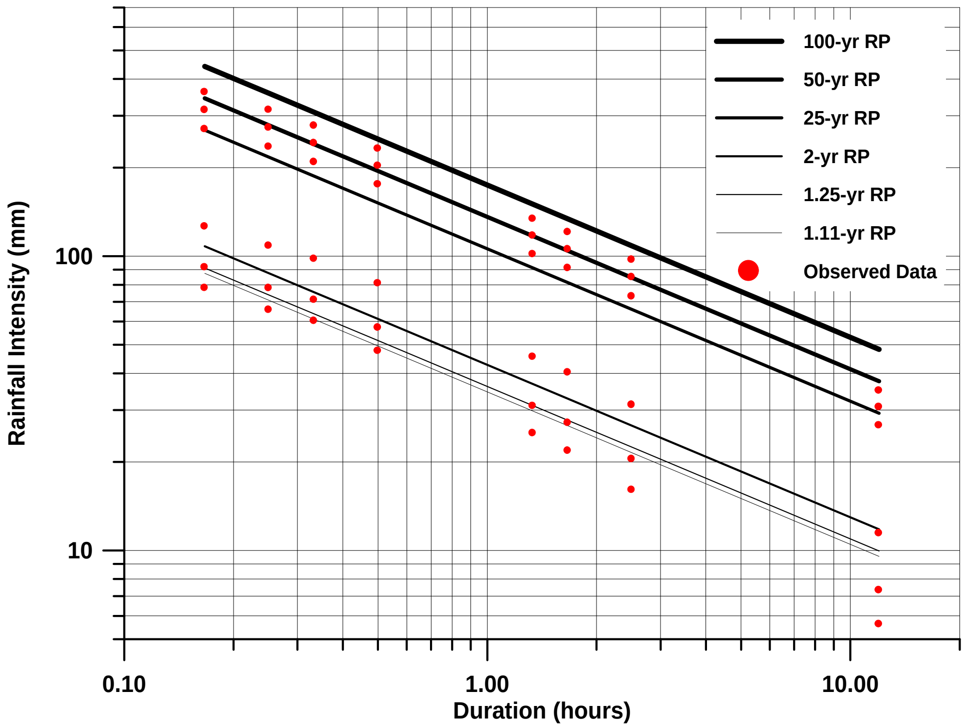


Figure 9.6 RIDF curve of Andong,KOREA.

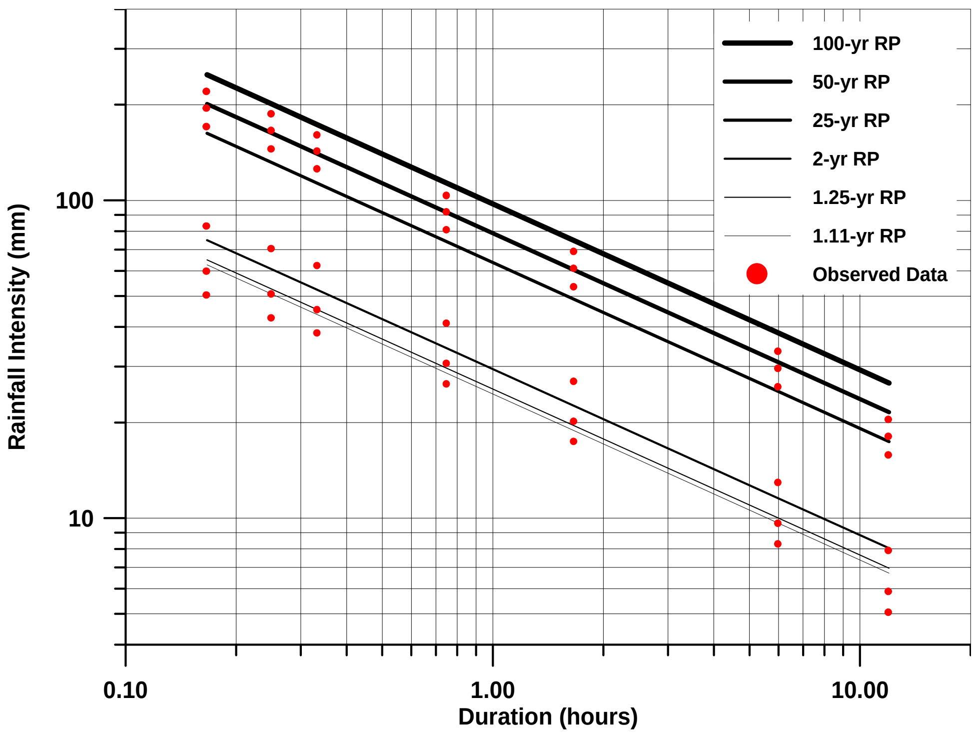


Figure 9.7 RIDF curve of NAIA, Manila, PHILIPPINES.

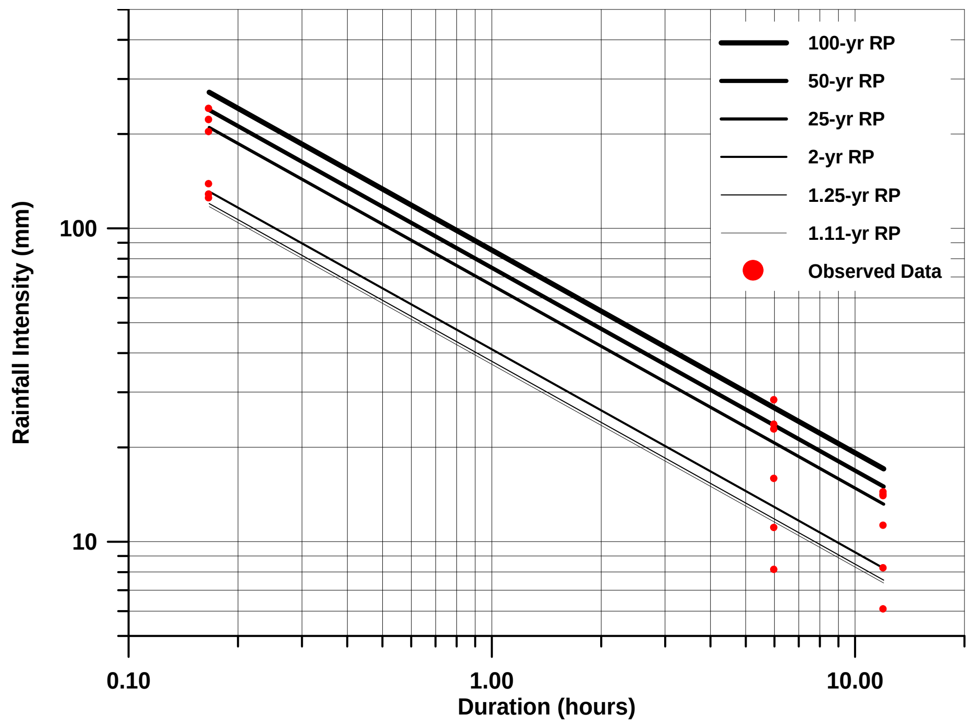


Figure 9.8 RIDF curve of Puerto Princesa, PHILIPPINES.

