

**SULIT**



**KEMENTERIAN PENDIDIKAN TINGGI  
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI**

**BAHAGIAN PEPERIKSAAN DAN PENILAIAN  
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI  
KEMENTERIAN PENDIDIKAN TINGGI**

**JABATAN KEJURUTERAAN AWAM**

**PEPERIKSAAN AKHIR**

**SESI II : 2022/2023**

**DCC50212 : HYDROLOGY**

**TARIKH : 08 JUN 2023**

**MASA : 2.30 PTG – 4.30 PTG (2 JAM)**

---

Kertas ini mengandungi **SEBELAS (11)** halaman bercetak.

Bahagian A: Subjektif ( 2 soalan)

Bahagian B: Subjektif ( 4 soalan)

Dokumen sokongan yang disertakan : MASMA

---

**JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIARAHKAN**

(CLO yang tertera hanya sebagai rujukan)

**SULIT**

**SECTION A: 50 MARKS**  
**BAHAGIAN A: 50 MARKAH**

**INSTRUCTION:**

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

**ARAHAN:**

*Bahagian ini mengandungi **DUA (2)** soalan subjektif. Jawab **SEMUA** soalan.*

**QUESTION 1**  
**SOALAN 1**

- CLO1 (a) Illustrate hydrologic cycle.  
*Ilustrasikan kitaran hidrologi.*
- [5 marks]  
[5 markah]
- CLO1 (b) The water storage in a river at a particular time is 50,000 m<sup>3</sup>. At that time, the recorded inflow and outflow are 15 m<sup>3</sup>/s and 30 m<sup>3</sup>/s respectively. One hour later, the inflow and outflow were recorded as 20 m<sup>3</sup>/s and 32 m<sup>3</sup>/s respectively. Calculate the change of storage and the new storage of water in the river.
- Simpanan air dalam sungai pada masa tertentu ialah 50,000 m<sup>3</sup>. Pada masa itu, aliran masuk dan keluar yang direkodkan ialah 15 m<sup>3</sup>/s dan 30 m<sup>3</sup>/s masing-masing. Satu jam kemudian, aliran masuk dan keluar direkodkan masing-masing sebagai 20 m<sup>3</sup>/s dan 32 m<sup>3</sup>/s. Kirakan perubahan simpanan dan simpanan baharu air di sungai.*
- [10 marks]  
[10 markah]
- CLO1 (c) A retention pond has a water elevation of 105.5 m above datum in early January 2020. In that month the retention pond received an average inflow of 10.0 m<sup>3</sup>/s from surface runoff sources. In the same period the outflow from the retention pond had an average value of 4.8 m<sup>3</sup>/s. In the same month, the pond received a

rainfall of 210 mm and the evaporation from the lake surface was estimated to be 6.10 cm. Calculate the water surface elevation of the pond at the end of the month. The average surface area can be taken as 6500 hectares.

*Sebuah kolam tadahan mempunyai ketinggian air 105.5 m di atas datum pada awal Januari 2020. Pada bulan tersebut kolam tadahan menerima purata aliran masuk 10.0 m<sup>3</sup>/s daripada sumber air larian permukaan. Dalam tempoh yang sama aliran keluar dari kolam tadahan mempunyai nilai purata 4.8 m<sup>3</sup>/s. Pada bulan tersebut juga, kolam menerima taburan hujan sebanyak 210 mm dan sejatan dari permukaan tasik dianggarkan 6.10 cm. Kira ketinggian permukaan air kolam pada akhir bulan. Purata keluasan permukaan boleh diambil sebagai 6500 hektar*

[10 marks]

[10 markah]

## QUESTION 2

### SOALAN 2

- CLO1 (a) Explain briefly the depth, duration, intensity, rainfall frequency and return period.

*Terangkan secara ringkas mengenai kedalaman, tempoh masa, keamatan, kekerapan hujan dan kala kembali.*

[10 marks]

[10 markah]

- CLO1 (b) Runoff is greatly affected by shape of watershed. Figure A2(b) show the types of watersheds. Explain both types of shapes.

*Air larian sangat dipengaruhi oleh bentuk tadahan air. Rajah A2(b) menunjukkan jenis-jenis tadahan air. Terangkan kedua-dua jenis bentuk tadahan air.*

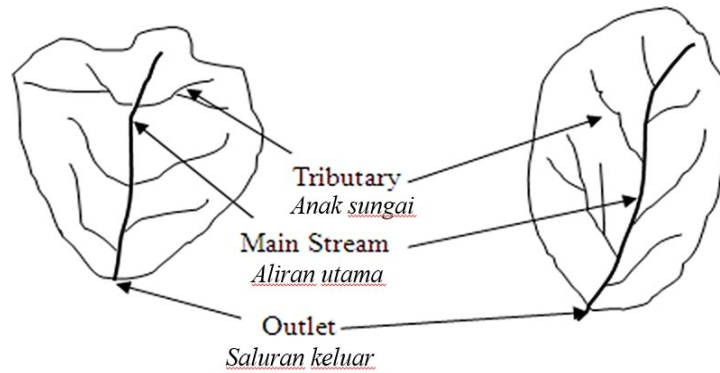


Figure A2(b) / Rajah A2(b)

[5 marks]

[5 markah]

CLO1

- (c) Velocity area method is one of the methods used to measure stream flow. With the aid of sketch diagram, explain the method.

*Kaedah halaju–luas merupakan salah satu kaedah yang digunakan untuk mengukur kadar alir sungai. Dengan bantuan gambar rajah, terangkan kaedah berkenaan.*

[10 marks]

[10 markah]

**SECTION B: 50 MARKS**  
**BAHAGIAN B: 50 MARKAH**

**INSTRUCTION:**

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

**ARAHAN:**

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

**QUESTION 1**

**SOALAN 1**

- CLO2 (a) Table B1(a) shows the ordinates of a 6-hour Unit Hydrograph. Using Superposition Method, calculate the ordinates of a 12-hour Unit Hydrograph for the same catchment.

*Jadual B1(a) menunjukkan ordinat 6-jam Unit Hidrograf. Menggunakan kaedah tindihan, kirakan ordinat untuk 12-jam Unit Hidrograf untuk kawasan tadahan tersebut.*

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

Time (hour) <i>Masa (jam)</i>	Ordinates of 6-hour UH <i>Ordinat 6-jam Unit Hidrograf</i>
0	0
6	20
12	60
18	150
24	120
30	90
36	66
42	50
48	32
54	20
60	10
66	0

[10 marks]

[10 markah]

CLO2

- (b) Given in Table B1(b) are the hydrograph of flow from a catchment area of 1150 km<sup>2</sup> due to 6-hour rainfall. Evaluate the ordinates of 6-hour Unit Hydrograph. Given base flow is 150 m<sup>3</sup>/s.

