SULIT

BAHAGIAN PEPERIKSAAN DAN PENILAIAN
JABATAN PENDIDIKAN POLITEKNIK
KEMENTERIAN PENDIDIKAN TINGGI

JABATAN KEJURUTERAAN AWAM

PEPERIKSAAN AKHIR

SESI JUN 2016

CC606: HYDROLOGY

TARIKH : 31 OKTOBER 2016
MASA : 11.15 AM - 1.15 PM (2 JAM)

Kertas ini mengandungi **SEBELAS (11)** halaman bercetak.
Bahagian A: Soalan Pendek (10 soalan)
Bahagian B: Struktur (4 soalan)
Dokumen sokongan yang disertakan : Manual 'MASMA'

JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIARAHKAN

(CLO yang tertera hanya sebagai rujukan)

SULIT

SECTION A: 40 MARKS

BAHAGIAN A: 40 MARKAH

INSTRUCTION:

This section consists of **TEN (10)** short questions. Answer **ALL** questions.

ARAHAN:

*Bahagian ini mengandungi **SEPULUH (10)** soalan pendek. Jawab **SEMUA** soalan.*

QUESTION 1

SOALAN 1

CLO1
C1

(a) With the aid of a sketch, describe briefly the followings :
Dengan bantuan lakaran, jelaskan secara ringkas proses berikut:

i. Evaporation
Sejatan

ii. Infiltration
Penyusupan

[4 marks]
[4 markah]

QUESTION 2

SOALAN 2

CLO1
C2

(a) Briefly explain **TWO (2)** effects of soil changes due to human activities towards the hydrological cycles.
*Terangkan secara ringkas **DUA (2)** kesan perubahan tanah akibat daripada aktiviti manusia ke atas kitaran hydrology.*

[4 marks]
[4 markah]

QUESTION 3

SOALAN 3

CLO1
C3

The intensity of 150 mm/hr rainfall fell on a catchment area of 300 ha for 8 hours. The runoff measured during this period was recorded to be 780 x 10^3 m^3. Calculate the amount of water lost from the total of 8 hours rainfall.

Keamatan hujan sebanyak 150 mm/jam telah menimpa satu kawasan tadahan seluas 300 hektar selama 8 jam. Air larian sepanjang tempoh tersebut telah direkodkan sebanyak 780 x 10^3 m^3. Kira jumlah kehilangan air sepanjang tempoh 8 jam itu.

[4 marks]

[4 markah]

QUESTION 4

SOALAN 4

CLO1
C1

Precipitation can be divided into liquid and frozen, state **TWO (2)** types of these precipitation.

*Curahan boleh terbahagi ke dalam cecair dan beku , nyatakan **DUA(2)** jenis curahan tersebut.*

[4 marks]

[4 markah]

QUESTION 5

SOALAN 5

CLO1
C2

Rainfall characteristic can be divided into **FOUR (4)** categories such as depth, duration, intensity and frequency. Explain briefly the term rain intensity.

*Ciri-ciri air hujan terbahagi kepada **EMPAT (4)** iaitu kedalaman, tempoh masa, intensity dan frekuensi. Terangkan maksud intensiti hujan.*

[4 marks]

[4 markah]

QUESTION 6

SOALAN 6

CLO1
C3

In year 1983, data at station A was missing due to faulty gauge as shown in **Table A6.** Calculate the missing data at station A using Normal Ratio Method.

*Dalam tahun 1983, data pada station A telah hilang disebabkan oleh kecuaian alat di dalam **Jadual A6**. Kirakan nilai data yang hilang pada station A menggunakan kaedah nisbah normal.*

Table A6 / *Jadual A6*

Station No. *No. Stesen*	Gauge Reading (mm) *Bacaan Tolok (mm)*	Annual Normal Rainfall Reading (mm) *Bacaan Hujan Normal Tahunan (mm)*
A	?	880
B	96	1008
C	84	842
D	112	1080

[4 marks]

[4 markah]

QUESTION 7
SOALAN 7

CLO1 C1 Define the term surface runoff.
Takrifkan air larian permukaan.

[4 marks]
[4 markah]

QUESTION 8
SOALAN 8

CLO1 C1 Define the term Hydrograph Unit (UH).
Takrifkan maksud Unit Hidrograf (UH).

[4 marks]
[4 markah]

QUESTION 9
SOALAN 9

CLO1 C2 Describe **TWO (2)** main reasons of flood routing.
*Terangkan **DUA (2)** tujuan utama penyaluran banjir*

[4 marks]
[4 markah]

QUESTION 10
SOALAN 10

CLO1 C2 Determine the value of coefficient for Intensity Duration Frequency (IDF) Polynomial Equations, for Melaka if the Average Recurrence Interval (ARI) is 5 years.
Tentukan nilai pekali Persamaan Polinomial IDF untuk Melaka jika kala ulang kembali (ARI) adalah 5 tahun.

[4 marks]
[4 markah]

SECTION B: 60 MARKS
BAHAGIAN B: 60 MARKAH

INSTRUCTION:
This section consists of **FOUR (4)** structured questions. Answer **THREE (3)** questions only.
ARAHAN:
*Bahagian ini mengandungi **EMPAT (4)** soalan berstruktur. Jawab **TIGA (3)** soalan sahaja.*

QUESTION 1
SOALAN 1

CLO2 C3 (a) Based on **Table B1(a),** a storm event with 10.0 cm of rainfall produced a direct runoff of 5.8 cm over a certain catchment area. Calculate the ϕ-index and rainfall excess for the catchment using the rainfall data given below in **Table B1(a).**
*Berdasarkan **Jadual B1(a)**, satu peristiwa ribut dengan hujan sebanyak 10.0 cm telah menghasilkan sebanyak 5.8 cm air larian permukaan bagi satu kawasan tadahan. Kirakan nilai indeks- ϕ dan lebihan hujan bagi kawasan tadahan tersebut dengan menggunakan data di bawah di dalam **Jadual B1(a)***

Table B1(a) / *Jadual B1(a)*

Time (hr) *Masa (jam)*	1	2	3	4	5	6	7	8
Rainfall (cm) *Hujan (cm)*	0.4	0.9	1.5	2.3	1.8	1.6	1.0	0.5

[10 marks]
[10 markah]

CLO2 C4 (b) Based on **Table B1(b),** estimate the net runoff and total rainfall for the following data if ϕ-index for the storm is 3.5 cm/hr.

