6

POLITEKNIK
MALAYSIA

BAHAGIAN PEPERIKSAAN DAN PENILAIAN
JABATAN PENDIDIKAN POLITEKNIK
KEMENTERIAN PENDIDIKAN TINGGI

JABATAN KEJURUTERAAN AWAM

PEPERIKSAAN AKHIR

SESI DISEMBER 2016

DCC6213 : HYDRAULICS AND HYDROLOGY

TARIKH : 12 APRIL 2017
MASA : 2.30 PM - 4.30 PM (2 JAM)

Kertas ini mengandungi **SEBELAS (11)** halaman bercetak.
Bahagian A: Struktur (2 soalan)
Bahagian B: Struktur (3 soalan)

Dokumen sokongan yang disertakan : Senarai rumus & Urban Storm Water Management Manual

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JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIARAHKAN

(CLO yang tertera hanya sebagai rujukan)

6

SECTION A : 50 MARKS
BAHAGIAN A : 50 MARKAH

INSTRUCTION:

This section consists of TWO (2) structured questions. Answer ALL questions.

ARAHAN:

Bahagian ini mengandungi DUA (2) soalan berstruktur. Jawab semua soalan.

QUESTION1 Bab 1
SOALAN 1

CLO1 C1

(a) Define terms below:

Takrifkan istilah berikut :

i. Hydraulics
Hidraulik

ii. Hydrology
Hidrologi

iii. Fluid Mechanics
Mekanik Bendalir

[5 marks]
[*5 markah*]

Bab 2.

CLO1 C3

(b) A triangular channel with an apex angle of 75° carries a flow of 1.20 m^3/s at a depth of 0.80 m as shown **Figure A1**. If the bed slope is $s = 0.009$, calculate the roughness coefficient, n of the channel.

*Satu saluran berbentuk segitiga mempunyai sudut 75° dengan kadaralir 1.20 m^3/s pada kedalaman 0.80 m seperti ditunjukkan dalam **Rajah A1**. Jika kecerunan saluran,s adalah 0.009, kirakan nilai pekali kekasaran,n bagi saluran tersebut.*

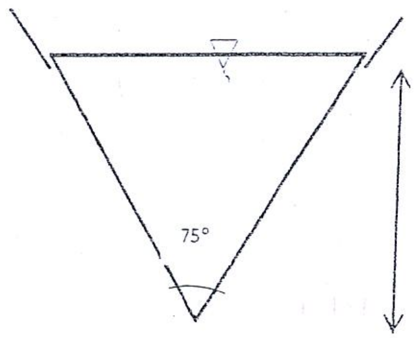

Figure A1 / *Rajah A1*

[10 marks]
[10 markah]

CLO1
C3

(c) A channel of rectangular section 4 m wide is discharges water at rate of 6.48 m^3/s. Value manning of coefficient for channel is 0.025. Calculate:

Satu saluran berbentuk segi empat dengan lebar 4m mengalirkan air pada kadaralir 6.48 m^3/s. Jika nilai pekali manning adalah 0.025. Kirakan :

i. Critical of Depth, y_c
Kedalaman Kritikal, y_c

ii. Critical velocity, v_c
Halaju Kritikal, v_c

iii. Critical slope, S_c
Kecerunan Kritikal, S_c

iv. Value of minimum specific energy, E_{min}
Tenaga Tentu Minima, E_{min}

[10 marks]
[10 markah]

QUESTION 2
SOALAN 2

CLO2
C3

(a) The lake capacity storage in the beginning of June 2016 is 25 x 10^6 m^3. During this time, the recorded inflow and outflow of the lake is 10.0 m^3/s and 15.5 m^3/s respectively. A month later, the lake received a rainfall of 100 cm and the evaporation from the lake was estimated to be 40 cm. The average surface area of the lake was 30 km^2. Calculate the changes of storage and its new storage of the lake (in m^3) at the end of July 2016. Assuming there is no contribution to or from the groundwater storage.