*Diberi dalam Jadual B1(b) hidrograf sungai di suatu kawasan tadahan seluas 1150 km<sup>2</sup> berikutan suatu ribut hujan yang berlaku selama 6- jam. Nilaiikan ordinat 6 -jam Unit Hidrograf. Diberi aliran dasar ialah 150 m<sup>3</sup>/s.*

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

Time (hour) <i>Masa (jam)</i>	Discharge (m <sup>3</sup> /s) <i>Kadar alir (m<sup>3</sup>/s)</i>
0	150
6	400
12	750
18	980
24	890
30	690
36	480
42	370
48	300
54	260
60	225
66	200
72	180
78	170
84	150

[15 marks]

[15 markah]

## QUESTION 2

## SOALAN 2

- CLO2 (a) Table B2(a) shows the observed data for a catchment area of 300 km<sup>2</sup>. Base flow given 20 m<sup>3</sup>/s. Determine the UH ordinates.

*Jadual B2(a) menunjukkan data yang dicerap di sebuah kawasan tadahan berkeluasan 300 km<sup>2</sup>. Diberi aliran dasar adalah 20 m<sup>3</sup>/s. Tentukan ordinat UH.*

Table B2(a) / Jadual B2(a)

Time (hour) <i>Masa (jam)</i>	Discharge (m <sup>3</sup> /s) <i>Kadar alir (m<sup>3</sup>/s)</i>
0	20
1	150
2	370
3	620
4	820
5	670
6	620
7	370
8	220
9	120
10	20

[10 marks]

[10 markah]

- CLO2 (b) The ordinates of 2-hour Unit Hydrograph for a catchment area are given as in Table B2(b). Evaluate the ordinate of the 6-hour hydrograph using S-Curve method.

*Ordinat Unit Hidrograf 2-jam bagi sebuah kawasan tadahan adalah seperti di Jadual B2(b). Nilaikan ordinat hidrograf 6-jam menggunakan kaedah Lengkung-S.*

Table B2(b) / *Jadual B2(b)*

Time (hour) <i>Masa (jam)</i>	2-hour UH ordinate (m <sup>3</sup> /s) <i>Unit Hidrograf 2-jam (m<sup>3</sup>/s)</i>
0	0
2	25
4	100
6	160
8	110
10	70
12	20
14	0

[15 marks]

[15 markah]



## QUESTION 3

## SOALAN 3

The following Table B3 shows the catchment data for an urban area at Ampang. A 500 mm depth and 600 mm width concrete smooth finish lined drain will be built in that area to accommodate the stormwater.

*Jadual B3 berikut menunjukkan data kawasan tadahan kawasan maju di Ampang. Longkang konkrit kemasan licin bersaiz 500 mm dalam dan 600 mm lebar akan dibina di kawasan tersebut bagi menampung aliran ribut hujan.*

Table B3 / *Jadual B3*

Data <i>Data</i>	Sub Catchment <i>Sub Tadahan</i>
Drainage system <i>Sistem saliran</i>	Minor <i>Minor</i>
Land use <i>Guna tanah</i>	Develop area <i>Keluasan kawasan dibangunkan</i>  Bungalow (10.7 ha.) <i>Banglo (10.7 hektar)</i>
Land use <i>Guna tanah</i>	Undeveloped area <i>Kawasan belum dibangunkan</i>  Average grass surface (3.2 ha.) <i>Permukaan berumput (3.3 hektar)</i>
Length of overland flow <i>Panjang aliran atas permukaan</i>	20.3 m
Land slope (%) <i>Kecerunan tanah (%)</i>	2.8
Length of drain <i>Panjang longkang</i>	255 m
Drain slope <i>Kecerunan longkang</i>	4/255

- CLO 2 (a) Determine time of concentration,  $t_c$ .  
*Tentukan masa tumpuan,  $t_c$ .*
- [10 marks]  
[10 markah]

- CLO 2 (b) Estimate peak discharge,  $Q_p$   
*Anggarkan kadar alir puncak,  $Q_p$ .*
- [15 marks]  
[15 markah]

#### QUESTION 4

#### SOALAN 4

- CLO 2 (a) Commercial development of 30 hectares in Bukit Bentong, Pahang is proposed to be developed. The undeveloped area, 5 hectares with poorly grassed. The post-development time of concentration,  $t_c$  at the development outlet is estimated to be 18.70 minutes and Average Runoff Coefficient,  $C$  is 0.8286. Determine the peak flow of rectangular drain to accommodate a 10 year ARI minor system design.

*Pembangunan komersial seluas 30 hektar di Bukit Bentong, Pahang dicadangkan untuk dibangunkan. Kawasan yang belum dibangunkan seluas 5 hektar dengan rumput yang buruk. Masa tumpuan bagi pasca pembangunan,  $t_c$  di outlet pembangunan dianggarkan selama 18.70 minit dan Purata Pekali Larian,  $C$  ialah 0.8286. Tentukan aliran puncak parit segi empat tepat untuk menampung aliran rekabentuk sistem minor ARI 10 tahun.*

[10 marks]  
[10 markah]

- CLO2 (b) A bungalow houses will be developed at Taman Maluri, Kuala Lumpur. The area for each isochrones as tabulated in Table B4(b), estimate the peak discharge of 20 years ARI rainfall for that catchment with assuming losses for that catchment is 2.5 mm and time of concentration,  $t_c$  is 30 minutes.