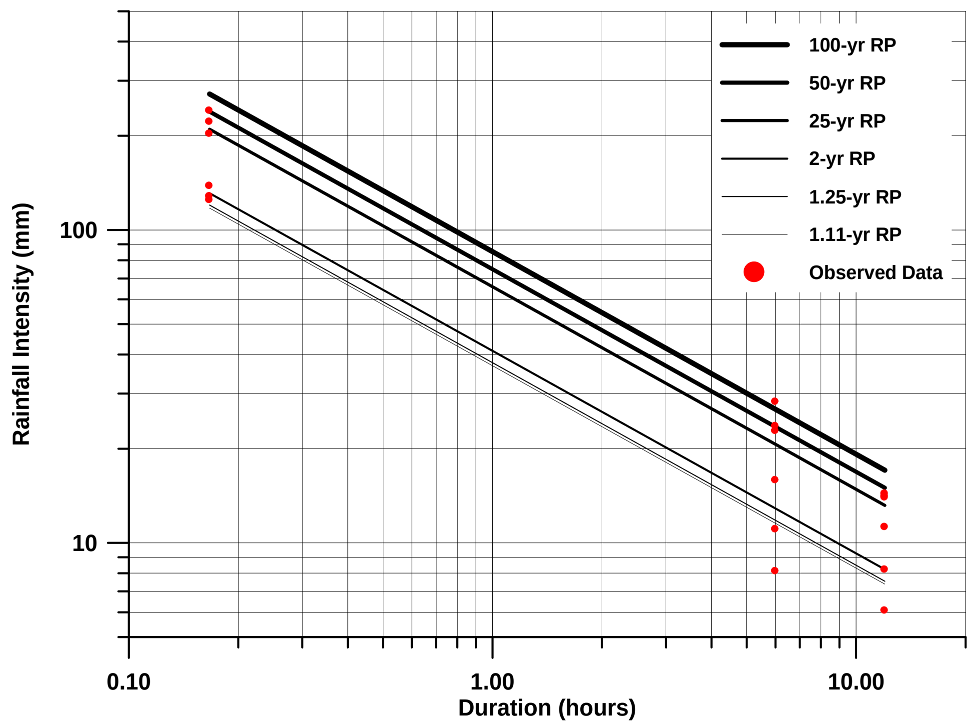


Figure 9.9 RIDF curve of Ha Noi, VIETNAM.

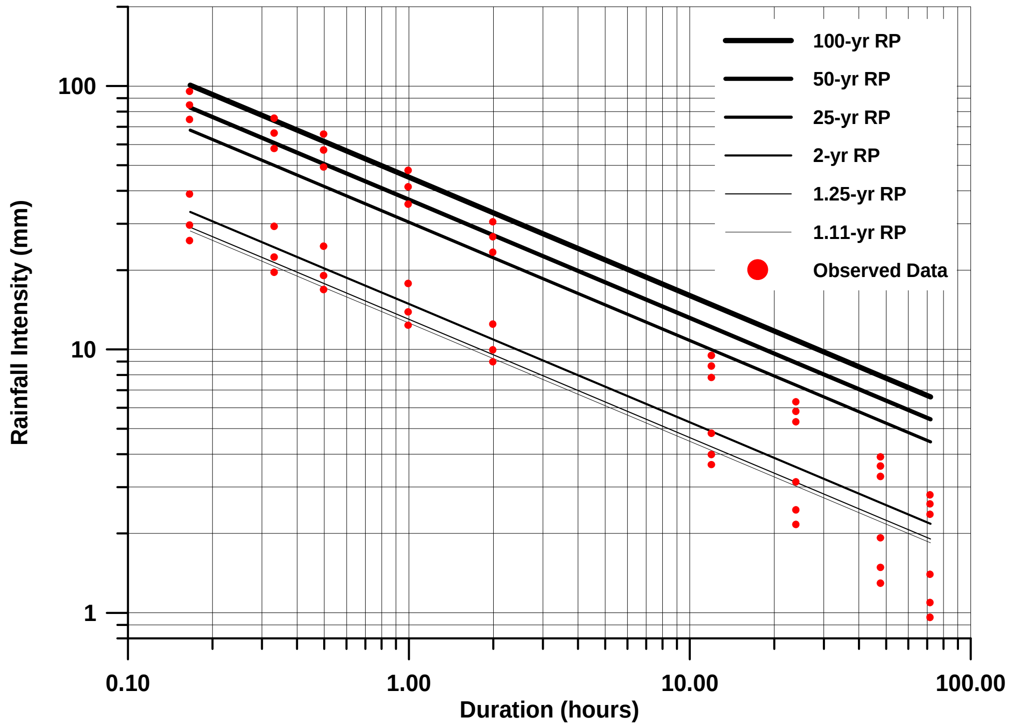


Figure 9.10 RIDF curve of Wellington, NEW ZEALAND

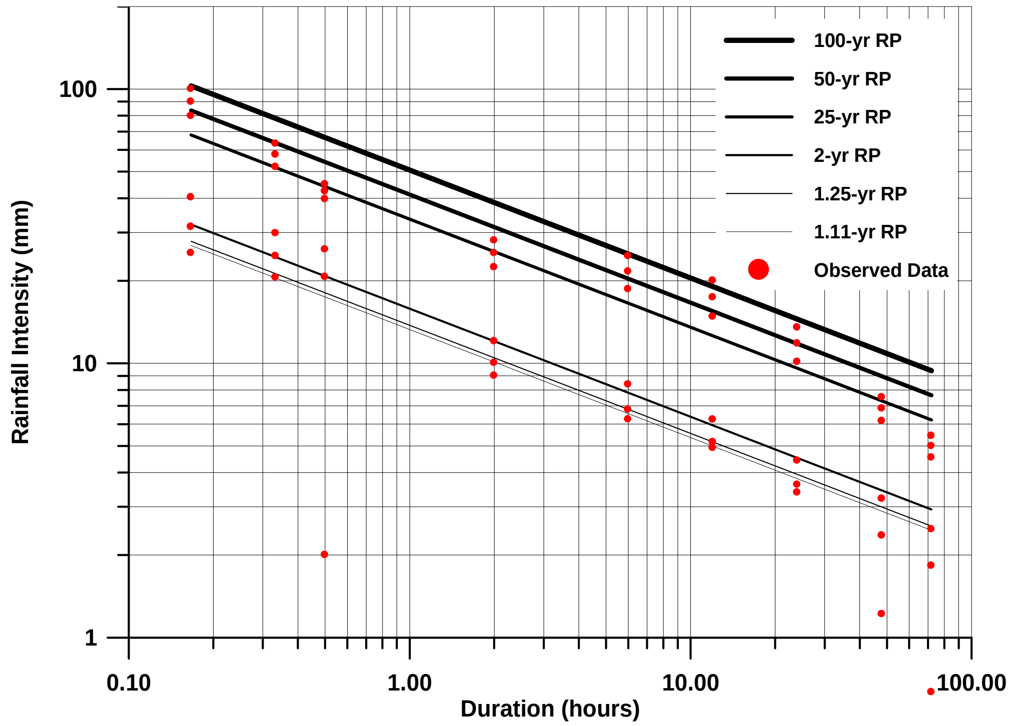


Figure 9.11 RIDF curve of Wainuiomata, NEW ZEALAND

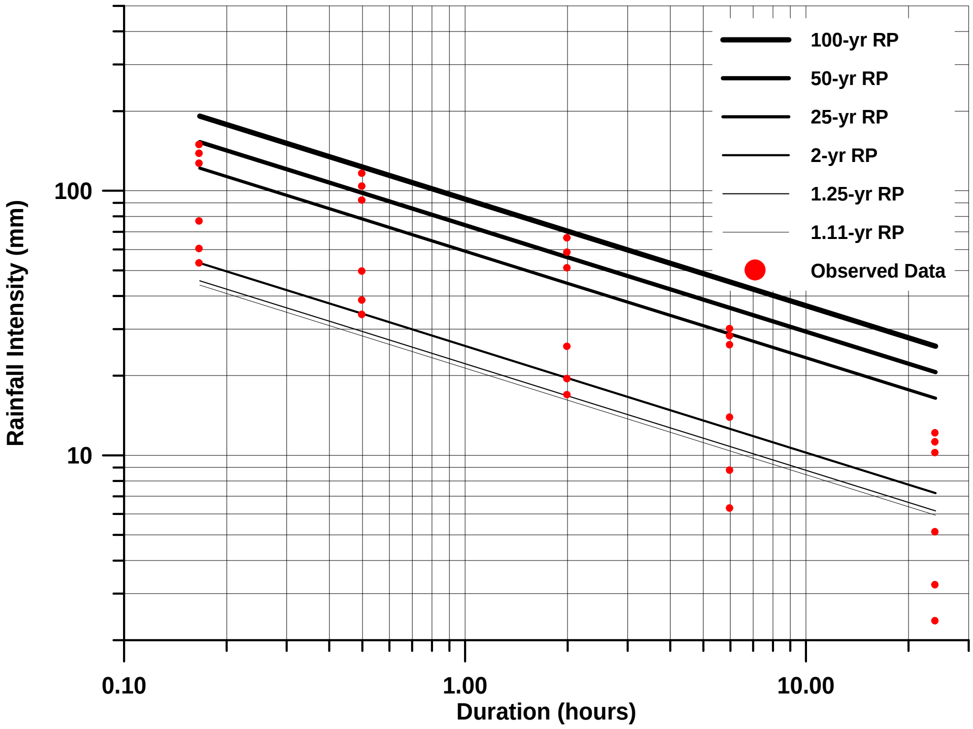


Figure 9.12 RIDF curve Toyohashi, JAPAN.