Simpanan bagi sebuah tasik pada awal Jun 2016 ialah 25 x 10^6 m^3. Pada waktu ini direkodkan kadar alir masuk adalah 10.0 m^3/s dan kadar alir keluar adalah 15.5 m^3/s. Pada bulan berikutnya, tasik tersebut menerima hujan sebanyak 100 cm dan penyejatan dari tasik tersebut dianggarkan sebanyak 40 cm. Luas kawasan tasik adalah 30 km^2. Kirakan perubahan simpanan dan simpanan baru bagi tasik tersebut (dalam m^3) pada penghujung bulan Julai 2016. Anggapkan tiada aliran bawah tanah.

[10 marks]
[10 markah]

~~CLO1~~
C4

(b) Based on **Table A2(b)**, calculate the rainfall depth at station G (0,0) by using the Quadrant Method.

*Berdasarkan **Jadual A2(b)**, kirakan kedalaman hujan pada stesen G (0,0) dengan menggunakan Kaedah Sukuan.*

Table A2(b) / *Jadual A2(b)*

Station *Stesen*	A	B	C	D	E	F	G
Station coordinate *Kordinat stesen*	(8,2)	(7,-5)	(5,10)	(-5,-9)	(-7, 12)	(-8,-10)	(0, 0)
Rainfall depth *Kedalaman hujan* (mm)	22.3	20.6	23.0	33.6	40.7	34	?

[15 marks]
[15 markah]

SECTION B : 50 MARKS
BAHAGIAN B : 50 MARKAH

INSTRUCTION:

This section consists of **FOUR** (4) structured questions. Answer **TWO** (2) questions only.

ARAHAN:

*Bahagian ini mengandungi **EMPAT** (4) soalan berstruktur. Jawab **DUA** (2) soalan sahaja.*

QUESTION 1
SOALAN 1

Table B1/Jadual B1

Discharge Kadaralir Q (liter/sec)	0	100	200	300	350	400	500
Head, Turus tekanan, H (m)	17	18	18	16	14	11.5	5
Efficiency, Kecekapan, η (%)	0	30	61	82	85	80	47

A centrifugal pump running at 720 rev/min produced the data in Table B1. The pump was used to deliver water from its low tank to a high tank through 500 mm diameter pipe along a 2600 m total length of pipe. If the friction coefficient of pipe is 0.0025 and the the head difference between the two tank is 15 m;

Sebuah pam empar beroperasi dengan kelajuan 720 pusingan/min menghasilkan data seperti Jadual B1. Pam ini telah digunakan untuk menyalurkan air dari sebuah tangki yang rendah kepada tangki yang tinggi menggunakan paip yang berdiameter 500 mm sepanjang 2600 m. Jika pekali geseran paip adalah 0.0025 dan perbezaan turus di antara dua tangki tersebut ialah 15 m:

CLO1
C3

(a) Draw the pump characteristics graph.

Lukiskan graf ciri-ciri pam

[19 marks]
[19 markah]

CLO1
C4

(b) Calculate the power output and pump efficiency at the operating point.

Kirakan kuasa yang terhasil dan kecekapan pam pada titik operasi.

[6 marks]
[6 markah]

QUESTION 2
SOALAN 2

CLO 2
C3

(a) Isohyets for rain storm in a catchment area is shown in **Table B2**. Using the Isohyetal method, calculate the average rainfall for the area.

Isohyets bagi satu ribut hujan di sebuah kawasan tadahan ditunjukkan dalam Jadual B2. Dengan menggunakan Kaedah Isohyets kirakan purata lebat hujan bagi kawasan tersebut.

Table B2 / *Jadual B2*

Isohyets (cm)	Area (km^2)
12.0	30
12.0 – 10.0	140
10.0 – 8.0	80
8.0 – 6.0	180
6.0 – 4.0	20
4.0 – 2.0	20
2.0 – 0.0	40

[13 marks]
[13 markah]

(b) Calculate the mean precipitation for the following data by using:
Kirakan purata hujan bagi data berikut dengan menggunakan:

i) Arithmetical mean method
Kaedah purata aritmetik

ii) Polygon Thiessen method
Kaedah polygon thiessen

$\frac{P \times A}{A}$

Table A2 / *Jadual A2*

Station	Area (km^2)	Precipitation (mm)
A	72	90
B	34	110
C	76	105
D	40	150
E	76	160
F	92	140
G	46	130
H	40	135
I	86	95

[12 marks]
[12 markah]

QUESTION 3

SOALAN 3

Chapter 6.

Table B3 below shows the current meter gauging data for Sungai Linggi. By using the Velocity-area Method.