*Sebuah rumah banglo akan dibangunkan di Taman Maluri, Kuala Lumpur. Luas bagi setiap isochrones seperti yang dijadualkan di dalam Jadual B4(b), anggarkan aliran puncak hujan untuk 20 tahun ARI bagi tadahan tersebut dengan mengandaikan kehilangan bagi tadahan itu ialah 2.5 mm dan masa tumpuan,  $t_c$  ialah 30 minit.*

Table B4(b) / *Jadual B4(b)*

Isochrones <i>Isokron</i>	Area (m <sup>2</sup> ) <i>Luas (m<sup>2</sup>)</i>	Time (min) <i>Masa (min)</i>	Total rainfall (mm) <i>Jumlah hujan (mm)</i>
0 - 5	44449	5	7.73
5 - 10	79304	10	12.83
10 - 15	229404	15	31.87
15 - 20	213852	20	13.07
20 - 25	160342	25	8.45
< 25	45306	30	5.74

[15 marks]

[15 markah]

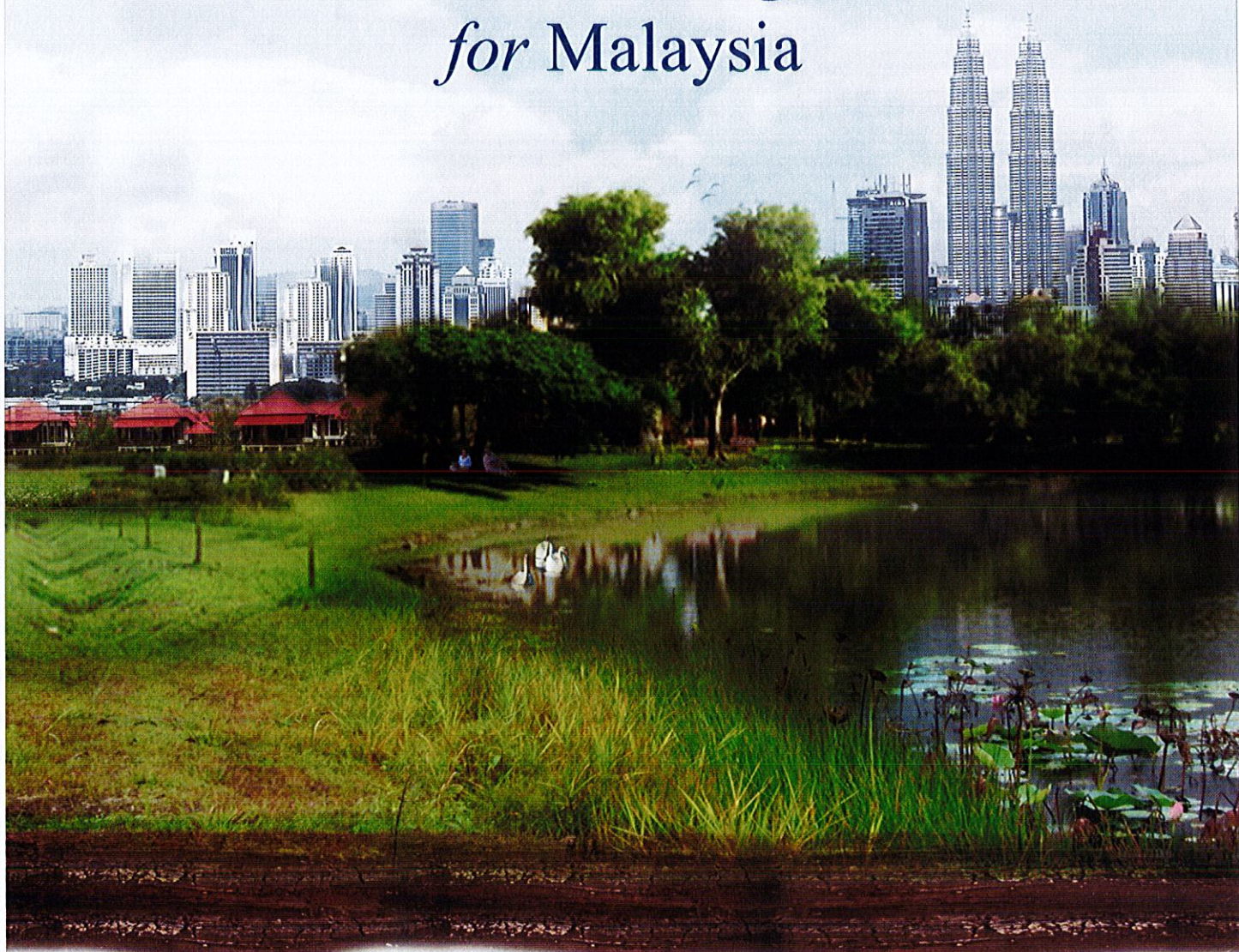
**SOALAN TAMAT**





Government of Malaysia  
Department of Irrigation and Drainage

# Urban Stormwater Management Manual *for Malaysia*



MSMA 2<sup>nd</sup> Edition



The criteria provided in this Chapter apply to *all* urban stormwater systems, while subsequent Chapters in the Manual give more detailed requirements for designing individual system components, quantity and quality facilities. The criteria are set based on the type of landuse, level of protection required, economy, risks of failure, public safety, ecology, aesthetics, etc. One of the most common criteria used in the facility design is the average recurrence interval (ARI), which is set based on whole life economy of the facility, the level of protection required and the hazard potentials to the downstream areas.

## 1.2 STORMWATER QUANTITY DESIGN CRITERIA

The minor and major systems are closely interrelated, and the design of each component must be done in conjunction with the overall stormwater management standards set by the authorities (Knox County, 2008).

Design storm ARIs to be adopted for the planning and design of minor and major storm runoff quantity systems shall be in accordance with Table 1.1. The storm runoff quantity design fundamentals are given in Chapter 2 of this Manual.

Table 1.1: Quantity Design Storm ARIs

Type of Development (See Note 1)	Minimum ARI (year) (See Note 2)	
	Minor System (See Note 3)	Major System (See Note 3)
Residential		
Bungalow and semi-detached dwellings	5	50
Link house/apartment	10	100
Commercial and business center	10	100
Industry	10	100
Sport field, park and agricultural land	2	20
Infrastructure/utility	5	100
Institutional building/complex	10	100

- Notes:
1. For mixed developments, the highest of the applicable storm ARIs from the Table shall be adopted.
  2. In the case where designing to the higher ARI would be impractical, the selection of appropriate ARI should be adjusted to optimise the cost to benefit ratio or social factors. If justified, a lower ARI might be adopted for the major system, with consultation and approval from the Department of Irrigation and Drainage (DID). Even if the stormwater system for the existing developed condition is designed for a lower ARI storm, sufficient land should be reserved for higher ARI flow rates, so that the system can be upgraded when the area is built up in the future.
  3. All development projects shall be protected from both minor and major floods and, therefore, must have combination of minor and major systems. Habitable floor levels of the buildings (platform levels) shall be set above the 100 year ARI flood level based on the most recent data available. The drainage submission must show the minor and major system components in their drawings and plans.

The *minor system* is intended to collect, control and convey runoff from buildings, infrastructures and utilities in relatively frequent storm events (up to 10 year ARI) to minimise inconvenience and nuisance flooding. During any event larger than the minor storm ARI, the higher runoff will overspill the minor drainage components.