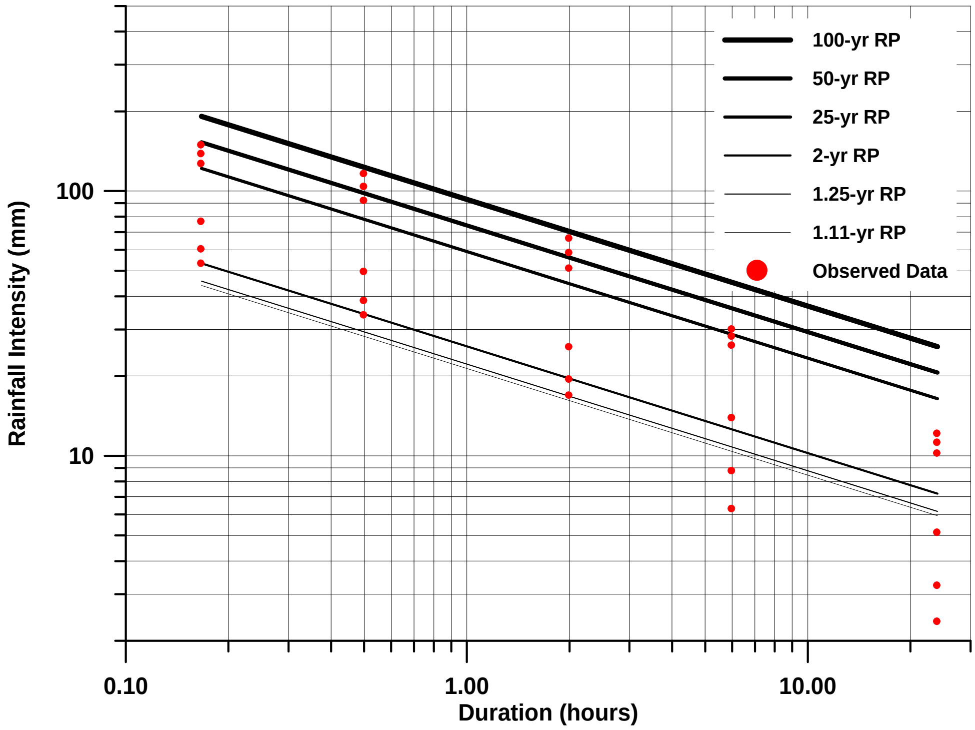


Figure 9.13 RIDF curve of Ohkusa, JAPAN.

9.5 Acknowledgments

The Philippine rainfall data used in this project was provided by PAGASA of the Philippines. The author gratefully acknowledges UNESCO-Jakarta Office for the support in this project.

.

Chapter 10 Vietnam

Tran Thuc, Dang Quang Thinh, Huynh Lan Huong, Phung Thu Trang

10.1 Introduction

Investigations of extreme rainfalls by the scientific and engineering community serves several purposes; (i) the estimation of extreme rainfalls for design purposes, (ii) the assessment of the rarity of observed rainfalls, (iii) comparison of methods to estimate design rainfalls and IDF. This chapter briefly presents a method used in the design rainfall estimation in Vietnam.

10.2 Methodology

10.2.1 Calculation of design precipitation depth using Pearson III Distribution

The Pearson Type III distribution, also called the three-parameter gamma distribution, introduces a third parameter, the lower bound ϵ, so that by the method of moments, three sample moments can be transformed into the three parameters α, β, and ϵ of the probability distribution. This is a very flexible distribution, assuming a number of different shapes as λ, β, and ϵ vary. The Pearson Type III distribution is popularly used in Vietnam for calculating design features of hydrologic factors. The final values for each station with various durations are shown in Appendix.

10.2.2 Calculation of design precipitation depth using Log-Pearson III Distribution

The Log - Pearson Type III distribution is popularly used in USA and several countries to calculate features of design flood peaks and design precipitation depth. The U. S. Water Resources Council recommended that the Log-Pearson III distribution should be used as a basic distribution for flood flow frequency studies.

Analyses of values of calculated design precipitation for various durations show that results achieved from two methods are the same, and have no great errors.

Through observed and calculated data of design precipitation depth for various durations, some comments can be made as follows:

Generally, the results of different countries can be divided into three groups:

1. Group with high maximum precipitation depth: Philippine, Indonesia, Vietnam and Malaysia; these countries have much duration average precipitation, but this is only initial comment basing on analyses of data from stations, therefore, comment on precipitation depth for whole country cannot be made. Maximum precipitation depth for various durations unevenly varies from station to station, for instance, in Philippine, maximum precipitation depth for duration of 60-minute is 90.5mm (at Baguio station), whereas this value is only 36.8 mm (at Puerto station)

2. Group with medium maximum precipitation depth: Japan and Australia. In these countries, maximum precipitation depth for various durations unevenly varies from station to station. For example, in Australia, maximum precipitation depth for duration of 60-minute is 13.0 mm at “094029” station, while this value is 61.2mm at “014015” station.

3. Group with low maximum precipitation depth is New Zealand

Results of frequency analysis show that the variation of precipitation depth for various durations throughout years is not similar at each station; for example, maximum precipitation depth for duration of 10-minute and 2-year return period at Puerto station (Philippine) is 13.1mm almost equal to 12.5 mm at AnDong station (Korea) but for return period of 100 years, these values are 40.6 mm and 29.2 mm, respectively.

10.2.3 Intensity – Duration – Frequency Relationships

The intensity is the time rate of precipitation, that is, depth per unit time (mm/h or in/h). It can be either the instantaneous intensity or the average intensity over the duration of rainfall. The average intensity is commonly used and can be expressed as follow:

$$I = X(T)/T$$

where: X = design precipitation for various durations (mm)
T = duration, usually in hours
I = intensity (mm/h)

Annual Maximum Precipitation data for 5-, 10-, 20-, 30-, 60- ... 1440-minute durations have been collected for many years. From this data, experimental distribution curves are developed then selected one type of theoretical distributions to depict experimental probability distribution regulation basing on most appropriate principle (normally, Pearson Type III, Log-Pearson Type III or Gumbel distributions are used).

10.3 Results of Calculation

Using values of design precipitation depth for 10-, 30-, 60-minute durations calculated from Pearson Type III, Log-Pearson Type III distributions to develops IDF curves.

Similarly, the values of design precipitation intensity calculated from Pearson Type III, and Log-Pearson Type III distributions are quite the same. Consequently, this report will apply Pearson III distribution for frequency analysis.

Because of the limitation of data, in some countries, there is only maximum precipitation depth for duration from 10-minute and longer, so it is difficult to estimate for basin that has short concentration time, especially less than 10-minute. To overcome that problem, it can be used extrapolation method basing on developing relationship between intensity and duration for each curve corresponding with each frequency. At present, there are a lot of different methods for developing IDF curve. In Vietnam, development of IDF curve is not identical and there are also several methods for developing IDF curves such as: experimental formula by Ministry of Construction (MoC), formula by Russia, formula by Europe Union, by U.S … This report uses Wenzel's equation, which is popular over the world, to develop IDF curves.