Jadual B3 di bawah menunjukkan bacaan data bagi Sungai Linggi. Dengan menggunakan kaedah Halaju-luas,

Table B3/ Jadual B3

Distance from left water edge (m)	Vertical depth (m)	Stream depth (m)	Time (s)	Revolution
1.7	0.23	0.6D	60	25
3.2	0.36	0.6D	60	39
6.3	0.67	0.6D	60	53
9	1.5	0.2D	65	67
		0.8D	65	87
13.5	3.7	0.2D	65	140
		0.8D	65	173
16.8	2.49	0.2D	65	130
		0.8D	65	92
20.5	0.9	0.6D	60	60

CLO2 C3

(a) Calculate the velocity of Sungai Linggi. Given V = 0.44N + 0.07

Kirakan halaju bagi Sungai Linggi. Diberi V = 0.44N + 0.07

[13 marks]
[13 markah]

CLO2 C4

(b) Calculate the discharge of the river

Kirakan kadaralir bagi sungai tersebut

[12 marks]
[12 markah]

QUESTION 4 chapter 7.
SOALAN 4

CLO 2
C3

(a) Calculate the design peak for the flow generated from a minor drainage of medium density residential area of 12 hectares in Kuala Lumpur. Assume 50 m of over land flow followed by 450 m of flow in an open drain. Average slope of catchment area is 0.5%. The design catchment paved surface, $n = 0.0015$, $t_0 = 7$ min, $v = 1.0$ m/s and $C = 0.87$ and design ARI for five (5) years.

Hitung rekabentuk puncak untuk menghasilkan suatu aliran dari saliran kecil untuk kapasiti penduduk sederhana yang berkeluasan 12 hektar di Kuala Lumpur. Anggapkan 50m aliran atas permukaan diikuti 450 m untuk aliran saliran terbuka. Kecerunan purata untuk kawasan tadahan tersebut adalah 0.5%. Rekabentuk kawasan tadahan seperti berikut bagi permukaan berturap, $n = 0.0015$, $t_0 = 7$ min, $v = 1.0$ m/s and $C = 0.87$ dan rekabentuk ARI untuk lima (5) tahun.

[15 marks]
[15 markah]

CLO 2
C4

(b) An urban drainage scheme is being carried out on the 15 hectares areas in Kuantan. The area has medium density and is equipped with an open drain of 600 meter and overland flow of 200 meter. The catchment area was designed with paved surface and the slope is 1% , assume velocity = 1.0 m/s and minus system, design ARI for five (5) years.

Sebuah skim saliran Bandar sedang dijalankan di kawasan seluas 15 hektar di Kuantan. Maklumat menunjukkan kawasan ini mempunyai kepadatan sederhana dan dilengkapi dengan parit terbuka 600meter dan 200 meter aliran darat. Rekabentuk kawasan tadahan merupakan permukaan berturap dan kecerunan adalah 1%. Andaikan halaju = 1.0 m/s dan system minus, rekabentuk ARI utk lima (5) tahun.

Calculate :

Kirakan :

i. Concentration time (t_c)

Masa tumpuan (t_c)

ii. Rainfall depth

Kedalaman hujan

[10 marks]
[10 markah]