The *major system* is intended to safely convey and control runoff collected by the minor drainage system together with its possible overspill to the larger downstream systems and water bodies. The major system must

The drain flow time equation should be used to estimate  $t_d$  for the remaining length of the flow paths downstream. Care should be given to obtain the values of hydraulic radius and friction slope for use in the drain flow time equation. Note that recommended minimum time of concentration for a catchment is 5 minutes which applies to roof drainage.

Table 2.1: Equations to Estimate Time of Concentration (QUDM, 2007)

Travel Path	Travel Time	Remark
Overland Flow	$t_o = \frac{107.n^*.L^{1/3}}{S^{1/5}}$	$t_o$ = Overland sheet flow travel time (minutes) $L$ = Overland sheet flow path length (m) <i>for Steep Slope (&gt;10%), <math>L \leq 50</math> m</i> <i>for Moderate Slope (&lt;5%), <math>L \leq 100</math> m</i> <i>for Mild Slope (&lt;1%), <math>L \leq 200</math> m</i> $n^*$ = Horton's roughness value for the surface (Table 2.2) $S$ = Slope of overland surface (%)
Curb Gutter Flow	$t_g = \frac{L}{40\sqrt{S}}$	$t_g$ = Curb gutter flow time (minutes) $L$ = Length of curb gutter flow (m) $S$ = Longitudinal slope of the curb gutter (%)
Drain Flow	$t_d = \frac{n.L}{60R^{2/3}S^{1/2}}$	$n$ = Manning's roughness coefficient (Table 2.3) $R$ = Hydraulic radius (m) $S$ = Friction slope (m/m) $L$ = Length of reach (m) $t_d$ = Travel time in the drain (minutes)

Table 2.2: Values of Horton's Roughness  $n^*$  (QUDM, 2007)

Land Surface	Horton's Roughness $n^*$
Paved	0.015
Bare Soil	0.0275
Poorly Grassed	0.035
Average Grassed	0.045
Densely Grassed	0.060

## 2.2.3 Design Rainfall Estimate

### 2.2.3.1 Intensity-Duration-Frequency Curves Development

The most common form of design rainfall data required for use in peak discharge estimation is from relationship represented by the intensity-duration-frequency (IDF) curves. The IDF can be developed from the historical rainfall data and they are available for most geographical areas in Malaysia.

Recognising that the rainfall data used to derive IDF are subjected to some interpolation and smoothing, it is desirable to develop IDF curves directly from local raingauge records, if these records are sufficiently long and reliable. The IDF development procedures involve the steps shown in Figure 2.1 while a typical developed curves are shown in Figure 2.2.

Table 2.3: Values of Manning's Roughness Coefficient ( $n$ ) for Open Drains and Pipes  
(Chow, 1959; DID, 2000 and French, 1985)

Drain/Pipe	Manning Roughness $n$
Grassed Drain	
Short Grass Cover (< 150 mm)	0.035
Tall Grass Cover ( $\geq$ 150 mm)	0.050
Lined Drain	
Concrete	
Smooth Finish	0.015
Rough Finish	0.018
Stone Pitching	
Dressed Stone in Mortar	0.017
Random Stones in Mortar or Rubble Masonry	0.035
Rock Riprap	0.030
Brickwork	0.020
Pipe Material	
Vitrified Clay	0.012
Spun Precast Concrete	0.013
Fibre Reinforced Cement	0.013
UPVC	0.011

### 2.2.3.2 Empirical IDF Curves

Empirical equation can be used to minimise error in estimating the rainfall intensity values from the IDF curves. It is expressed as

$$i = \frac{\lambda T^\kappa}{(d + \theta)^\eta} \quad (2.2)$$

where,

$i$  = Average rainfall intensity (mm/hr);

$T$  = Average recurrence interval - ARI ( $0.5 \leq T \leq 12$  month and  $2 \leq T \leq 100$  year);

$d$  = Storm duration (hours),  $0.0833 \leq d \leq 72$ ; and

$\lambda$ ,  $\kappa$ ,  $\theta$  and  $\eta$  = Fitting constants dependent on the raingauge location (Table 2.B1 in Appendix 2.B).

The equation application is simple when analysis is prepared by spreadsheet. Alternatively designers can manually use the IDF curves provided in Annexure 3.

### 2.2.4 Temporal Patterns

It is important to emphasise that the rainfall temporal patterns are intended for use in hydrograph generation *design* storms. They should not be confused with the real rainfall data in historical storms, which is usually required to calibrate and validate hydrological and hydraulic simulation results.

The standard time intervals recommended for urban stormwater modelling are listed in Table 2.4. The design temporal patterns to be used for a set of durations are given in Appendix 2.C.