Wenzel (1982) provided coefficients from a number of cities in the United States for an equation of the form:

$$i = c/(T^e+f)$$

where:
c, e, f = coefficients varying with location and return period;
i = design rainfall intensity (in/h) or (mm/h)

It is also possible to apply a simpler form basing on Wenzel equation by relationship:

$$i = f(1/T+1)$$

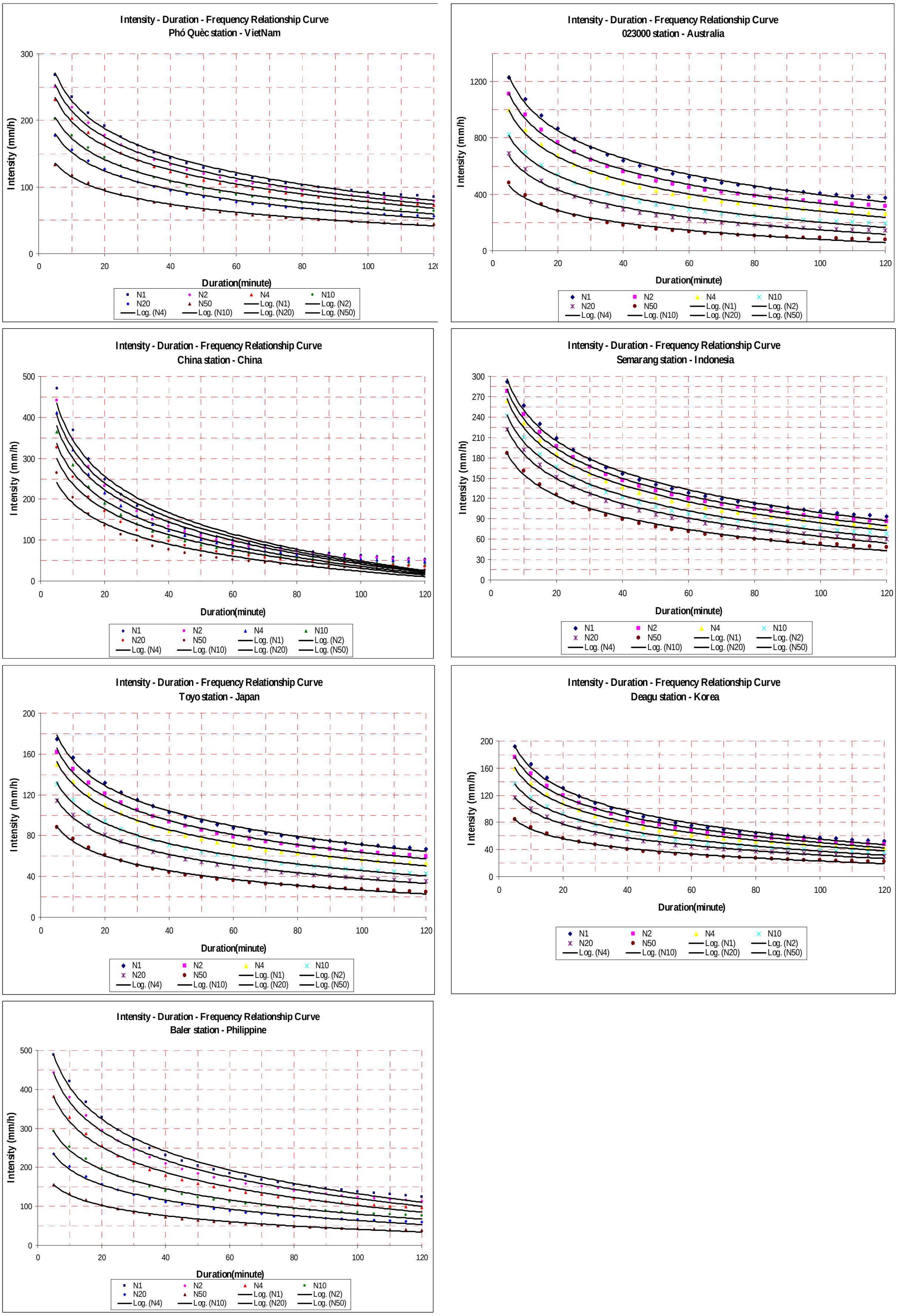


Figure 10.1 IDF Curves for various countries.

This relationship has an exponential function form using values of design precipitation depth for durations from 10 to 120-minute and the results are shown in Table 6 (see appendix), Figure 1.

Based on above-mentioned equations, IDF curves were developed and illustrated in the above figures.

10.4 Data supplied

Annual maximum rainfall series from durations ranging from 5 minutes to over 15 days were supplied by participating countries attending the APFRIEND Workshop in Kuala Lumpur, Malaysia in June 2005. Countries to supply extreme rainfall data, have been listed in the preamble to this report, and were:

Australia	10 sites
People's Republic of China	3 sites
Indonesia	5 sites
Republic of Korea	2 sites
Malaysia	3 sites
New Zealand	3 manual sites & 3 co-located automatic sites
Philippines	8 sites
Vietnam	3 sites
Japan	5 sites

The record lengths of each rainfall data series varied from a minimum of 6 years to over 90 years.

10.5 Acknowledgements

Vietnam Institute of Meteorology, Hydrology and Environment carried out analysis and supplied the data for Vietnam's stations. Grateful thanks to other people who make their efforts to prepare this paper.

10.6 References

Chow, V.T. (1964) *Handbook of applied hydrology*. McGraw-Hill, USA.

Bandyopadhyay, M. (1972) *Synthetic storm pattern and runoff for Gauhati, India,* J.Hyd. Div., Am. Soc. Civ. Eng., vol. 98, no. HY5.

Frederick, R. H., V. A. Myers and E. P. Auciello. (June, 1977) *Five to 60-minute precipitation frequency for the eastern and central United States*, NOAA technical memo NWS HYDRO-35, National Weather Service, Silver Spring, Maryland.

Hershfield, D. M. (May 1961) *Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years*, tech. paper 40, U. S. Dept. of Comm.,Weather Bureau, Washington, D. C.

Huff, F. A. (1967) *Time distribution of rainfall in heavy storms*, Water Resources. Res., vol. 3, no. 4.
Marsalek, J. (1978) *Research on the design storm concept*, tech. memo. 33, Am. Soc. Civ. Eng., Urban Water Resources. Res. Prog., New York.

Keifer, C. J. and H. H. Chu. (1957) *Synthetic storm pattern for drainage design*, J. Hyd. Div., Am. Soc. Civ. Eng., vol. 83, no. HY4.

Preul, H. D. and C. N. Papadakis. (1973) *Development of design storm hyetographs for Cincinnati, Ohio*, Water Resour. Bull., vol. 9, no. 2.

U. S. Weather Bureau. (March 1958) *Rainfall-intensity-frequency regime*, *Part 2 – Southeastern United States*, tech. paper no. 29.

U. S. Weather Bureau. (May 1964) *Two- to ten- day precipitation for return periods of 2 to 100 years in the contiguous United states*, tech. paper 49, Washington, D. C.

World Meteorological Organization, Guide to Hydrological Practices*, vol.* II, (1983) *Analysis, forecasting and other applications*, WMO no. 168, 4th ed., Geneva, Switzerland.

Yen, B. C. (July 1975) *Risk-based design of storm sewers*, report no. INT 141, Hydraulics Research Station, Wallingford, Oxford shire, England .