*Berdasarkan **Jadual B1(b),** anggarkan jumlah air larian permukaan dan jumlah hujan bagi data berikut jika indeks-ϕ bagi hujan tersebut adalah 3.5 cm/jam.*

Table B1(b) / *Jadual B1(b)*

Time (min) *Masa (min)*	0	30	60	90	120	150
Rainfall intensity (cm/hr) *Keamatan hujan (cm/jam)*	0	2.5	5.0	15.0	8.5	3.0

[10 marks]
[10 markah]

QUESTION 2
SOALAN 2

CLO2 C4 (a) Streamflow hydrograph generated from rainfall event occurs on a 100 hectare catchment area. The catchment is given in Table B2. The baseflow for the river is estimated at 2.5 m^3/s. Determine the following:

Hidrograf kadaralir sungai yang dihasilkan oleh suatu peristiwa hujan daripada kawasan tadahan seluas 100 hektar diberikan dalam Jadual B2. Dianggarkan aliran dasar untuk sungai tersebut ialah 2.5m^3/s. Tentukan perkara berikut:

i.) Volume of Direct runoff
Isipadu air larian permukaan

[3 marks]
[3 markah]

ii.) Depth of Effective rainfall
Kedalaman hujan efektif

[3 marks]
[3 markah]

iii.) Unit hydrograph for the catchment
Unit hidrograf kawasan tadahan.

[14 marks]
[14 markah]

Table B2/*Jadual B2*

Time (hour) *Masa (jam)*	Streamflow Discharge (m^3/s) *Kadar Alir (m^3/s)*
0	2.5
0.15	9.5
0.30	11.5
0.45	18.5
1.00	29.5
1.15	40.5
1.30	48.5
1.45	55.5
2.00	50.5
2.15	41.5
2.30	33.5
2.45	28.5
3.00	19.5
3.15	13.5
3.30	9.5
3.45	5.5
4.00	2.5

QUESTION 3

SOALAN 3

CLO2
C4

By using Muskingum method, calculate the hydrograph outflow, with x = 0.2 and K = 20 hours. Assume that the initial inflow equals to outflow for the first day.

Dengan menggunakan kaedah Muskingham, kirakan aliran keluar dengan x = 0.2 dan K = 20 jam. Anggapkan aliran keluar awalan sama dengan hari pertama.

Table B3
Jadual B3

Time (hr) *Masa (Jam)*	Inflow (ft^3/s) *Aliran masuk (ft^3/s)*
12	100
24	320
36	700
48	520
60	380
72	300
84	200
96	160
108	120
120	40

[20 marks]
[20 markah]

QUESTION 4
SOALAN 4

Data shows the information for a residential area in Kota Bharu, Kelantan with the housing characteristics are given as follows:
Data menunjukkan informasi bagi kawasan kediaman di Kota Bharu, Kelantan dengan ciri-ciri berikut:

Residential Area	= 10 Hectares
Kawasan Penduduk	*= 10 hektar*
Density Residential Area	= Medium Density
Ketumpatan Penduduk	*= berketumpatan sederhana*
Drainage Types	= Minor Drainage
Jenis Saliran	*= Saliran minor*
Flow On The Ground	= 80m
Aliran di atas Tanah	*= 80m*
The Flow Channel	= 400m
Aliran di dalam Saluran	*= 400m*
The Slope of The Catchment Area	= 0.5%
Kecerunan Kawasan	*= 0.5%*
ARI	= 5 years

Assume Velocity = 1.0 m/s
Halaju Anggaran = 1.0 m/s

CLO2 C3 (a) Calculate the time of concentration for the area.
Kirakan masa tumpuan bagi kawasan tersebut

[6 marks]
[6 markah]

CLO2 C5 (b) Estimate the peak flow value for the area.
Anggarkan aliran puncak bagi kawasan tersebut

[14 marks]
[14 markah]

SOALAN TAMAT

Table 0.1 Design Storm ARIs for Urban Stormwater Systems

Type of Development (See Note 1)	Average Recurrence Interval (ARI) of Design Storm (year)		
	Quantity		Quality
	Minor System	Major System (see Note 2 and 3)	
Open Space, Parks and Agricultural Land in urban areas	1	up to 100	3 month ARI (for all types of development)
Residential:			
• Low density	2	up to 100	
• Medium density	5	up to 100	
• High density	10	up to 100	
Commercial, Business and Industrial – Other than CBD	5	up to 100	
Commercial, Business, Industrial in Central Business District (CBD) areas of Large Cities	10	up to 100	

Notes:

(1) If a development falls under two categories then the higher of the applicable storm ARIs from the Table shall be adopted.

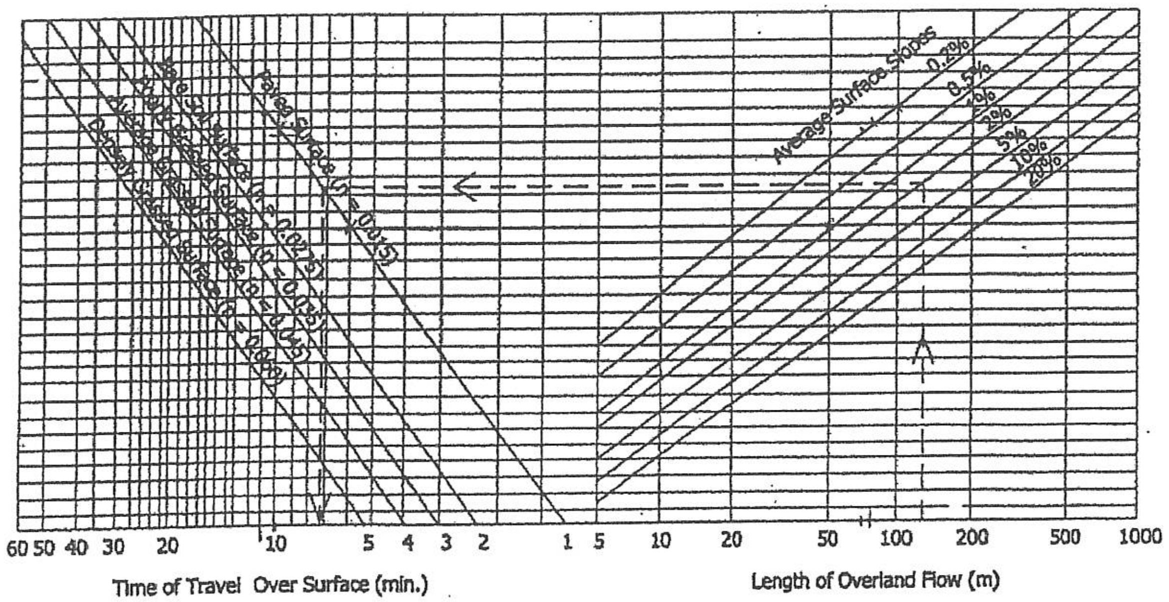
(2) The required size of trunk drains within the major drainage system, varies. According to current practices the trunk drains are provided for the areas larger than 40 ha. Proceeding downstream in the drainage system, a point may be reached where it becomes necessary to increase the size of the trunk drain in order to limit the magnitude of "gap flows" as described in Section 0.**Error! Bookmark not defined..Error! Bookmark not defined.**.