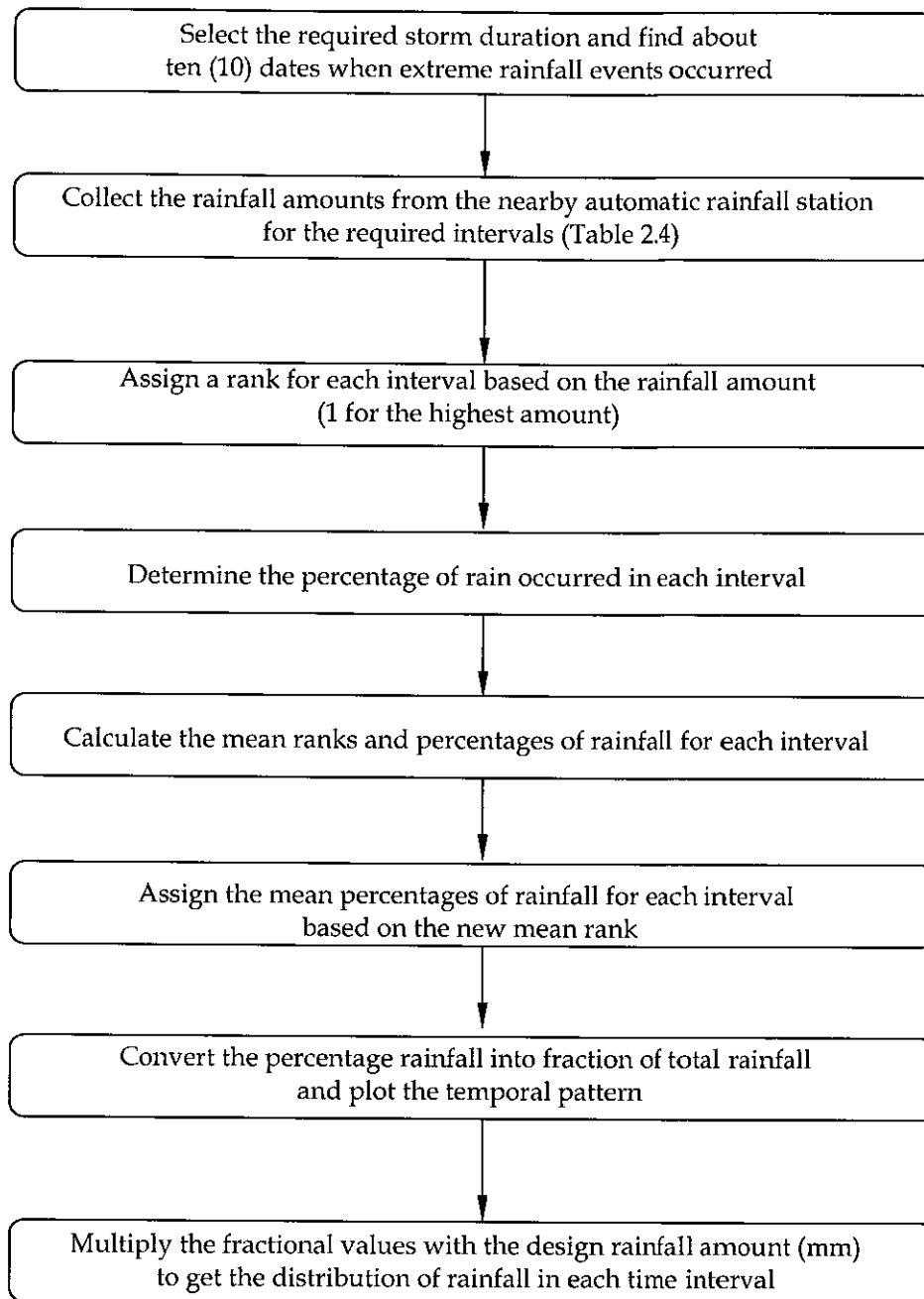


Figure 2.3: Typical Steps for the Development of Design Rainfall Temporal Pattern

### 2.3.1.1 Runoff Coefficient for Mixed Development

Segments of different landuse within a sub-catchment can be combined to produce an average runoff coefficient (Equation 2.4). For example, if a sub-catchment consists of segments with different landuse denoted by  $j = 1, 2, \dots, m$ ; the average runoff coefficient is estimated,  $C$ , by:

$$C_{avg} = \frac{\sum_{j=1}^m C_j A_j}{\sum_{j=1}^m A_j} \quad (2.4)$$



## APPENDIX 2.B IDF CONSTANTS

Table 2.B1: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for High ARIs between 2 and 100 Year and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Johor	1	1437116	Stor JPS Johor Bahru	59.972	0.163	0.121	0.793
	2	1534002	Pusat Kem. Pekan Nenas	54.265	0.179	0.100	0.756
	3	1541139	Johor Silica	59.060	0.202	0.128	0.660
	4	1636001	Balai Polis Kg Seelong	50.115	0.191	0.099	0.763
	5	1737001	SM Bukit Besar	50.554	0.193	0.117	0.722
	6	1829002	Setor JPS Batu Pahat	64.099	0.174	0.201	0.826
	7	1834124	Ladang Ulu Remis	55.864	0.166	0.174	0.810
	8	1839196	Simpang Masai K. Sedili	61.562	0.191	0.103	0.701
	9	1931003	Emp. Semberong	60.568	0.163	0.159	0.821
	10	2025001	Pintu Kaw. Tg. Agas	80.936	0.187	0.258	0.890
	11	2033001	JPS Kluang	54.428	0.192	0.108	0.740
	12	2231001	Ladang Chan Wing	57.188	0.186	0.093	0.777
	13	2232001	Ladang Kekayaan	53.457	0.180	0.094	0.735
	14	2235163	Ibu Bekalan Kahang	52.177	0.186	0.055	0.652
	15	2237164	Jalan Kluang-Mersing	56.966	0.190	0.144	0.637
	16	2330009	Ladang Labis	45.808	0.222	0.012	0.713
	17	2528012	Rmh. Tapis Segamat	45.212	0.224	0.039	0.711
	18	2534160	Kg Peta Hulu Sg Endau	59.500	0.185	0.129	0.623
	19	2636170	Setor JPS Endau	62.040	0.215	0.103	0.592
Kedah	1	5507076	Bt. 27, Jalan Baling	52.398	0.172	0.104	0.788
	2	5704055	Kedah Peak	81.579	0.200	0.437	0.719
	3	5806066	Klinik Jeniang	59.786	0.165	0.203	0.791
	4	5808001	Bt. 61, Jalang Baling	47.496	0.183	0.079	0.752
	5	6103047	Setor JPS Alor Setar	64.832	0.168	0.346	0.800
	6	6108001	Kompleks Rumah Muda	52.341	0.173	0.120	0.792
	7	6206035	Kuala Nerang	54.849	0.174	0.250	0.810
	8	6107032	AmpangPadu	66.103	0.177	0.284	0.842
	9	6306031	Padang Senai	60.331	0.193	0.249	0.829

Table 2.B1: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for High ARIs between 2 and 100 Year and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Kelantan	1	4614001	Brook	49.623	0.159	0.242	0.795
	2	4726001	Gunung Gagau	43.024	0.220	0.004	0.527
	3	4819027	Gua Musang	57.132	0.155	0.119	0.795
	4	4915001	Chabai	47.932	0.169	0.108	0.794
	5	4923001	Kg Aring	47.620	0.187	0.020	0.637
	6	5120025	Balai Polis Bertam	61.338	0.168	0.193	0.811
	7	5216001	Gob	41.783	0.175	0.122	0.720
	8	5320038	Dabong	51.442	0.189	0.077	0.710
	9	5322044	Kg Lalok	53.766	0.197	0.121	0.705
	10	5522047	JPS Kuala Krai	39.669	0.231	0.000	0.563
	11	5718033	Kg Jeli, Tanah Merah	72.173	0.196	0.360	0.703
	12	5719001	Kg Durian Daun Lawang	51.161	0.193	0.063	0.745
	13	5722057	JPS Machang	48.433	0.219	0.000	0.601
	14	5824079	Sg Rasau Pasir Putih	51.919	0.216	0.062	0.560
	15	6019004	Rumah Kastam Rantau Pjg	49.315	0.228	0.000	0.609
	16	6122064	Setor JPS Kota Bharu	60.988	0.214	0.148	0.616
Kuala Lumpur	1	3015001	Puchong Drop, K Lumpur	69.650	0.151	0.223	0.880
	2	3116003	Ibu Pejabat JPS	61.976	0.145	0.122	0.818
	3	3116004	Ibu Pejabat JPS1	64.689	0.149	0.174	0.837
	4	3116005	SK Taman Maluri	62.765	0.132	0.147	0.820
	5	3116006	Ladang Edinburgh	63.483	0.146	0.210	0.830
	6	3216001	Kg. Sungai Tua	64.203	0.152	0.250	0.844
	7	3216004	SK Jenis Keb. Kepong	73.602	0.164	0.330	0.874
	8	3217001	Ibu Bek. KM16, Gombak	66.328	0.144	0.230	0.859
	9	3217002	Emp. Genting Kelang	70.200	0.165	0.290	0.854
	10	3217003	Ibu Bek. KM11, Gombak	62.609	0.152	0.221	0.804
	11	3217004	Kg. Kuala Seleh, H. Klg	61.516	0.139	0.183	0.837
	12	3217005	Kg. Kerdas, Gombak	63.241	0.162	0.137	0.856
	13	3317001	Air Terjun Sg. Batu	72.992	0.162	0.171	0.871
	14	3317004	Genting Sempah	61.335	0.157	0.292	0.868