SOALAN TAMAT

LIST OF FORMULA FOR

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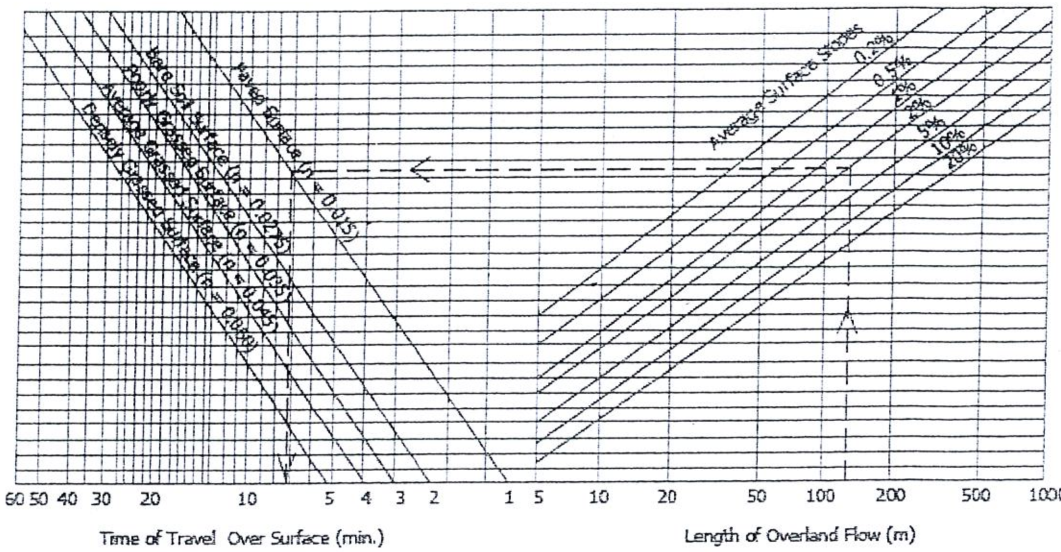
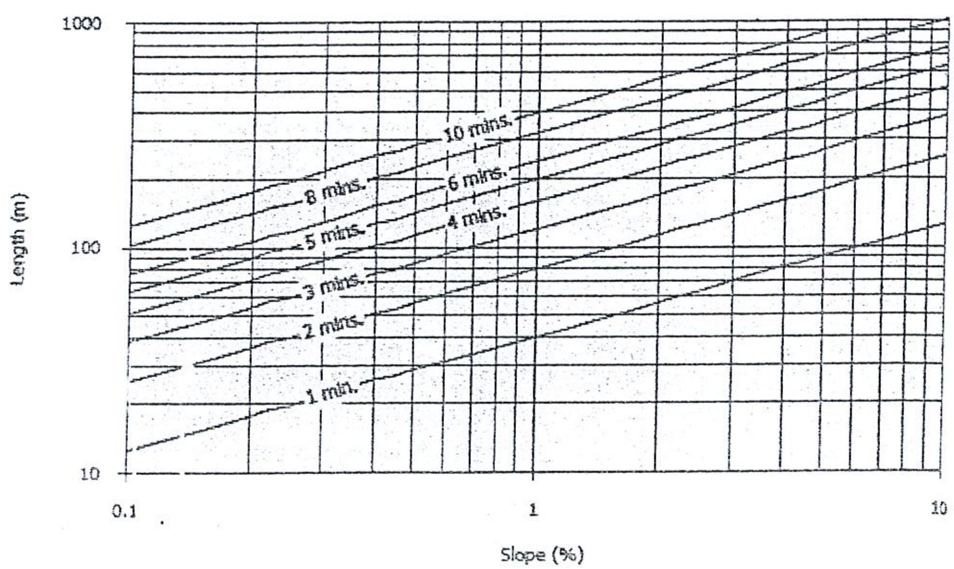
OPEN CHANNEL FLOW	
$E = y + V^2/2g$	$E_{min} = \frac{3}{2} y_c$
$y_c = \left(\frac{q^2}{g}\right)^{1/3}$	$V_c = \sqrt{g y_c}$
$Q = [AR^{2/3}S^{1/2}] / n$	$q = \frac{Q}{b}$
$V = \frac{q}{y}$	$F_r = \frac{v}{\sqrt{gy}}$
$\frac{y_1}{y_2} = \frac{1}{2}\left(\sqrt{1 + 8{Fr_2}^2} - 1\right)$	$E_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$
PUMPS	
$P_o = \rho g H Q$	$P_i = 2\pi N T$
$H_L = \frac{f L Q^2}{3 d^5}$	$H_m = H_s + H_L$
$\eta = \frac{H_1 + H_2}{\left(\frac{H_1}{\eta_1} + \frac{H_2}{\eta_2}\right)}$	$\eta = \frac{Q_1 + Q_2}{\left(\frac{Q_1}{\eta_1} + \frac{Q_2}{\eta_2}\right)}$
$\eta = \frac{P_o}{P_i} \times 100\%$	
WATER BALANCE EQUATION	
ΔS = Total Inflow - Total Outflow	