Appendix Chapter 10
Results of RIDF Analyses

Table A10.1 List of rainfall stations

TT	Country	Station	Period	Duration
1	Australia	008051	1955-2004	6',12',18',30',60',120',180',360',720'
		014015	1954-2004	6',12',18',30',60',120',180',360',720'
		015590	1952-2004	6',12',18',30',60',120',180',360',720'
		02300	1897 -1978	6',12',18',30',60',120',180',360',720'
		031011	1943-2003	6',12',18',30',60',120',180',360',720'
		040223	1950-1999	6',12',18',30',60',120',180',360',720'
		066062	1913-2004	6',12',18',30',60',120',180',360',720'
		086071	1878-2004	6',12',18',30',60',120',180',360',720'
		094029	1912-2004	6',12',18',30',60',120',180',360',720'
2	Japan	ToYo	1932-2000	10',30',60',120',180',6h,12h,24h
		NagoYa	1940-2000	10',30',60',120',180',6h,12h,24h
		TaGuChi	1956-2000	10',30',60',120',180',6h,12h,24h
		OhKuSa	1962-2000	10',30',60',120',180',6h,12h,24h
		OKaZaKi	1942-2000	10',30',60',120',180',6h,12h,24h
3	Korea	Daegu	1916-2004	10',30',1h,2h,3h,6h,12h
		An Dong	1972-2004	10',30',1h,2h,3h,6h,12h,24h,48h,72h
4	Indonesia	Semarang	1995-2004	5',10',15',30',45',60',120',180',360',720'
		JaKarta	1958-1995	5',10',15',30',45',60',120',180',360',720'
		Bali	1995-2004	5',10',15',30',45',60',120',180',360',720'
		Bogor	1995-2004	5',10',15',30',45',60',120',180',360',720'
5	Viet Nam	Phu Quoc	1979-2004	10',30',60'
		Nho Quan	1976-2004	10',30',60'
		Tuan Giao	1976-2004	10',30',60'
		Tam §ao	1976-2004	10',30',60'
6	Philippine	Naia	1961-1991	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Baler	1961-1993	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Ambulong	1961-1991	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Puerto	1961-1990	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Daet	1961-1991	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Port area	1961-1991	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Dagupan	1961-1991	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
		Baguio	1961-1991	5', 10', 15', 20', 30', 45', 60', 80', 100', 120', 150', 3h, 6h, 12h, 1d, 2d, 3d
7	China	China		

Table A10.2 Average values of 60-minute duration rainfall at stations

Japan			**Philippine**			**Australia**		
1	Toyo	39.4	1	Naia	59.0	1	008051	20.6
2	Taguchi	42.5	2	Baler	65.5	2	014015	61.2
3	Ohkusa	43.8	3	Ambulong	58.0	3	015590	22.7
4	Okazaki	35.3	4	Puerto	36.8	4	023000	15.7
5	Nagoya	42.0	5	Daet	61.0	5	031011	51.6
Korea			6	Port Area	61.0	6	040223	43.2
1	Daegu	34.8	7	Dagupan	66.7	7	044021	25.8
2	Andong	29.8	8	Baguio	90.5	8	066062	38.1
Indonesia			**Vietnam**			9	086071	18.9
1	Bali	62.4	1	Phu Quoc	61.9	10	094029	13.0
2	Semarang	77.5	2	Tam Dao	65.7	**NewZealand**		
3	Jakarta	57.7	3	Nho Quan	59.9	1	E14272	19.5
4	Bogor	82.3	4	Tuan Giao	39.6	2	E15021	22.0
5	Bandung	51.1				3	E14296	18.0
						Malaysia		
						1	3117070	66.1
						2	3216001	60.6
						3	3217002	60.1

Table A10.3 Design rainfall (mm) by Pearson – III for 10-min duration.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	47.9	43.8	39.7	33.3	28.1	19.6
		Nho Quan	38.4	36.1	33.7	29.9	26.7	21.1
		Tam Dao	25.5	24.0	22.5	20.2	18.1	14.7
		Tuan Giao	25.9	24.4	22.9	20.3	18.2	14.7
2	Australia	044021	-	-	-	-	-	-
		066062	-	-	-	-	-	-
		086071	-	-	-	-	-	-
		094029	-	-	-	-	-	-
		031011	-	-	-	-	-	-
		040223	-	-	-	-	-	-
		015590	-	-	-	-	-	-
		023000	-	-	-	-	-	-
		008051	-	-	-	-	-	-
		014015	-	-	-	-	-	-
3	Indonesia	Semarang	42.0	39.5	36.9	33.0	29.7	24.3
		Jakarta	49.5	45.9	42.2	36.3	31.3	22.3
		Bali	43.1	40.1	37.1	32.5	28.6	22.2
		Bogor	35.1	32.7	30.4	27.2	24.8	21.5
4	Philippine	Baguio	136.4	121.1	99.6	71.8	52.5	26.6
		Naia	63.0	57.1	49.4	38.0	30.3	20.1
		Ambulong	62.2	56.3	48.6	37.3	29.7	19.5
		Puerto	40.6	36.8	31.3	24.7	19.7	13.1
		Port area	54.5	50.2	44.0	36.3	30.2	21.2
		Dagupan	73.8	67.1	57.9	45.3	36.3	24.0
		Daet	52.5	48.1	42.2	33.8	27.9	19.7
		Baler	73.4	66.3	56.9	43.4	34.5	22.4
5	Japan	Toyo	25.4	23.6	21.8	18.9	16.6	12.9
		Nagoya	24.5	23.3	22.0	19.9	18.1	14.8
		Taguchi	26.2	24.0	21.9	18.8	16.3	12.6
		Ohkusa	30.6	28.7	26.7	23.4	20.7	15.8
		Okazaki	24.1	22.4	20.3	18.1	15.9	12.0
6	Korea	Daegu	26.5	24.4	22.3	19.1	16.4	11.9
		Andong	29.2	26.5	23.9	20.0	17.0	12.5
7	China	China	-	-	-	-	-	-

Table A10.4 Design rainfall (mm) by Pearson – III for 30-min duration.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	92.5	84.9	77.5	66.5	57.9	44.8
		Nho Quan	76.5	71.1	65.8	57.9	51.7	42.3
		Tam Dao	66.0	59.9	54.2	45.3	38.6	28.9
		Tuan Giao	67.5	60.8	54.5	45.3	38.4	28.7
2	Australia	044021	46.1	42.0	37.9	31.8	26.9	19.5
		066062	71.0	63.0	55.4	44.3	36.1	24.3
		086071	44.6	38.8	33.4	25.7	20.2	12.9
		094029	27.4	24.3	21.3	17.0	13.7	9.2
		031011	62.0	58.3	54.5	48.6	43.6	35.2
		040223	76.7	69.4	62.2	51.7	43.4	30.8
		015590	67.3	57.8	48.9	36.2	27.0	14.6
		023000	35.7	31.0	26.6	20.2	15.8	10.0
		008051	35.7	32.4	29.1	24.3	20.5	14.8
		014015	68.8	65.4	61.9	56.5	52.1	44.7
3	Indonesia	Semarang	81.5	77.3	73.0	66.4	60.9	51.8
		Jakarta	96.3	88.5	80.7	68.6	58.6	41.9
		Bali	81.3	76.0	70.8	62.7	56.2	45.8
		Bogor	79.6	76.7	73.7	68.9	64.6	56.7
4	Philippine	Baguio	232.2	207.0	171.0	125.6	93.9	50.9
		Naia	123.1	111.5	95.4	74.2	59.0	38.4
		Ambulong	124.8	112.7	96.1	74.3	58.5	37.2
		Puerto	69.5	63.6	54.8	44.2	36.2	24.8
		Port area	102.4	94.7	83.2	68.9	57.6	40.6
		Dagupan	133.7	121.9	105.1	83.4	67.5	44.8
		Daet	111.4	101.7	88.2	70.9	58.3	41.2
		Baler	122.9	111.2	95.0	73.4	58.7	38.7
5	Japan	Toyo	58.8	53.2	47.9	40.0	33.9	24.8
		Nagoya	57.6	53.1	48.5	41.5	35.8	26.5
		Taguchi	52.4	48.4	44.4	38.5	33.9	26.8
		Ohkusa	61.8	57.7	53.5	46.8	41.2	31.4
		Okazaki	53.5	49.2	44.7	38.0	32.5	23.5
6	Korea	Daegu	55.3	50.4	45.6	38.4	32.5	23.4
		Andong	58.3	51.4	44.0	35.9	29.3	20.7
7	China	China	-	-	-	-	-	-