(Continued)

Table 2.B1: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for High ARIs between 2 and 100 Year and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Malacca	1	2222001	Bukit Sebukor	95.823	0.169	0.660	0.947
	2	2224038	Chin Chin Tepi Jalan	54.241	0.161	0.114	0.846
	3	2321006	Ladang Lendu	72.163	0.184	0.376	0.900
Negeri Sembilan	1	2719001	Setor JPS Sikamat	52.823	0.167	0.159	0.811
	2	2722202	Kg Sawah Lebar K Pilah	44.811	0.181	0.137	0.811
	3	2723002	Sungai Kepis	54.400	0.176	0.134	0.842
	4	2725083	Ladang New Rompin	57.616	0.191	0.224	0.817
	5	2920012	Petaling K Kelawang	50.749	0.173	0.235	0.854
Pahang	1	2630001	Sungai Pukim	46.577	0.232	0.169	0.687
	2	2634193	Sungai Anak Endau	66.179	0.182	0.081	0.589
	3	2828173	Kg Gambir	47.701	0.182	0.096	0.715
	4	3026156	Pos Iskandar	47.452	0.184	0.071	0.780
	5	3121143	Simpang Pelangai	57.109	0.165	0.190	0.867
	6	3134165	Dispensari Nenasi	61.697	0.152	0.120	0.593
	7	3231163	Kg Unchang	55.568	0.179	0.096	0.649
	8	3424081	JPS Temerloh	73.141	0.173	0.577	0.896
	9	3533102	Rumah Pam Pahang Tua	58.483	0.212	0.197	0.586
	10	3628001	Pintu Kaw. Pulau Kertam	50.024	0.211	0.089	0.716
	11	3818054	Setor JPS Raub	53.115	0.168	0.191	0.833
	12	3924072	Rmh Pam Paya Kangsar	62.301	0.167	0.363	0.868
	13	3930012	Sungai Lembing PCC Mill	45.999	0.210	0.074	0.590
	14	4023001	Kg Sungai Yap	65.914	0.195	0.252	0.817
	15	4127001	Hulu Tekai Kwsn."B"	59.861	0.226	0.213	0.762
	16	4219001	Bukit Bentong	73.676	0.165	0.384	0.879
	17	4223115	Kg Merting	52.731	0.184	0.096	0.805
	18	4513033	Gunung Brinchang	42.004	0.164	0.046	0.802
Penang	1	5204048	Sg Simpang Ampat	62.089	0.220	0.402	0.785
	2	5302001	Tangki Air Besar Sg Pinang	67.949	0.181	0.299	0.736
	3	5302003	Kolam Tkgn Air Hitam	52.459	0.191	0.106	0.729
	4	5303001	Rmh Kebajikan P Pinang	57.326	0.203	0.325	0.791
	5	5303053	Komplek Prai	52.771	0.203	0.095	0.717
	6	5402001	Klinik Bkt Bendera P Pinang	64.504	0.196	0.149	0.723
	7	5402002	Kolam Bersih P Pinang	53.785	0.181	0.125	0.706
	8	5404043	Ibu Bekalan Sg Kulim	57.832	0.188	0.245	0.751
	9	5504035	Lahar Ikan Mati Kepala Batas	48.415	0.221	0.068	0.692

(Continued)

Table 2.B1: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for High ARIs between 2 and 100 Year and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Perak	1	4010001	JPS Teluk Intan	54.017	0.198	0.084	0.790
	2	4207048	JPS Setiawan	56.121	0.174	0.211	0.854
	3	4311001	Pejabat Daerah Kampar	69.926	0.148	0.149	0.813
	4	4409091	Rumah Pam Kubang Haji	52.343	0.164	0.177	0.840
	5	4511111	Politeknik Ungku Umar	70.238	0.164	0.288	0.872
	6	4807016	Bukit Larut Taiping	87.236	0.165	0.258	0.842
	7	4811075	Rancangan Belia Perlop	58.234	0.198	0.247	0.856
	8	5005003	Jln. Mtg. Buloh Bgn Serai	52.752	0.163	0.179	0.795
	9	5207001	Kolam Air JKR Selama	59.567	0.176	0.062	0.807
	10	5210069	Stesen Pem. Hutan Lawin	52.803	0.169	0.219	0.838
	11	5411066	Kuala Kenderong	85.943	0.223	0.248	0.909
	12	5710061	Dispensari Keroh	53.116	0.168	0.112	0.820
Perlis	1	6401002	Padang Katong, Kangar	57.645	0.179	0.254	0.826
Selangor	1	2815001	JPS Sungai Manggis	56.052	0.152	0.194	0.857
	2	2913001	Pusat Kwln. JPS T Gong	63.493	0.170	0.254	0.872
	3	2917001	Setor JPS Kajang	59.153	0.161	0.118	0.812
	4	3117070	JPS Ampang	65.809	0.148	0.156	0.837
	5	3118102	SK Sungai Lui	63.155	0.177	0.122	0.842
	6	3314001	Rumah Pam JPS P Setia	62.273	0.175	0.205	0.841
	7	3411017	Setor JPS Tj. Karang	68.290	0.175	0.243	0.894
	8	3416002	Kg Kalong Tengah	61.811	0.161	0.188	0.816
	9	3516022	Loji Air Kuala Kubu Baru	67.793	0.176	0.278	0.854
	10	3710006	Rmh Pam Bagan Terap	60.793	0.173	0.185	0.884
Terengganu	1	3933001	Hulu Jabor, Kemaman	103.519	0.228	0.756	0.707
	2	4131001	Kg, Ban Ho, Kemaman	65.158	0.164	0.092	0.660
	3	4234109	JPS Kemaman	55.899	0.201	0.000	0.580
	4	4332001	Jambatan Tebak, Kem.	61.703	0.185	0.088	0.637
	5	4529001	Rmh Pam Paya Kempian	53.693	0.194	0.000	0.607
	6	4529071	SK Pasir Raja	48.467	0.207	0.000	0.600
	7	4631001	Almuktafibilah Shah	66.029	0.199	0.165	0.629
	8	4734079	SM Sultan Omar, Dungun	51.935	0.213	0.020	0.587
	9	4832077	SK Jerangau	54.947	0.212	0.026	0.555
	10	4930038	Kg Menerong, Hulu Trg	60.436	0.204	0.063	0.588
	11	5029034	Kg Dura, Hulu Trg	60.510	0.220	0.087	0.617
	12	5128001	Sungai Gawi, Hulu Trg	48.101	0.215	0.027	0.566
	13	5226001	Sg Petualang, Hulu Trg	48.527	0.228	0.000	0.547
	14	5328044	Sungai Tong, Setiu	52.377	0.188	0.003	0.558
	15	5331048	Setor JPS K Terengganu	58.307	0.210	0.123	0.555
	16	5426001	Kg Seladang, Hulu Setiu	57.695	0.197	0.000	0.544
	17	5428001	Kg Bt. Hampar, Setiu	55.452	0.186	0.000	0.545
	18	5524002	SK Panchor, Setiu Klinik	53.430	0.206	0.000	0.524
	19	5725006	Kg Raja, Besut	52.521	0.225	0.041	0.560