(3) Ideally, the selection of design storm ARI should also be on the basis of economic efficiency. In practice, however, economic efficiency is typically replaced by the concept of the level of protection. In the case where the design storm for higher ARI would be impractical, then the selection of appropriate ARI should be adjusted to optimise the ratio cost to benefit or social factors. Consequently lower ARI should be adopted for the major system, with consultation and approval from Local Authority. However, the consequences of the higher ARI shall be investigated and made known. Even though the stormwater system for the existing developed condition shall be designed for a lower ARI storm, the land should be reserved for higher ARI, so that the system can be upgraded when the area is built up in the future.

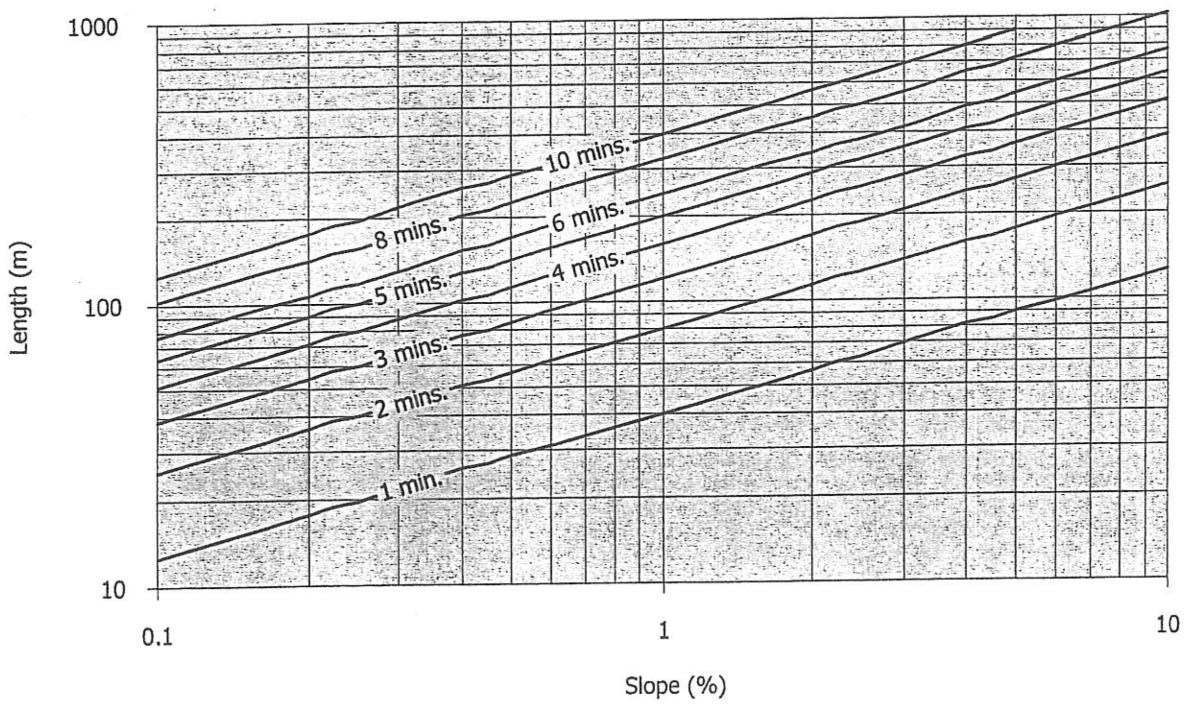
(4) Habitable floor levels of buildings shall be above the 100 year ARI flood level.

(5) In calculating the discharge from the design storm, allowance shall be made for any reduction in discharge due to quantity control (detention or retention) measures installed as described in Section 0.**Error! Bookmark not defined.**.

APPENDIX 0.A DESIGN CHARTS



Design Chart 0.1 Nomograph for Estimating Overland Sheet Flow Times (Source: AR&R, 1977) (Overland Sheet Flow Times - Shallow Sheet Flow Only)



Design Chart 0.2 Kerb Gutter Flow Time

- The lower limit of the durations analysed was 15 minutes. DID should expedite the installation of digital pluviometers to capture data from short storm bursts, down to 5 minutes duration.
- The limits of rainfall ARI were between 2 years and 100 years.
- The curves were not in a convenient form for use in modern computer models.
- There was no guidance given for urban areas outside the 42 centres listed.

It is recommended that the curves should be updated by DID to incorporate additional data and extend the coverage as outlined above.

0.0.1 IDF Curves for Other Urban Areas

IDF curves are calculated from local pluviometer data. Recognising that the precipitation data used to derive the above were subject to some interpolation and smoothing, it is desirable to develop IDF curves directly from local rain-gauge records if these records are sufficiently long and reliable. The analyses involve the following steps:

Data Series (identification)

⇓

Data Tests

⇓

Distribution Identification

⇓

Estimation of Distribution Parameters

⇓

Selection of Distribution

⇓

Quantile Estimation at chosen ARI

The required analyses are highly specialised and would be outside the scope of interest of most users of this Manual.

Local authorities are advised to find out from the DID to the availability of IDF curves or coefficients for their respective areas, or to obtain local pluviometer data for those wishing to conduct their own analysis.

0.0.2 Polynomial Approximation of IDF Curves

Polynomial expressions in the form of Equation 0.1 have been fitted to the published IDF curves for the 35 main cities/towns in Malaysia.

$$ln({}^{R}I_t) = a + b\,ln(t) + c(ln(t))^2 + d(ln(t))^3 \qquad (0.1)$$

where,

${}^{R}I_t$ = the average rainfall intensity (mm/hr) for ARI and duration t

R = average return interval (years)

t = duration (minutes)

a to d are fitting constants dependent on ARI.

Four coefficients are considered in Equation 0.1 to keep the calculation simple for a reasonable degree of accuracy. Higher degree of polynomial can be used to get more accurate values of rainfall intensity. The Equation can be used for deriving rainfall intensity values for a given duration and ARI, once the values of coefficients a to d are known. The equation is in a more suitable form for most spreadsheet of computer calculation procedures.

The curves in "Hydrological Data" (1991) are valid for durations between 15 minutes and 72 hours. Extrapolation of the curve beyond these limits introduces possible errors, and is not recommended. Also, Equation 0.1 should not be used outside these limits. Alternative procedures for deriving IDF values for short durations are given in Section 0.0.3.