Table A10.5 Design rainfall (mm) by Pearson – III for 60-min duration.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	149.8	134.7	120.3	99.1	83.2	60.1
		Nho Quan	107.3	100.3	93.5	82.4	73.6	59.1
		Tam Dao	89.1	80.9	73.0	61.0	51.7	37.5
		Tuan Giao	90.4	81.5	73.0	60.5	50.9	36.8
2	Australia	044021	58.7	53.3	47.9	40.0	33.8	24.3
		066062	107.5	94.5	82.2	64.7	51.8	34.2
		086071	55.6	48.6	42.0	32.6	25.8	16.6
		094029	30.9	27.7	24.6	20.1	16.8	12.0
		031011	86.9	82.2	77.4	69.8	63.2	51.6
		040223	111.9	99.9	88.4	71.4	58.5	39.4
		015590	82.1	70.7	60.0	44.8	33.7	18.8
		023000	53.1	45.3	38.1	28.2	21.4	13.0
		008051	56.4	49.8	43.5	34.5	27.8	18.6
		014015	105.8	99.2	92.5	82.4	74.0	60.4
3	Indonesia	Semarang	137.8	128.8	119.9	106.3	95.3	77.7
		Jakarta	151.6	136.3	121.4	99.2	81.9	55.5
		Bali	116.1	108.0	99.6	87.1	77.0	61.2
		Bogor	124.4	116.4	108.8	105.9	90.2	79.7
4	Philippine	Baguio	318.3	283.8	234.3	172.9	129.3	71.0
		Naia	157.2	143.3	123.9	98.1	79.2	51.8
		Ambulong	152.2	138.0	118.1	92.1	74.2	50.0
		Puerto	89.4	81.9	70.8	57.5	47.4	33.0
		Port area	143.2	132.7	117.2	97.5	81.8	56.8
		Dagupan	178.8	162.8	140.1	111.1	89.7	58.7
		Daet	141.8	129.6	112.4	90.3	75.0	54.2
		Baler	178.4	161.6	138.1	108.1	86.1	56.5
5	Japan	Toyo	89.3	81.0	72.8	60.9	51.3	37.0
		Nagoya	104.3	93.3	83.4	67.5	55.8	38.8
		Taguchi	82.8	76.1	69.6	59.9	52.3	40.8
		Ohkusa	90.5	83.4	76.4	65.6	56.7	42.2
		Okazaki	90.1	80.9	72.1	58.9	48.6	33.2
6	Korea	Daegu	80.4	72.8	64.4	54.4	45.8	32.8
		Andong	78.0	68.3	59.2	46.7	37.8	26.5
7	China	China	92.6	86.1	79.6	69.7	61.6	48.4

Table A10.6 Design rainfall (mm) by Log-Pearson – III for 10-min duration.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	55.9	49.8	41.9	33.2	27.4	19.5
		Nho Quan	42.5	38.9	33.8	28.5	24.8	19.7
		Tam Dao	32.1	29.4	26.0	22.2	19.3	15.2
		Tuan Giao	30.3	28.2	25.3	21.5	18.9	14.7
2	Australia	044021	-	-	-	-	-	-
		086071	-	-	-	-	-	-
		040223	-	-	-	-	-	-
		023000	-	-	-	-	-	-
		008051	-	-	-	-	-	-
3	Indonesia	Semarang	41.7	38.9	34.5	30.0	26.6	22.0
		Jakarta	50.9	46.5	40.9	34.5	29.4	21.5
		Bali	48.9	44.7	38.9	32.1	27.7	20.9
		Bogor	34.5	32.1	29.1	26.0	23.8	21.1
4	Philippine	Puerto	52.9	44.8	35.0	25.6	19.8	13.1
		Port area	64.4	57.5	48.3	38.2	31.0	21.3
		Daet	59.7	52.4	43.2	34.0	28.1	21.1
		Baler	77.8	67.1	53.2	39.7	31.8	22.8
5	Japan	Toyo	24.5	23.1	20.9	18.4	16.1	12.7
		Taguchi	24.5	22.6	20.1	17.1	15.0	11.8
		Ohkusa	37.7	34.1	29.7	24.5	20.7	15.3
		Okazaki	28.2	25.8	22.2	18.4	15.5	11.4
6	Korea	Daegu	29.1	26.6	23.1	18.9	16.0	11.5
		Andong	28.8	26.3	22.9	18.9	16.3	12.3
7	China	China	-	-	-	-	-	-

Table A10.7 Design rainfall (mm) by Log-Pearson – III for 30-min duration.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	106.3	95.6	81.5	65.9	54.8	39.4
		Nho Quan	120.3	106.7	88.2	70.1	58.0	42.5
		Tam Dao	74.4	68.7	60.3	50.4	43.4	32.1
		Tuan Giao	59.7	55.7	24.3	42.9	37.7	30.0
2	Australia	044021	55.8	50.0	42.4	33.9	27.7	18.9
		086071	44.5	38.9	31.7	24.2	19.3	13.1
		040223	81.1	73.7	63.6	51.8	43.2	30.4
		023000	40.1	34.4	27.3	20.1	15.6	10.1
		008051	34.3	31.6	27.9	23.5	20.1	14.9
3	Indonesia	Semarang	79.8	76.7	71.5	65.4	59.7	51.4
		Jakarta	112.2	101.5	87.4	70.8	59.1	41.3
		Bali	60.3	55.7	49.4	42.1	36.6	28.5
		Bogor	80.6	77.5	73.0	67.4	62.8	55.1
4	Philippine	Puerto	102.0	85.9	66.5	48.0	36.9	24.2
		Port area	123.1	109.5	91.7	72.4	58.6	40.3
		Daet	115.0	101.3	83.9	66.4	55.2	41.8
		Baler	150.7	126.5	97.8	71.5	56.5	40.1
5	Japan	Toyo	55.7	51.4	45.2	38.5	32.8	24.8
		Taguchi	50.4	47.5	42.5	37.0	32.8	26.6
		Ohkusa	69.4	63.4	55.7	46.1	39.3	29.4
		Okazaki	61.6	55.7	47.5	38.5	31.8	22.9
6	Korea	Daegu	59.7	54.1	46.5	37.7	31.5	22.4
		Andong	56.3	49.9	41.7	33.1	27.4	20.3
7	China	China	-	-	-	-	-	-

Table A10.8 Design rainfall (mm) by Log-Pearson – III for 60-min duration.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	151.6	136.7	116.9	95.0	79.7	58.7
		Nho Quan	121.5	112.2	99.5	83.9	73.7	58.0
		Tam Dao	131.6	117.9	58.0	79.0	64.7	44.3
		Tuan Giao	108.9	97.5	82.3	65.4	54.6	39.3
2	Australia	044021	75.5	67.0	55.7	43.6	35.0	23.8
		086071	55.0	47.9	39.1	29.8	23.9	16.4
		040223	128.1	113.5	94.6	73.8	59.1	39.2
		023000	61.2	50.6	38.1	26.8	20.2	13.0
		008051	53.0	47.7	40.7	32.7	26.9	18.9
3	Indonesia	Semarang	134.3	126.5	114.4	102.5	91.8	74.4
		Jakarta	146.9	133.0	114.4	93.7	78.3	54.6
		Bali	109.9	102.5	93.7	82.3	73.7	60.3
		Bogor	59.1	114.4	105.6	94.6	88.2	79.0
4	Philippine	Puerto	110.6	95.7	77.2	58.7	47.0	32.8
		Port area	185.7	165.0	137.8	107.7	86.3	56.8
		Daet	161.7	141.5	116.0	90.6	74.5	55.2
		Baler	199.7	170.0	134.0	100.1	79.5	56.4
5	Japan	Toyo	86.5	79.0	69.4	58.0	49.4	36.6
		Taguchi	78.3	73.0	66.0	57.4	50.9	40.9
		Ohkusa	93.7	85.6	74.4	62.2	53.0	39.6
		Okazaki	97.5	86.5	73.0	57.4	46.5	31.5
6	Korea	Daegu	79.8	73.0	63.4	52.5	43.8	32.1
		Andong	74.4	66.0	54.6	43.4	39.3	26.6
7	China	China	93.7	87.4	78.3	68.0	59.7	47.5