(Continued)

Table 2.B2: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for Low ARIs between 0.5 and 12 Month and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Johor	1	1437116	Stor JPS Johor Bahru	73.6792	0.2770	0.2927	0.8620
	2	1534002	Pusat Kem. Pekan Nenas	62.6514	0.3231	0.1557	0.8212
	3	1541139	Johor Silica	79.5355	0.3363	0.2947	0.8097
	4	1636001	Balai Polis Kg Seelong	61.2124	0.3373	0.2375	0.8427
	5	1737001	SM Bukit Besar	61.3513	0.3027	0.2029	0.8240
	6	1829002	Setor Daerah JPS Batu Pahat	62.1576	0.3055	0.1423	0.8253
	7	1834124	Ladang Ulu Remis	59.1713	0.2935	0.1847	0.8380
	8	1839196	Simpang Masai K. Sedili	71.7947	0.2683	0.1863	0.8071
	9	1931003	Emp. Semberong	66.8854	0.3549	0.2107	0.8384
	10	2025001	Pintu Kaw. Tg. Agas	77.7719	0.3102	0.2806	0.8789
	11	2231001	Ladang Chan Wing	66.1439	0.3236	0.1778	0.8489
	12	2232001	Ladang Kekayaan	66.7541	0.3076	0.2270	0.8381
	13	2235163	Ibu Bekalan Kahang	62.3394	0.2786	0.1626	0.7389
	14	2237164	Jalan Kluang-Mersing	73.2358	0.3431	0.2198	0.7733
	15	2330009	Ladang Labis	65.2220	0.3947	0.2353	0.8455
	16	2528012	Rmh. Tapis Segamat	63.6892	0.3817	0.2586	0.8711
	17	2534160	Kg Peta Hulu Sg Endau	69.9581	0.3499	0.1808	0.7064
	18	2636170	Setor JPS Endau	77.6302	0.3985	0.2497	0.6927
Kedah	1	5507076	Bt. 27, Jalan Baling	62.7610	0.2580	0.3040	0.8350
	2	5704055	Kedah Peak	58.5960	0.3390	0.0640	0.661
	3	5806066	Klinik Jeniang	67.1200	0.3820	0.2380	0.8230
	4	5808001	Bt. 61, Jalan Baling	56.3990	0.3880	0.2520	0.8030
	5	6103047	Setor JPS Alor Setar	67.6410	0.3340	0.2740	0.8280
	6	6108001	Kompleks Rumah Muda	58.4040	0.2780	0.2340	0.8290
	7	6206035	Kuala Nerang	62.9600	0.3080	0.3590	0.8590
	8	6207032	Ampang Padu	70.9970	0.2930	0.3820	0.8630
	9	6306031	Padang Sanai	63.6150	0.3130	0.3090	0.8520

Table 2.B2: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for Low ARIs between 0.5 and 12 Month and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Kelantan	1	4614001	Brook	49.7311	0.3159	0.1978	0.7924
	2	4915001	Chabai	56.2957	0.2986	0.1965	0.8384
	3	4923001	Kg Aring	70.2651	0.3810	0.2416	0.8185
	4	5120025	Balai Polis Bertam	67.7195	0.3271	0.2430	0.8424
	5	5216001	Gob	47.4654	0.2829	0.1531	0.7850
	6	5320038	Dabong	67.7907	0.3777	0.2740	0.8115
	7	5322044	Kg Lalok	67.7660	0.3288	0.2367	0.8188
	8	5522047	JPS Kuala Krai	63.0690	0.4681	0.3096	0.7833
	9	5718033	Kg Jeli, Tanah Merah	73.8139	0.3878	0.1161	0.7600
	10	5719001	Kg Durian Daun Lawang	67.2398	0.3651	0.1822	0.7531
	11	5722057	JPS Machang	57.3756	0.3441	0.1742	0.7085
	12	5824079	Sg Rasau, Pasir Putih	68.5083	0.4079	0.2019	0.7003
	13	6019004	Rumah Kastam Rantau Pjg	65.3650	0.4433	0.1582	0.7527
Kuala Lumpur	1	3015001	Puchong Drop, K Lumpur	68.5873	0.3519	0.1697	0.8494
	2	3116004	Ibu Pejabat JPS	65.9923	0.2857	0.1604	0.8341
	3	3116005	SK Taman Maluri	74.4510	0.2663	0.3120	0.8608
	4	3116006	Ladang Edinburgh	64.5033	0.2751	0.1814	0.8329
	5	3216001	Kg. Sungai Tua	62.9398	0.2579	0.1989	0.8374
	6	3216004	SK Jenis Keb. Kepong	69.7878	0.2955	0.1672	0.8508
	7	3217001	Ibu Bek. KM16, Gombak	66.0685	0.2565	0.2293	0.8401
	8	3217002	Emp. Genting Kelang	66.2582	0.2624	0.2423	0.8446
	9	3217003	Ibu Bek. KM11, Gombak	73.9540	0.2984	0.3241	0.8238
	10	3217004	Kg. Kuala Seleh, H. Klang	64.3175	0.2340	0.1818	0.8645
	11	3217005	Kg. Kerdas, Gombak	68.8526	0.2979	0.2024	0.8820
	12	3317001	Air Terjun Sg. Batu	75.9351	0.2475	0.2664	0.8668
	13	3317004	Genting Sempah	55.3934	0.2822	0.1835	0.8345