The possible uncertainty range of the IDF figures derived in accordance with this Manual is likely to be up to ± 20%. Among the sources of error noted are: problems of extrapolation to long ARIs, use of local rather than generalised analysis, and problems with the accuracy of short-duration intensity records. The error is likely to be highest for the durations shorter than 30 minutes and longer than 15 hours, and for ARI longer than 50 years. For particularly critical applications it may be appropriate to conduct sensitivity tests for the effects of design rainfall errors.

Table 0.2 gives values of the fitted coefficients in Equation 0.1 for Kuala Lumpur, for rainfall ARIs between 2 years and 100 years and durations within 30 to 1000 minutes (see Figure 0.1 for the graphs). Appendix 0.A gives derived values of the coefficients in Equation 0.1 for the 26 and 10 urban centres in Peninsular and East Malaysia, respectively. Due to irregular shape of the curves, coefficients for 6 other urban centres in East Malaysia are not suitable to be used in Equation 0.1. IDF values for these 6 stations should be taken from their respective curves available in HP-26 (1983).

Table 0.2 Coefficients of the Fitted IDF Equation for Kuala Lumpur

ARI (years)	a	b	c	d
2	5.3255	0.1806	-0.1322	0.0047
5	5.1086	0.5037	-0.2155	0.0112
10	4.9696	0.6796	-0.2584	0.0147
20	4.9781	0.7533	-0.2796	0.0166
50	4.8047	0.9399	-0.3218	0.0197
100	5.0064	0.8709	-0.307	0.0186

(data period 1953 – 1983); Validity: $30 \le t \le 1000$ minutes

APPENDIX 0.A FITTED COEFFICIENTS FOR IDF CURVES FOR 35 URBAN CENTRES

Table 0.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia (30 ≤ t ≤ 1000 min)

State	Location	Data Period	ARI (year)	Coefficients of the IDF Polynomial Equations			
				a	b	c	d
Perlis	Kangar	1960-1983	2	4.6800	0.4719	-0.1915	0.0093
			5	5.7949	-0.1944	-0.0413	-0.0008
			10	6.5896	-0.6048	0.0445	-0.0064
			20	6.8710	-0.6670	0.0478	-0.0059
			50	7.1137	-0.7419	0.0621	-0.0067
			100	6.5715	-0.2462	-0.0518	0.0016
Kedah	Alor Setar	1951-1983	2	5.6790	-0.0276	-0.0993	0.0033
			5	4.9709	0.5460	-0.2176	0.0113
			10	5.6422	0.1575	-0.1329	0.0056
			20	5.8203	0.1093	-0.1248	0.0053
			50	5.7420	0.2273	-0.1481	0.0068
			100	6.3202	-0.0778	-0.0849	0.0026
Pulau Pinang	Penang	1951-1990	2	4.5140	0.6729	-0.2311	0.0118
			5	3.9599	1.1284	-0.3240	0.0180
			10	3.7277	1.4393	-0.4023	0.0241
			20	3.3255	1.7689	-0.4703	0.0286
			50	2.8429	2.1456	-0.5469	0.0335
			100	2.7512	2.2417	-0.5610	0.0341
Perak	Ipoh	1951-1990	2	5.2244	0.3853	-0.1970	0.0100
			5	5.0007	0.6149	-0.2406	0.0127
			10	5.0707	0.6515	-0.2522	0.0138
			20	5.1150	0.6895	-0.2631	0.0147
			50	4.9627	0.8489	-0.2966	0.0169
			100	5.1068	0.8168	-0.2905	0.0165
Perak	Bagan Serai	1960-1983	2	4.1689	0.8160	-0.2726	0.0149
			5	4.7867	0.4919	-0.1993	0.0099
			10	5.2760	0.2436	-0.1436	0.0059
			20	5.6661	0.0329	-0.0944	0.0024
			50	5.3431	0.3538	-0.1686	0.0078
			100	5.3299	0.4357	-0.1857	0.0089
Perak	Teluk Intan	1960-1983	2	5.6134	-0.1209	-0.0651	0.00004
			5	6.1025	-0.2240	-0.0484	-0.0008
			10	6.3160	-0.2756	-0.0390	-0.0012
			20	6.3504	-0.2498	-0.0377	-0.0016
			50	6.7638	-0.4595	0.0094	-0.0050
			100	6.7375	-0.3572	-0.0070	-0.0043
Perak	Kuala Kangsar	1960-1983	2	4.2114	0.9483	-0.3154	0.0179
			5	4.7986	0.5803	-0.2202	0.0107
			10	5.3916	0.2993	-0.1640	0.0071
			20	5.7854	0.1175	-0.1244	0.0044
			50	6.5736	-0.2903	-0.0482	0.00002
			100	6.0681	0.1478	-0.1435	0.0065
Perak	Setiawan	1951-1990	2	5.0790	0.3724	-0.1796	0.0081
			5	5.2320	0.3330	-0.1635	0.0068
			10	5.5868	0.0964	-0.1014	0.0021
			20	5.5294	0.2189	-0.1349	0.0051
			50	5.2993	0.4270	-0.1780	0.0082
			100	5.5575	0.3005	-0.1465	0.0058
Selangor	Kuala Kubu Bahru	1970-1990	2	4.2095	0.5056	-0.1551	0.0044
			5	5.1943	-0.0350	-0.0392	-0.0034
			10	5.5074	-0.1637	-0.0116	-0.0053
			20	5.6772	-0.1562	-0.0229	-0.0040
			50	6.0934	-0.3710	0.0239	-0.0073
			100	6.3094	-0.4087	0.0229	-0.0068

(Continued)

Table 0.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia (30 ≤ t ≤ 1000 min)