Distance from river bank (m)	Vertical depth (m)	Depth of measurement (m)	Time (s)	Number of rotation	Number of rotation per time Ns	Velocity			Width	Vertical depth average	Area	Flow rate
						At point V	Vertical average	Horizontal average				
1.7	[illegible]	0.60	[illegible]	25	0.417	[illegible]	[illegible]		1.7	0.115	0.196	[illegible]
2.2	[illegible]	0.60	[illegible]	39	0.65	0.356	[illegible]		1.5	[illegible]	0.495	1.151
6.2	[illegible]	0.60	[illegible]	[illegible]	0.882	0.457	0.408		3.1	[illegible]	[illegible]	0.652
9	1.6	0.20	[illegible]	64	1.031	0.524 } 0.59	[illegible]		2.9	[illegible]	2.980	1.588
		0.80	[illegible]	84	1.288	0.659						
[illegible]	[illegible]	0.50	[illegible]	[illegible]	[illegible]	1.018 } 1.12	0.86		4.5	2.6	11.7	10.062
		0.80	[illegible]	[illegible]	[illegible]	1.241						
16.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] } 0.82	[illegible]		3.3	[illegible]	[illegible]	9.959
		[illegible]	[illegible]		[illegible]	0.693						
[illegible]	[illegible]	0.60	[illegible]		[illegible]	0.476	0.618		[illegible]	[illegible]	[illegible]	11.064
											32.401	26.1151

APPENDIX 14.A DESIGN CHARTS



Design Chart 14.1 Nomograph for Estimating Overland Sheet Flow Times (Source: AR&R, 1977)
(Overland Sheet Flow Times - Shallow Sheet Flow Only)



Design Chart 14.2 Kerb Gutter Flow Time

Table 4.1 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 4.6.2.

(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.

(4) 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 4.5.

APPENDIX 13.A FITTED COEFFICIENTS FOR IDF CURVES FOR 35 URBAN CENTRES

Table 13.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia ($30 \le t \le 1000$ 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)

- 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.

13.2.5 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.

13.2.6 Polynomial Approximation of IDFCurves

Polynomial expressions in the form of Equation 13.2 have been fitted to the published IDF curves for the 35 main cities/towns in Malaysia.

$$ln(^{R}I_{t}) = a + b\,ln(t) + c(ln(t))^{2} + d(ln(t))^{3} \qquad (13.2)$$

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 13.2 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 13.2 should not be used outside these limits. Alternative procedures for deriving IDF values for short durations are given in Section 13.2.7.

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 13.2 gives values of the fitted coefficients in Equation 13.2 for Kuala Lumpur, for rainfall ARIs between 2 years and 100 years and durations within 30 to 1000 minutes (see Figure 13.2 for the graphs). Appendix 13.A gives derived values of the coefficients in Equation 13.2 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 13.2. IDF values for these 6 stations should be taken from their respective curves available in HP-26 (1983).

Table 13.2 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

Table 13.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia ($30 \le t \le 1000$ 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 13.A1 Coefficients for the IDF Equations for the Different Major Cities and Towns in Malaysia ($30 \le t \le 1000$ 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)

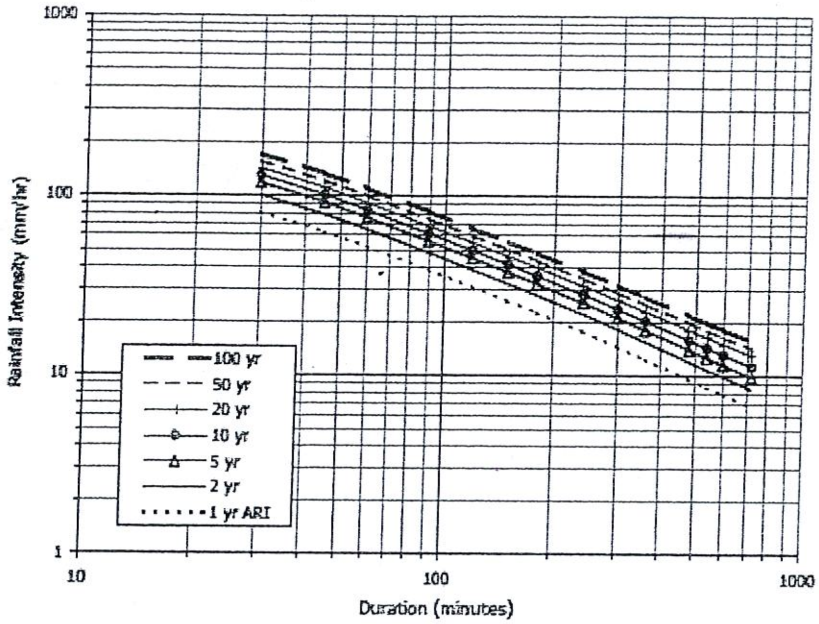


Figure 13.2 IDF Curves for Kuala Lumpur

13.2.7 IDF Values for Short Duration Storms

It is recommended that Equation 13.2 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,