Table A10.9 Rainfall intensity (mm/hr) for 10-min duration by Pearson – III.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	287.4	262.8	238.2	199.8	168.6	117.6
		Nho Quan	230.4	216.6	202.2	179.4	160.2	126.6
		Tam Dao	153.0	144.0	135.0	121.2	108.6	88.2
		Tuan Giao	155.4	146.4	137.4	121.8	109.2	88.2
2	Australia	044021	-	-	-	-	-	-
		066062	-	-	-	-	-	-
		086071	-	-	-	-	-	-
		094029	-	-	-	-	-	-
		031011	-	-	-	-	-	-
		040223	-	-	-	-	-	-
		015590	-	-	-	-	-	-
		023000	-	-	-	-	-	-
		008051	-	-	-	-	-	-
		014015	-	-	-	-	-	-
3	Indonesia	Semarang	252.0	237.0	221.4	198.0	178.2	145.8
		Jakarta	297.0	275.4	253.2	217.8	187.8	133.8
		Bali	258.6	240.6	222.6	195.0	171.6	133.2
		Bogor	210.6	196.2	182.4	163.2	148.8	129.0
4	Philippine	Baguio	818.1	726.4	597.9	430.8	314.9	159.5
		Naia	378.0	342.5	296.1	227.7	182.1	120.3
		Ambulong	373.1	337.7	291.7	223.6	178.3	116.9
		Puerto	243.7	221.1	187.6	148.0	118.4	78.4
		Port area	326.9	301.4	263.7	217.5	181.3	126.9
		Dagupan	443.0	402.3	347.1	271.5	218.1	143.9
		Daet	315.1	288.5	253.2	202.6	167.6	118.3
		Baler	440.3	397.7	341.3	260.4	206.7	134.1
5	Japan	Toyo	152.4	141.6	130.8	113.4	99.6	77.4
		Nagoya	147.0	139.8	132.0	119.4	108.6	88.8
		Taguchi	157.2	144.0	131.4	112.8	97.8	75.6
		Ohkusa	183.6	172.2	160.2	140.4	124.2	94.8
		Okazaki	144.6	134.4	121.8	108.6	95.4	72.0
6	Korea	Daegu	159.0	146.4	133.8	114.6	98.4	71.4
		Andong	175.2	159.0	143.4	120.0	102.0	75.0
7	China	China	-	-	-	-	-	-

Table A10.10 Rainfall intensity (mm/hr) for 30-min duration by Pearson – III.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	185.0	169.8	155.0	133.0	115.8	89.6
		Nho Quan	153.0	142.2	131.6	115.8	103.4	84.6
		Tam Dao	132.0	119.8	108.4	90.6	77.2	57.8
		Tuan Giao	135.0	121.6	109.0	90.6	76.8	57.4
2	Australia	044021	92.3	84.0	75.8	63.6	53.9	38.9
		066062	142.0	126.0	110.7	88.6	72.1	48.7
		086071	89.2	77.6	66.8	51.4	40.4	25.8
		094029	54.7	48.5	42.6	33.9	27.5	18.3
		031011	124.0	116.5	108.9	97.1	87.2	70.3
		040223	153.3	138.7	124.4	103.3	86.7	61.5
		015590	134.6	115.6	97.8	72.4	53.9	29.2
		023000	71.5	61.9	53.1	40.5	31.6	20.0
		008051	71.4	64.8	58.3	48.6	41.1	29.6
		014015	137.6	130.7	123.8	113.0	104.1	89.3
3	Indonesia	Semarang	163.0	154.6	146.0	132.8	121.8	103.6
		Jakarta	192.6	177.0	161.4	137.2	117.2	83.8
		Bali	162.6	152.0	141.6	125.4	112.4	91.6
		Bogor	159.2	153.4	147.4	137.8	129.2	113.4
4	Philippine	Baguio	464.4	413.9	342.1	251.3	187.7	101.8
		Naia	246.2	222.9	190.8	148.4	118.0	76.9
		Ambulong	249.5	225.4	192.2	148.5	117.0	74.4
		Puerto	139.0	127.1	109.6	88.5	72.5	49.7
		Port area	204.9	189.3	166.4	137.8	115.2	81.2
		Dagupan	267.5	243.8	210.2	166.8	135.0	89.6
		Daet	222.7	203.4	176.4	141.8	116.6	82.4
		Baler	245.7	222.3	190.0	146.8	117.3	77.4
5	Japan	Toyo	117.6	106.4	95.8	80.0	67.8	49.6
		Nagoya	115.2	106.2	97.0	83.0	71.6	53.0
		Taguchi	104.8	96.8	88.8	77.0	67.8	53.6
		Ohkusa	123.6	115.4	107.0	93.6	82.4	62.8
		Okazaki	107.0	98.4	89.4	76.0	65.0	47.0
6	Korea	Daegu	110.6	100.8	91.2	76.8	65.0	46.8
		Andong	116.6	102.8	88.0	71.8	58.6	41.4
7	China	China	-	-	-	-	-	-

Table A10.11 Rainfall intensity (mm/hr) for 60-min duration by Pearson – III.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	149.8	134.7	120.3	99.1	83.2	60.1
		Nho Quan	107.3	100.3	93.5	82.4	73.6	59.1
		Tam Dao	89.1	80.9	73.0	61.0	51.7	37.5
		Tuan Giao	90.4	81.5	73.0	60.5	50.9	36.8
2	Australia	044021	58.7	53.3	47.9	40.0	33.8	24.3
		066062	107.5	94.5	82.2	64.7	51.8	34.2
		086071	55.6	48.6	42.0	32.6	25.8	16.6
		094029	30.9	27.7	24.6	20.1	16.8	12.0
		031011	86.9	82.2	77.4	69.8	63.2	51.6
		040223	111.9	99.9	88.4	71.4	58.5	39.4
		015590	82.1	70.7	60.0	44.8	33.7	18.8
		023000	53.1	45.3	38.1	28.2	21.4	13.0
		008051	56.4	49.8	43.5	34.5	27.8	18.6
		014015	105.8	99.2	92.5	82.4	74.0	60.4
3	Indonesia	Semarang	137.8	128.8	119.9	106.3	95.3	77.7
		Jakarta	151.6	136.3	121.4	99.2	81.9	55.5
		Bali	116.1	108.0	99.6	87.1	77.0	61.2
		Bogor	124.4	116.4	108.8	105.9	90.2	79.7
4	Philippine	Baguio	318.3	283.8	234.3	172.9	129.3	71.0
		Naia	157.2	143.3	123.9	98.1	79.2	51.8
		Ambulong	152.2	138.0	118.1	92.1	74.2	50.0
		Puerto	89.4	81.9	70.8	57.5	47.4	33.0
		Port area	143.2	132.7	117.2	97.5	81.8	56.8
		Dagupan	178.8	162.8	140.1	111.1	89.7	58.7
		Daet	141.8	129.6	112.4	90.3	75.0	54.2
		Baler	178.4	161.6	138.1	108.1	86.1	56.5
5	Japan	Toyo	89.3	81.0	72.8	60.9	51.3	37.0
		Nagoya	104.3	93.3	83.4	67.5	55.8	38.8
		Taguchi	82.8	76.1	69.6	59.9	52.3	40.8
		Ohkusa	90.5	83.4	76.4	65.6	56.7	42.2
		Okazaki	90.1	80.9	72.1	58.9	48.6	33.2
6	Korea	Daegu	80.4	72.8	64.4	54.4	45.8	32.8
		Andong	78.0	68.3	59.2	46.7	37.8	26.5
7	China	China	92.6	86.1	79.6	69.7	61.6	48.4