State	Location	Data Period	ARI (year)	Coefficients of the IDF Polynomial Equations			
				a	b	c	d
Federal Territory	Kuala Lumpur	1953-1983	2	5.3255	0.1806	-0.1322	0.0047
			5	5.1086	0.5037	-0.2155	0.0112
			10	4.9696	0.6796	-0.2584	0.0147
			20	4.9781	0.7533	-0.2796	0.0166
			50	4.8047	0.9399	-0.3218	0.0197
			100	5.0064	0.8709	-0.3070	0.0186
Malacca	Malacca	1951-1990	2	3.7091	1.1622	-0.3289	0.0176
			5	4.3987	0.7725	-0.2381	0.0112
			10	4.9930	0.4661	-0.1740	0.0069
			20	5.0856	0.5048	-0.1875	0.0082
			50	4.8506	0.7398	-0.2388	0.0117
			100	5.3796	0.4628	-0.1826	0.0081
Negeri Sembilan	Seremban	1970-1990	2	5.2565	0.0719	-0.1306	0.0065
			5	5.4663	0.0586	-0.1269	0.0062
			10	6.1240	-0.2191	-0.0820	0.0039
			20	6.3733	-0.2451	-0.0888	0.0051
			50	6.9932	-0.5087	-0.0479	0.0031
			100	7.0782	-0.4277	-0.0731	0.0051
Negeri Sembilan	Kuala Pilah	1970-1990	2	3.9982	0.9722	-0.3215	0.0185
			5	3.7967	1.2904	-0.4012	0.0247
			10	4.5287	0.8474	-0.3008	0.0175
			20	4.9287	0.6897	-0.2753	0.0163
			50	4.7768	0.8716	-0.3158	0.0191
			100	4.6588	1.0163	-0.3471	0.0213
Johor	Kluang	1976-1990	2	4.5860	0.7083	-0.2761	0.0170
			5	5.0571	0.4815	-0.2220	0.0133
			10	5.2665	0.4284	-0.2131	0.0129
			20	5.4813	0.3471	-0.1945	0.0116
			50	5.8808	0.1412	-0.1498	0.0086
			100	6.3369	-0.0789	-0.1066	0.0059
Johor	Mersing	1951-1990	2	5.1028	0.2883	-0.1627	0.0095
			5	5.7048	-0.0635	-0.0771	0.0036
			10	5.8489	-0.0890	-0.0705	0.0032
			20	4.8420	0.7395	-0.2579	0.0165
			50	6.2257	-0.1499	-0.0631	0.0032
			100	6.7796	-0.4104	-0.0160	0.0005
Johor	Batu Pahat	1960-1983	2	4.5023	0.6159	-0.2289	0.0119
			5	4.9886	0.3883	-0.1769	0.0085
			10	5.2470	0.2916	-0.1575	0.0074
			20	5.7407	0.0204	-0.0979	0.0032
			50	6.2276	-0.2278	-0.0474	0.00002
			100	6.5443	-0.3840	-0.0135	-0.0022
Johor	Johor Bahru	1960-1983	2	3.8645	1.1150	-0.3272	0.0182
			5	4.3251	1.0147	-0.3308	0.0205
			10	4.4896	0.9971	-0.3279	0.0205
			20	4.7656	0.8922	-0.3060	0.0192
			50	4.5463	1.1612	-0.3758	0.0249
			100	5.0532	0.8998	-0.3222	0.0215
Johor	Segamat	1970-1983	2	3.0293	1.4428	-0.3924	0.0232
			5	4.2804	0.9393	-0.3161	0.0200
			10	6.2961	-0.1466	-0.1145	0.0080
			20	7.3616	-0.6982	-0.0131	0.0021
			50	7.4417	-0.6247	-0.0364	0.0041
			100	8.1159	-0.9379	0.0176	0.0013

(Continued)

Table 0.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia (30 ≤ t ≤ 1000 min)

State	Location	Data Period	ARI (year)	Coefficients of the IDF Polynomial Equations			
				a	b	c	d
Pahang	Raub	1966-1983	2	4.3716	0.3725	-0.1274	0.0026
			5	4.5461	0.4017	-0.1348	0.0036
			10	5.4226	-0.1521	-0.0063	-0.0056
			20	5.2525	0.0125	-0.0371	-0.0035
			50	4.8654	0.3420	-0.1058	0.0012
			100	5.1818	0.2173	-0.0834	0.0001
Pahang	Cameron Highland	1951-1990	2	4.9396	0.2645	-0.1638	0.0082
			5	4.6471	0.4968	-0.2002	0.0099
			10	4.3258	0.7684	-0.2549	0.0134
			20	4.8178	0.5093	-0.2022	0.0100
			50	5.3234	0.2213	-0.1402	0.0059
			100	5.0166	0.4675	-0.1887	0.0089
Pahang	Kuantan	1951-1990	2	5.1899	0.2562	-0.1612	0.0096
			5	4.7566	0.6589	-0.2529	0.0167
			10	4.3754	0.9634	-0.3068	0.0198
			20	4.8517	0.7649	-0.2697	0.0176
			50	5.0350	0.7267	-0.2589	0.0167
			100	5.2158	0.6752	-0.2450	0.0155
Pahang	Temerloh	1970-1983	2	4.6023	0.4622	-0.1729	0.0066
			5	5.3044	0.0115	-0.0590	-0.0019
			10	4.5881	0.5465	-0.1646	0.0049
			20	4.4378	0.7118	-0.1960	0.0068
			50	4.4823	0.8403	-0.2288	0.0095
			100	4.5261	0.7210	-0.1988	0.0071
Terengganu	Kuala Dungun	1971-1983	2	5.2577	0.0572	-0.1091	0.0057
			5	5.5077	-0.0310	-0.0899	0.0050
			10	5.4881	0.0698	-0.1169	0.0074
			20	5.6842	-0.0393	-0.0862	0.0051
			50	5.5773	0.1111	-0.1231	0.0081
			100	6.1013	-0.1960	-0.0557	0.0035
Terengganu	Kuala Terengganu	1951-1983	2	4.6684	0.3966	-0.1700	0.0096
			5	4.4916	0.6583	-0.2292	0.0143
			10	5.2985	0.2024	-0.1380	0.0089
			20	5.8299	-0.0935	-0.0739	0.0046
			50	6.1694	-0.2513	-0.0382	0.0021
			100	6.1524	-0.1630	-0.0575	0.0035
Kelantan	Kota Bharu	1951-1990	2	5.4683	0.0499	-0.1171	0.0070
			5	5.7507	-0.0132	-0.1117	0.0078
			10	5.2497	0.4280	-0.2033	0.0139
			20	5.4724	0.3591	-0.1810	0.0119
			50	5.3578	0.5094	-0.2056	0.0131
			100	5.0646	0.7917	-0.2583	0.0161
Kelantan	Gua Musang	1971-1990	2	4.6132	0.6009	-0.2250	0.0114
			5	3.8834	1.2174	-0.3624	0.0213
			10	4.6080	0.8347	-0.2848	0.0161
			20	4.7584	0.7946	-0.2749	0.0154
			50	4.6406	0.9382	-0.3059	0.0176
			100	4.6734	0.9782	-0.3152	0.0183

(Continued)

Table 0.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia (30 ≤ t ≤ 1000 min)