$$P_d = P_{30} - F_D(P_{60} - P_{30}) \qquad (13.3)$$

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 13.3 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 13.3 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 13.3. Intermediate values should be interpolated.

Note that Equation 13.3 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:

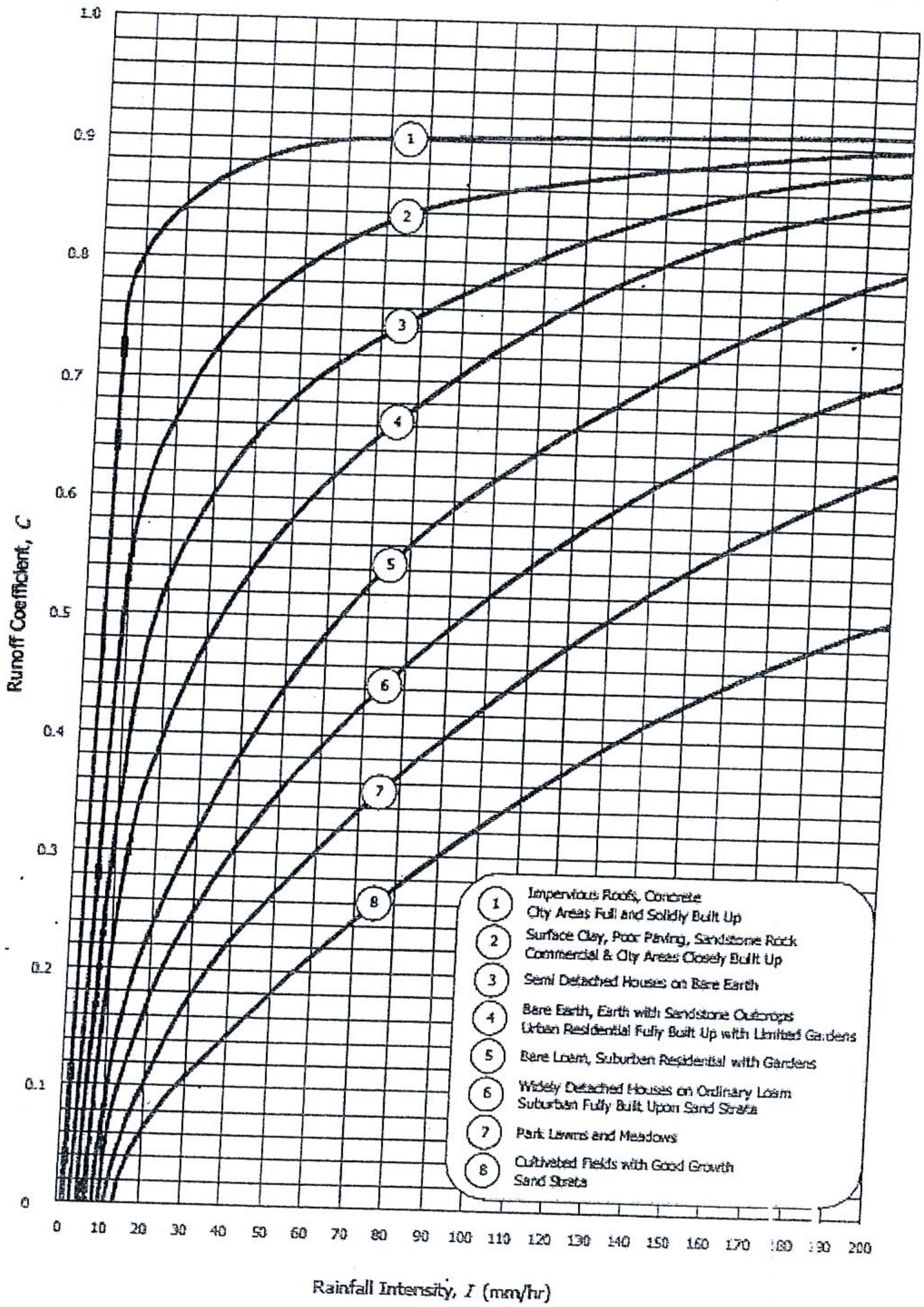
$$I = \frac{P_d}{d} \qquad (13.4)$$

Table 13.3 Values of F_D for Equation 13.3

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

Table 13.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



Design Chart 14.3 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