Table A10.12 Rainfall intensity (mm/hr) for 10-min duration by Log-Pearson – III.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	335.2	298.8	251.3	199.5	164.1	116.8
		Nho Quan	255.1	233.2	202.7	171.0	148.7	118.1
		Tam Dao	192.8	176.2	156.3	133.2	115.8	91.1
		Tuan Giao	181.6	169.3	151.7	129.3	113.5	88.4
2	Australia	014015	-	-	-	-	-	-
		015590	-	-	-	-	-	-
		044021	-	-	-	-	-	-
		086071	-	-	-	-	-	-
		040223	-	-	-	-	-	-
		023000	-	-	-	-	-	-
		008051	-	-	-	-	-	-
3	Indonesia	Semarang	250.1	233.2	206.8	179.8	159.5	131.9
		Jakarta	305.4	279.2	245.1	206.8	176.2	129.3
		Bali	293.5	268.2	233.2	192.8	166.0	125.4
		Bogor	206.8	192.8	174.5	156.3	142.8	126.7
4	Philippine	Puerto	317.3	268.7	210.0	153.4	118.8	78.6
		Port area	386.4	344.7	290.0	229.0	186.0	128.1
		Daet	358.4	314.4	259.2	204.1	168.8	126.8
		Baler	466.7	402.5	319.2	238.4	190.7	136.6
5	Japan	Toyo	147.2	138.6	125.4	110.1	96.7	76.1
		Taguchi	147.2	135.9	120.5	102.7	90.2	70.9
		Ohkusa	226.3	204.7	178.0	147.2	124.2	92.0
		Okazaki	169.3	154.7	133.2	110.1	92.9	68.2
6	Korea	Daegu	174.5	159.5	138.6	113.5	95.8	68.8
		Andong	172.7	157.9	137.2	113.5	97.7	73.8
7	China	China	-	-	-	-	-	-

Table A10.13 Rainfall intensity (mm/hr) for 30-min duration by Log-Pearson – III.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	212.5	191.2	163.1	131.8	109.5	78.8
		Nho Quan	240.6	213.4	176.5	140.2	115.9	85.0
		Tam Dao	148.9	137.4	120.7	100.8	86.8	64.3
		Tuan Giao	119.5	111.4	48.6	85.9	75.4	59.9
2	Australia	044021	-	-	-	-	-	-
		086071	-	-	-	-	-	-
		040223	-	-	-	-	-	-
		023000	-	-	-	-	-	-
		008051	-	-	-	-	-	-
3	Indonesia	Semarang	159.7	153.4	143.0	130.7	119.5	102.8
		Jakarta	224.3	203.0	174.7	141.6	118.3	82.5
		Bali	120.7	111.4	98.8	84.2	73.2	57.0
		Bogor	161.3	155.0	145.9	134.7	125.6	110.3
4	Philippine	Puerto	204.0	171.8	133.0	96.1	73.7	48.4
		Port area	246.2	219.0	183.4	144.8	117.2	80.7
		Daet	230.0	202.6	167.8	132.8	110.4	83.5
		Baler	301.3	252.9	195.5	143.0	113.0	80.3
5	Japan	Toyo	111.4	102.8	90.3	76.9	65.6	49.6
		Taguchi	100.8	94.9	85.0	73.9	65.6	53.2
		Ohkusa	138.8	126.9	111.4	92.1	78.5	58.7
		Okazaki	123.1	111.4	94.9	76.9	63.6	45.7
6	Korea	Daegu	119.5	108.1	93.1	75.4	63.0	44.8
		Andong	112.5	99.8	83.4	66.2	54.8	40.6
7	China	China	-	-	-	-	-	-

Table A10.14 Rainfall intensity (mm/hr) for 60-min duration by Log-Pearson – III.

TT	Country	Station	100 years	50 years	25 years	10 years	5 years	2 years
1	Vietnam	Phu Quoc	151.6	136.7	116.9	95.0	79.7	58.7
		Nho Quan	121.5	112.2	99.5	83.9	73.7	58.0
		Tam Dao	131.6	117.9	58.0	79.0	64.7	44.3
		Tuan Giao	108.9	97.5	82.3	65.4	54.6	39.3
2	Australia	044021	-	-	-	-	-	-
		086071	-	-	-	-	-	-
		040223	-	-	-	-	-	-
		023000	-	-	-	-	-	-
		008051	-	-	-	-	-	-
3	Indonesia	Semarang	134.3	126.5	114.4	102.5	91.8	74.4
		Jakarta	146.9	133.0	114.4	93.7	78.3	54.6
		Bali	109.9	102.5	93.7	82.3	73.7	60.3
		Bogor	59.1	114.4	105.6	94.6	88.2	79.0
4	Philippine	Puerto	110.6	95.7	77.2	58.7	47.0	32.8
		Port area	185.7	165.0	137.8	107.7	86.3	56.8
		Daet	161.7	141.5	116.0	90.6	74.5	55.2
		Baler	199.7	170.0	134.0	100.1	79.5	56.4
5	Japan	Toyo	86.5	79.0	69.4	58.0	49.4	36.6
		Taguchi	78.3	73.0	66.0	57.4	50.9	40.9
		Ohkusa	93.7	85.6	74.4	62.2	53.0	39.6
		Okazaki	97.5	86.5	73.0	57.4	46.5	31.5
6	Korea	Daegu	79.8	73.0	63.4	52.5	43.8	32.1
		Andong	74.4	66.0	54.6	43.4	39.3	26.6
7	China	China	93.7	8 7.4	78.3	68.0	59.7	47.5

Chapter 11 Summary and Discussion

Trevor Daniell and Guilermo Q. Tabios III

11.1 Summary of RIDF Methodologies

Australia RIDF method of analysis was to fit first the three-parameter probability distributions such as generalised logistic, generalised extreme value (GEV), generalised normal, Pearson Type III and generalised Pareto to the rainfall data. It was found that in the majority of cases, the GEV gave the best fit for rainfall duration from 1 hour to 72 hours. The L-moments were used to estimate the parameters of the generalised extreme value (GEV).

China used the Pearson Type III distribution and then the Sherman or Horner formula was used to fit a generalized IDF curve for each station.

Indonesia first found the best fitting distributions were namely normal, lognormal, Pearson Type III, log-Pearson Type III and Gumbel (extreme value type 1) distribution. Then the estimated intensity-duration curves for a given frequency were fitted to parametric function using either the Talbot, Sherman or Ishiguro formulas at that given frequency.

Japan fitted the general extreme value distribution then either the Talbot, Bernard, Kimijima or Sherman equations were fitted to the intensity-duration curves for various frequencies. Then the final intensity-frequency-duration (IDF) curve is obtained from another equation based on scaling method to ensure that there is no inconsistency in the intensity-duration curves at different frequencies.

Malaysia fitted the general extreme value distribution and then a generalized IDF curve called Bernard equation was used.

New Zealand fitted the general extreme value distribution.

Korea fitted various probability distributions and they found out that the Gumbel distribution was the best fitting probability distribution for Sydney of Australia, Changzhou of China, Bogor of Indonesia, both Ha Noi and An Nhon of Vietnam and for all stations in Korea. The rest of the rainfall stations fitted other distributions such as log-normal for Melbourne in Australia, gamma for Yongcuan, GEV for Bandung and log-normal for Nagoya and Ohkusa in Japan, gamma for Empangan genting kelang of Indonesia, among other. Likewise a generalized IDF curve was fitted for each station after fitting the distributions.

The Philippines fitted only the Pearson Type III distribution which is the standard procedure in the Philippines and then a generalized IDF curve equation was fitted for the rainfall station analyzed

Finally, Vietnam only fitted the log-Pearson Type III distribution and then a generalized IDF equation.

11.2 Discussion

This exercise shows that the RIDF analyses employed by the various participating countries can be grouped into 2 or 3 approaches. Some countries found the best fitting probability distribution function to each rainfall station data while other countries adopted a single probability distribution to be fitted to all rainfall data. In this latter case, 3-parameter probability distributions (i.e., GEV, Pearson Type III or log-Pearson Type III) were used to ensure that they are versatile enough to accommodate all rainfall data. With regard to the fitting RIDF parametric or smoothed curves, some countries only fitted intensity-duration curves for a given frequency while most countries employed a generalized intensity-frequency-duration (IDF) curve. The use of the generalized IDF equation ensured that the IDF curves result in consistent curves (i.e., intensity-duration curves) at different frequencies in contrast to fitting only an intensity-duration function where the resulting curves may cross each other at the different frequencies. On the other hand, the generalized IDF function used by the various countries cannot perfectly fit the entire empirical IDF curve since the form of the IDF equation with 3 parameters at most cannot be expected to accommodate the observed ranges of rainfall intensities, durations and frequencies unless perhaps a higher-order model or a model with more model parameters is used.