State	Location	Data Period	ARI (year)	Coefficients of the IDF Polynomial Equations			
				a	b	c	d
Sabah	Kota Kinabalu	1957-1980	2	5.1968	0.0414	-0.0712	-0.0002
			5	5.6093	-0.1034	-0.0359	-0.0027
			10	5.9468	-0.2595	-0.0012	-0.0050
			20	5.2150	0.3033	-0.1164	0.0026
			50	5.1922	0.3652	-0.1224	0.0027
Sabah	Sandakan	1957-1980	2	3.7427	1.2253	-0.3396	0.0191
			5	4.9246	0.5151	-0.1886	0.0095
			10	5.2728	0.3693	-0.1624	0.0083
			20	4.9397	0.6675	-0.2292	0.0133
			50	5.0022	0.6587	-0.2195	0.0123
Sabah	Tawau	1966-1978	2	4.1091	0.6758	-0.2122	0.0093
			5	3.1066	1.7041	-0.4717	0.0298
			10	4.1419	1.1244	-0.3517	0.0220
			20	4.4639	1.0439	-0.3427	0.0220
Sabah	Kuamut	1969-1980	2	4.1878	0.9320	-0.3115	0.0183
			5	3.7522	1.3976	-0.4086	0.0249
			10	4.1594	1.2539	-0.3837	0.0236
			20	3.8422	1.5659	-0.4505	0.0282
			50	5.6274	0.3053	-0.1644	0.0079
			100	6.3202	-0.0778	-0.0849	0.0026
Sarawak	Simanggang	1963-1980	2	4.3333	0.7773	-0.2644	0.0144
			5	4.9834	0.4624	-0.1985	0.0100
			10	5.6753	0.0623	-0.1097	0.0038
			20	5.9006	-0.0189	-0.0922	0.0027
Sarawak	Sibu	1962-1980	2	3.0879	1.6430	-0.4472	0.0262
			5	3.4519	1.4161	-0.3754	0.0200
			10	3.6423	1.3388	-0.3509	0.0177
			20	3.3170	1.5906	-0.3955	0.0202
Sarawak	Bintulu	1953-1980	2	5.2707	0.1314	-0.0976	0.0025
			5	5.5722	0.0563	-0.0919	0.0031
			10	6.1060	-0.2520	-0.0253	-0.0012
			20	6.0081	-0.1173	-0.0574	0.0014
			50	6.2652	-0.2584	-0.0244	-0.0008
Sarawak	Kapit	1964-1974	2	3.2235	1.2714	-0.3268	0.0164
			5	4.5416	0.2745	-0.0700	-0.0032
			10	4.5184	0.2886	-0.0600	-0.0045
			20	5.0785	-0.0820	0.0296	-0.0110
Sarawak	Kuching	1951-1980	2	5.1719	0.1558	-0.1093	0.0043
			5	4.8825	0.3871	-0.1455	0.0068
			10	5.1635	0.2268	-0.1039	0.0039
			20	5.2479	0.2107	-0.0968	0.0035
			50	5.2780	0.2240	-0.0932	0.0031
Sarawak	Miri	1953-1980	2	4.9302	0.2564	-0.1240	0.0038
			5	5.8216	-0.2152	-0.0276	-0.0021
			10	6.1841	-0.3856	0.0114	-0.0048
			20	6.1591	-0.3188	0.0021	-0.0044
			50	6.3582	-0.3823	0.0170	-0.0054

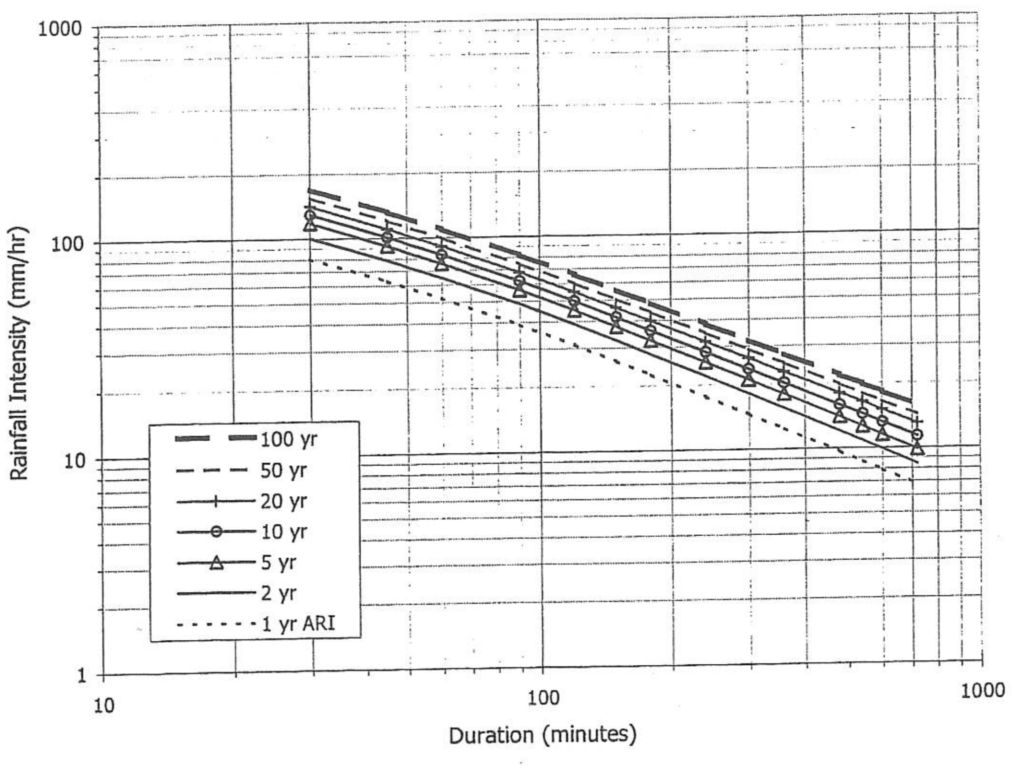


Figure 0.1 IDF Curves for Kuala Lumpur

0.0.3 IDF Values for Short Duration Storms

It is recommended that Equation 0.1 be used to derive design rainfall intensities for durations down to a lower limit of 30 minutes. This value corresponds to the original range of durations used in deriving the curves.

Estimation of rainfall intensities for durations between 5 and 30 minutes involves extrapolation beyond the range of the data used in deriving the curve fitting coefficients. The recommended method of extending the data is based on HP No.1-1982, which gives a rainfall depth-duration plotting graph for durations between 15 minutes and 3 hours. This graphical procedure was converted into an equation and extended as described below. An additional adjustment for storm intensity was included based on the method used in "PNG Flood Estimation Manual" (SMEC, 1990), for tropical climates similar to Malaysia. This adjustment uses the 2 year, 24-hour rainfall depth ${}^2P_{24h}$ as a parameter.

The design rainfall depth P_d for a short duration d (minutes) is given by,

$$P_d = P_{30} - F_D(P_{60} - P_{30}) \qquad (0.2)$$

where P_{30}, P_{60} are the 30-minute and 60-minute duration rainfall depths respectively, obtained from the published design curves. F_D is the adjustment factor for storm duration

Equation 0.2 should be used for durations less than 30 minutes. For durations between 15 and 30 minutes, the results should be checked against the published IDF curves. The relationship is valid for any ARI within the range of 2 to 100 years.