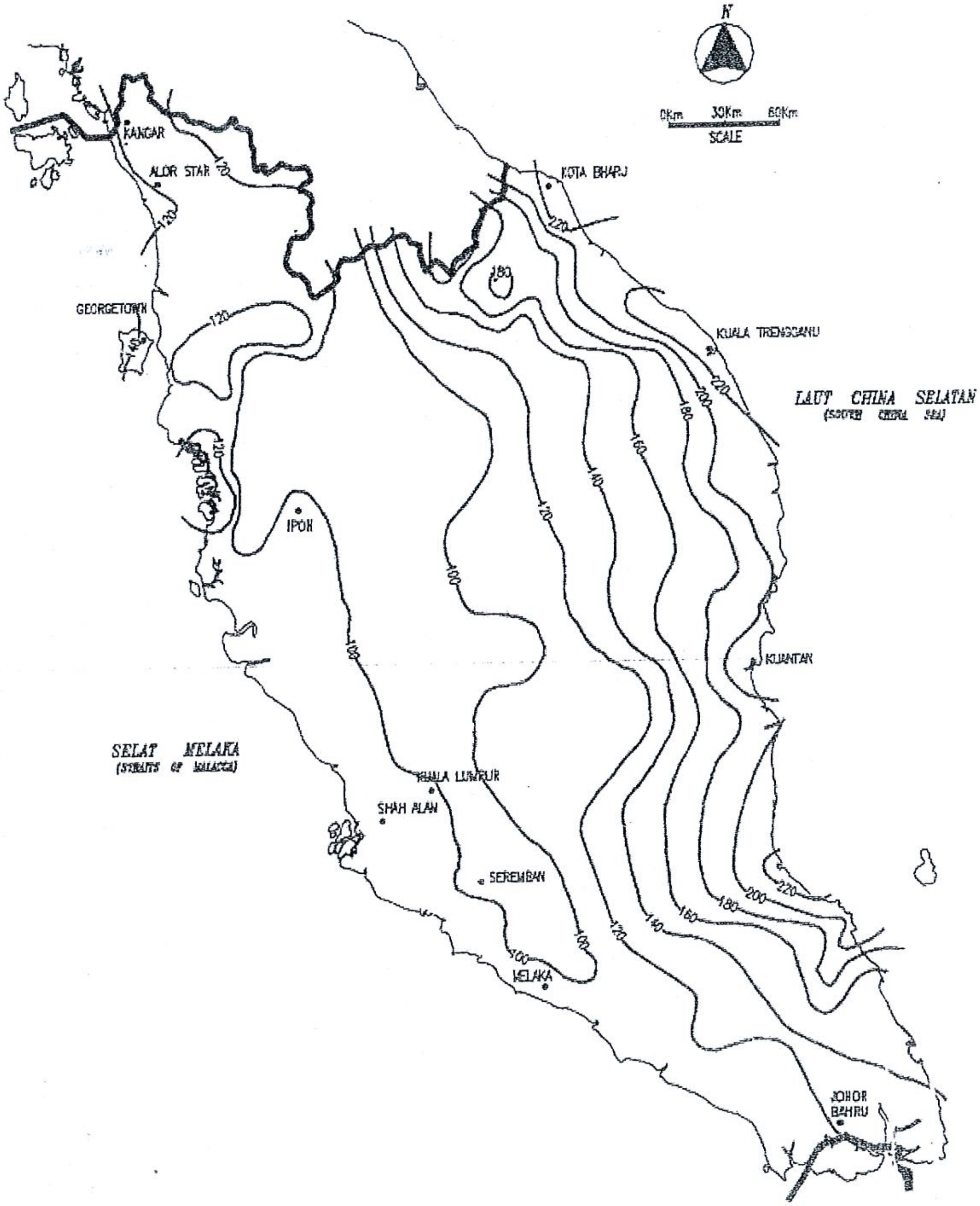
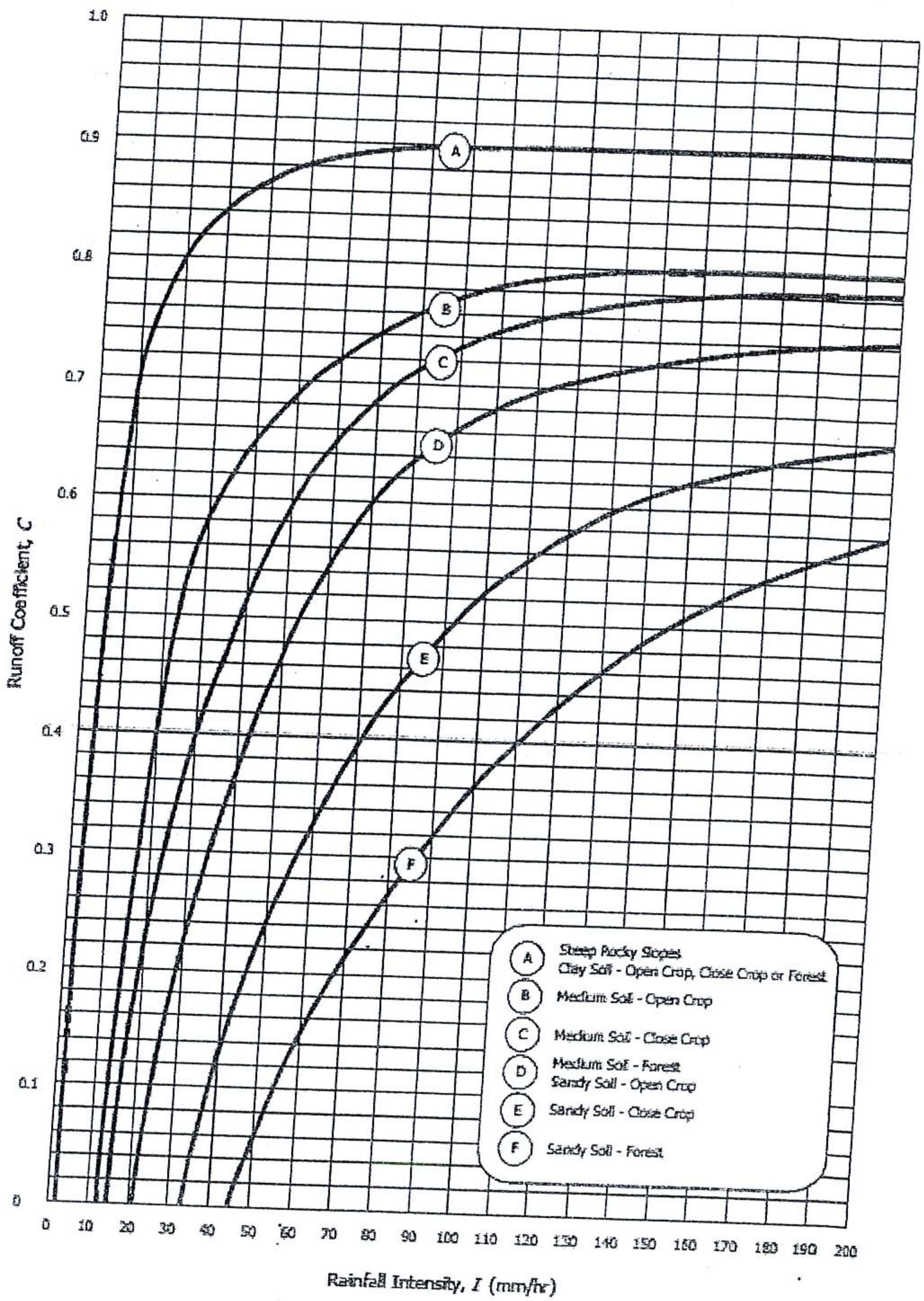


Figure 13.3 Values of $^{2}P_{24h}$ for use with Table 13.3
(source: HP 1, 1982)



Design Chart 14.4 Runoff Coefficients for Rural Catchments

Source: AR&R, 1977

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