The value of F_D is obtained from Table 0.3 as a function of ${}^2P_{24h}$, the 2-year ARI 24-hour rainfall depth. Values of ${}^2P_{24h}$ for Peninsular Malaysia are given in Figure 0.**Error! Bookmark not defined.**. Intermediate values should be interpolated.

Note that Equation 0.2 is in terms of rainfall depth, not intensity. If intensity is required, such as for roof drainage, the depth P_d (mm) is converted to an intensity I (mm/hr) by dividing by the duration d in hours:

$$I = \frac{P_d}{d} \qquad (0.3)$$

Table 0.3 Values of F_D for Equation 0.2

Duration	${}^2P_{24h}$ (mm)				
	West Coast				East Coast
(minutes)	≤ 100	120	150	≥ 180	All
5	2.08	1.85	1.62	1.40	1.39
10	1.28	1.13	0.99	0.86	1.03
15	0.80	0.72	0.62	0.54	0.74
20	0.47	0.42	0.36	0.32	0.48
30	0.00	0.00	0.00	0.00	0.00

Some computer models such as XP-RatHGL (see Chapter 17), require a continuous set of rainfall intensity data for a range of durations. If it is necessary to prepare data for such models, the recommended method is to use Equation 0.2 to derive intensities for short durations and use the resulting values in an IDF table or fitted polynomial curve.

0.0.4 IDF Values for Frequent Storms

Water quality studies, in particular, require data on IDF values for relatively small, frequent storms. These storms are of interest because on an annual basis, up to 90% of the total pollutant load is carried in storms of up to 3 month ARI. Chapter 4 recommends that the *water quality design storm* be that with a 3 month ARI. The typical IDF curves given in Appendix 0.A have a lower limit of 2 years ARI and therefore cannot be used directly.

The following preliminary equations are recommended for calculating the 1, 3, 6-month and 1 year ARI rainfall intensities in the design storm, for all durations:

$$^{0.083}I_D = 0.4 \times {}^2I_D \qquad (0.4a)$$

$$^{0.25}I_D = 0.5 \times {}^2I_D \qquad (0.4b)$$

$$^{0.5}I_D = 0.6 \times {}^2I_D \qquad (0.4c)$$

$$^{1}I_D = 0.8 \times {}^2I_D \qquad (0.4d)$$

where, ${}^{0.083}I_D$, ${}^{0.25}I_D$, ${}^{0.5}I_D$ and ${}^1I_D$ are the required 1, 3, 6-month and 1-year ARI rainfall intensities for any duration D, and ${}^2I_D$ is the 2-year ARI rainfall intensity for the same duration D, obtained from IDF curves.

Users should be aware of the limitations of these Equations 0.4a to 0.4d. They were derived by fitting a distribution to the 1-hour duration rainfalls, and extrapolating the distribution to frequent ARIs. This method is subject to considerable uncertainty. These preliminary equations were derived using Ipoh rainfall data. Further research is required to confirm the relationships, particularly in other parts of Malaysia where different climatic influences apply.

0.0.5 IDF Values for Rare Storms

Further research is required in order to allow design rainfall information to be given for storms with ARI greater than 100 years.

This Manual does not cover the design of major structures such as dams or bridges, for which a special hydrologic analysis is required.

0.1 DESIGN RAINFALL TEMPORAL PATTERNS

0.1.1 Purpose

The temporal distribution of rainfall within the design storm is an important factor that affects the runoff volume, and the magnitude and timing of the peak discharge. Design rainfall temporal patterns are used to represent the typical variation of rainfall intensities during a typical storm burst. Standardisation of temporal patterns allows standard design procedures to be adopted in flow calculation.

It is important to emphasise that these temporal patterns are intended for use in *design* storms. They should not be confused with the real rainfall variability in historical storms.

Realistic estimates of temporal distributions are best obtained by analysis of local rainfall data from recording gauge networks. Such an analysis may have to be done for several widely varying storm durations to cover various types of storms and to produce distributions for various design problems. Different distributions may apply to different climatic regions of the country.

Temporal patterns should be chosen so that the resulting runoff hydrographs are consistent with observed hydrographs. Therefore the form of the temporal pattern and the method of runoff computation are closely inter-linked. The statistical basis of this approach is discussed in "*Australian Rainfall and Runoff*" (AR&R, 1987).

A range of methods to distribute rainfall have been suggested in the literature:

1. Average temporal patterns developed from local point-rainfall data measured in short time intervals (15 minutes or less).
2. Simple idealised rainfall distribution fitted to local storm data by the method of moments.
3. Temporal patterns from local IDF relationships.

The second method is not recommended, as the idealised patterns are not representative of real storm patterns. Triangular patterns, for example, give unrealistically high peak intensities.

The third approach for distributing rainfall within a design storm makes use of the local IDF relationship for the design ARI. This approach is based on the assumption that the maximum rainfall for any duration less than or equal to the total storm duration should have the same ARI. For example, a 10 year ARI three-hour design storm of this type would contain the 10 year ARI rainfall depths for all durations from the shortest time interval considered (perhaps 5 minutes) up to three hours. These rainfalls are generally skewed.

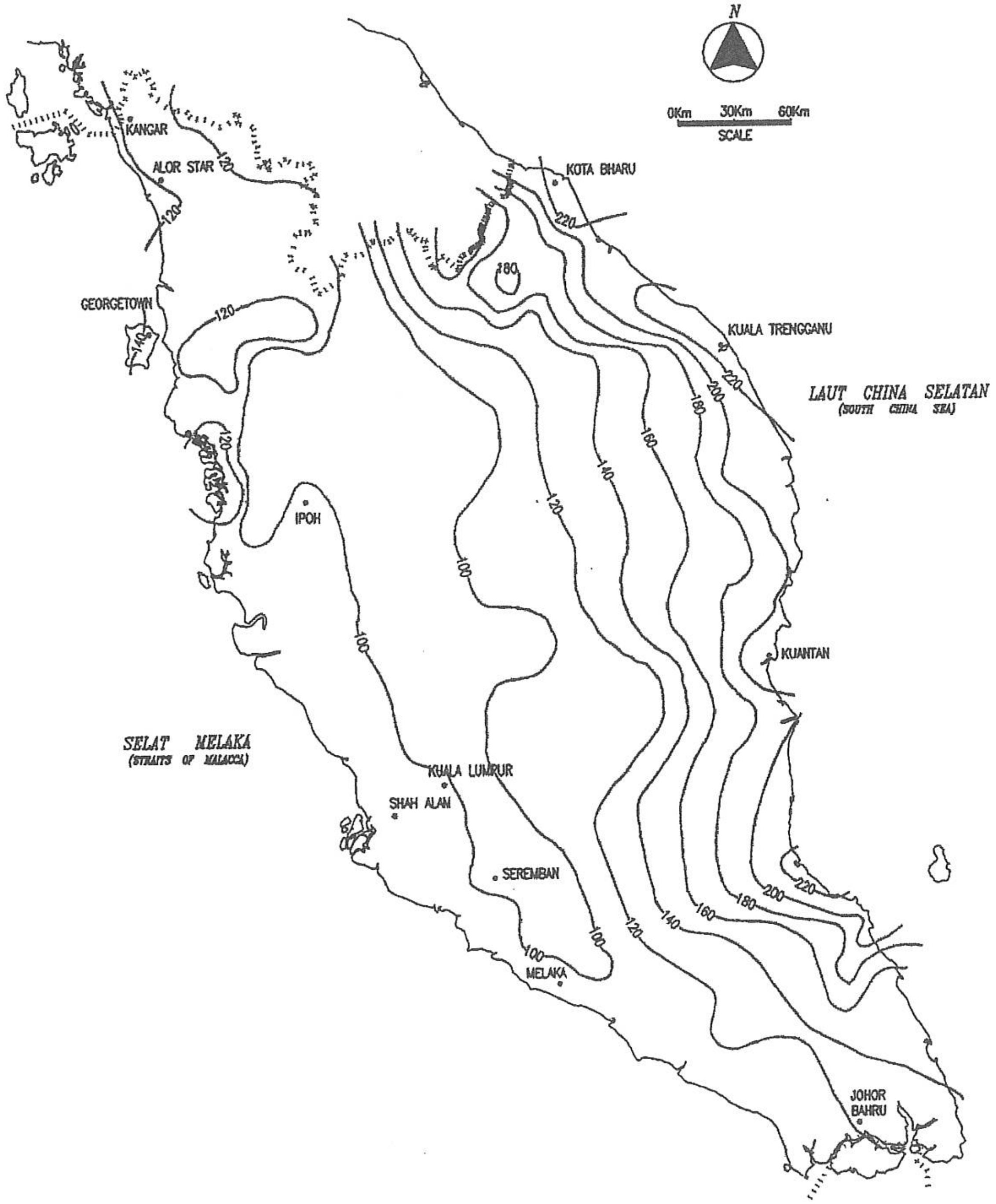
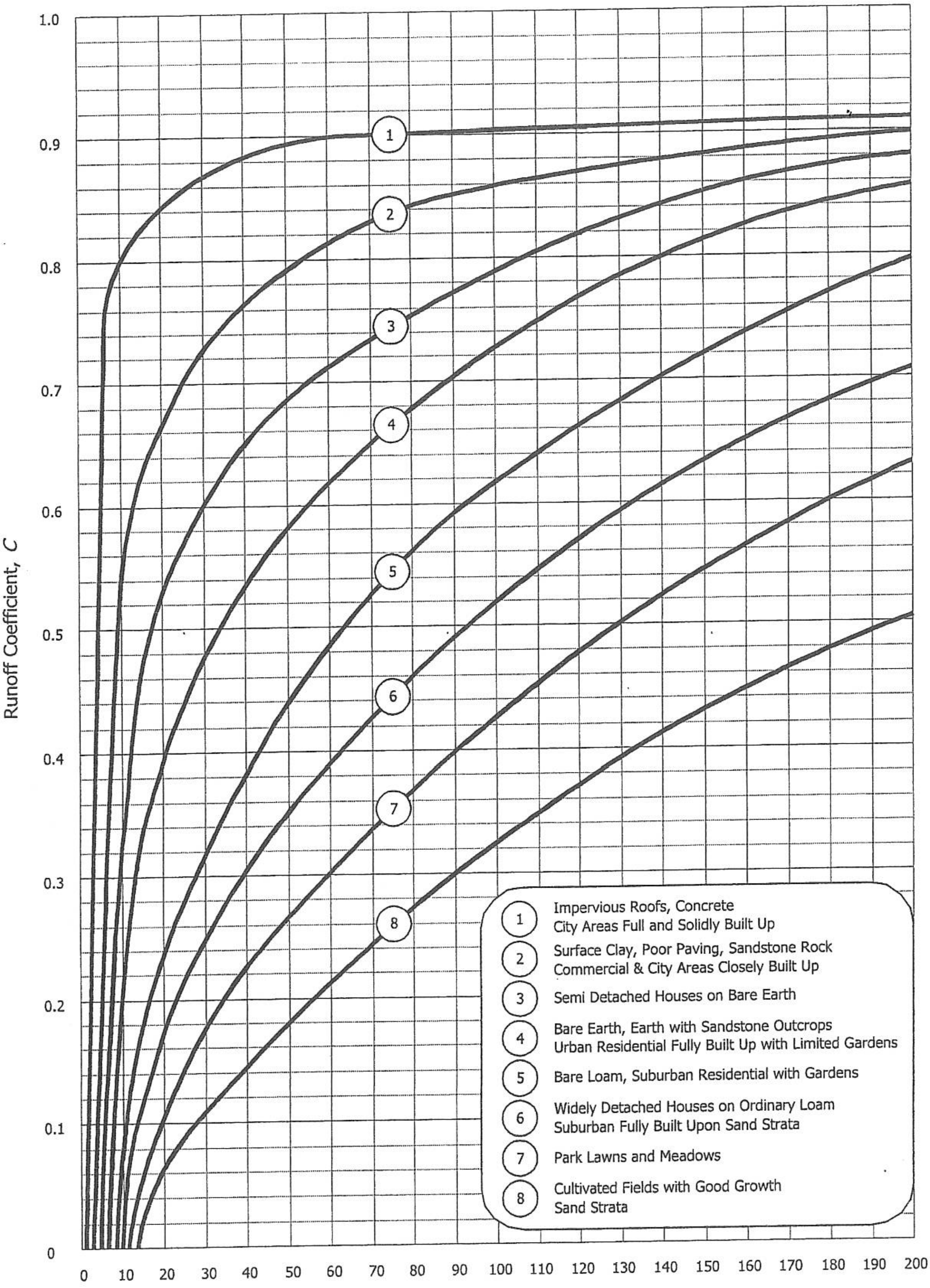


Figure 13.3 Values of $^{4}P_{24h}$ for use with Table 13.3 (source : HP 1, 1982)

JPZ/5015/FINAL/FIG 13.3



Design Chart 0.3 Runoff Coefficients for Urban Catchments
Source: AR&R, 1977

Note: For $I > 200$ mm/hr, interpolate linearly to $C = 0.9$ at $I = 400$ mm/hr