(Continued)

Table 2.B2: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for Low ARIs between 0.5 and 12 Month and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Malacca	1	2222001	Bukit Sebukor	78.1482	0.2690	0.3677	0.8968
	2	2224038	Chin Chin Tepi Jalan	66.0589	0.3363	0.3301	0.8905
	3	2321006	Ladang Lendu	64.7588	0.2975	0.2896	0.8787
Negeri Sembilan	1	2719001	Setor JPS Sikamat	60.4227	0.2793	0.2694	0.8540
	2	2722202	Kg Sawah Lebar K Pilah	49.3232	0.2716	0.2164	0.8503
	3	2723002	Sungai Kepis	61.3339	0.2536	0.3291	0.8717
	4	2725083	Ladang New Rompin	65.0249	0.3575	0.3546	0.8750
	5	2920012	Petaling K Kelawang	51.7343	0.2919	0.2643	0.8630
Pahang	1	2630001	Sungai Pukim Sungai	63.9783	0.3906	0.2556	0.8717
	2	2634193	Anak Endau	79.4310	0.3639	0.1431	0.7051
	3	2828173	Kg Gambir	61.1933	0.3857	0.1878	0.8237
	4	3026156	Pos Iskandar	59.9903	0.3488	0.2262	0.8769
	5	3121143	Simpang Pelangai	64.9653	0.3229	0.3003	0.8995
	6	3134165	Dispensari Nenasi	88.6484	0.3830	0.4040	0.7614
	7	3231163	Kg Unchang	71.6472	0.3521	0.1805	0.7886
	8	3424081	JPS Temerloh	62.2075	0.3528	0.3505	0.8368
	9	3533102	Rumah Pam Pahang Tua	80.8887	0.3611	0.4800	0.7578
	10	3628001	Pintu Kaw. Pulau Kertam	63.5073	0.3830	0.2881	0.8202
	11	3818054	Setor JPS Raub	61.3432	0.3692	0.3929	0.8445
	12	3924072	Rmh Pam Paya Kangsar	58.3761	0.3334	0.2421	0.8430
	13	3930012	Sungai Lembing PCC Mill	77.0004	0.4530	0.5701	0.8125
	14	4023001	Kg Sungai Yap	77.1488	0.3725	0.3439	0.8810
	15	4127001	Hulu Tekai Kwsn."B"	60.2235	0.4650	0.1241	0.8020
	16	4219001	Bukit Bentong	67.6128	0.2706	0.2459	0.8656
	17	4223115	Kg Merting	62.7511	0.2843	0.3630	0.9024
	18	4513033	Gunung Brinchang	42.1757	0.2833	0.1468	0.7850
Penang	1	5204048	Sg Simpang Ampat	59.3122	0.3394	0.3350	0.8090
	2	5302001	Tangki Air Besar Sg Pinang	71.7482	0.2928	0.2934	0.7779
	3	5302003	Kolam Tkgn Air Hitam	56.1145	0.2975	0.1778	0.7626
	4	5303001	Rmh Kebajikan P Pinang	60.1084	0.3575	0.2745	0.8303
	5	5303053	Kompleks Prai P Pinang	49.4860	0.3314	0.0518	0.7116
	6	5402001	Klinik Bkt Bendera P Pinang	68.0999	0.3111	0.1904	0.7662
	7	5402002	Kolam Bersih P Pinang	62.7533	0.2688	0.2488	0.7757
	8	5504035	Lahar Ikan Mati Kepala Batas	60.8596	0.3369	0.2316	0.7981

(Continued)

Table 2.B2: Fitting Constants for the IDF Empirical Equation for the Different Locations in Malaysia for Low ARIs between 0.5 and 12 Month and Storm Durations from 5 Minutes to 72 Hours

State	No.	Station ID	Station Name	Constants			
				$\lambda$	$\kappa$	$\theta$	$\eta$
Perak	1	5005003	JPS Teluk Intan	65.1854	0.3681	0.2552	0.8458
	2	4010001	JPS Setiawan	56.2695	0.3434	0.2058	0.8465
	3	4207048	Pejabat Daerah Kampar	79.2706	0.1829	0.3048	0.8532
	4	4311001	Rumah Pam Kubang Haji	47.8316	0.3527	0.1038	0.8018
	5	4409091	Politeknik Ungku Umar	62.9315	0.3439	0.1703	0.8229
	6	4511111	Bukit Larut Taiping	83.3964	0.3189	0.1767	0.8166
	7	4807016	Rancangan Belia Perlop	57.4914	0.3199	0.2027	0.8696
	8	4811075	Jln. Mtg. Buloh Bgn Serai	63.2357	0.3176	0.3330	0.8462
	9	5207001	Kolam Air JKR Selama	67.0499	0.3164	0.2255	0.8080
	10	5210069	Stesen Pem. Hutan Lawin	53.7310	0.3372	0.2237	0.8347
	11	5411066	Kuala Kenderong	68.5357	0.4196	0.1558	0.8378
	12	5710061	Dispensari Keroh	59.2197	0.3265	0.1621	0.8522
Perlis	1	6401002	Padang Katong, Kangar	52.1510	0.3573	0.1584	0.7858
Selangor	1	2815001	JPS Sungai Manggis	57.3495	0.2758	0.1693	0.8672
	2	2913001	Pusat Kwln. JPS T Gong	65.3556	0.3279	0.3451	0.8634
	3	2917001	Setor JPS Kajang	62.9564	0.3293	0.1298	0.8273
	4	3117070	JPS Ampang	69.1727	0.2488	0.1918	0.8374
	5	3118102	SK Sungai Lui	68.4588	0.3035	0.2036	0.8726
	6	3314001	Rumah Pam JPS P Setia	65.1864	0.2816	0.2176	0.8704
	7	3411017	Setor JPS Tj. Karang	70.9914	0.2999	0.2929	0.9057
	8	3416002	Kg Kalong Tengah	59.9750	0.2444	0.1642	0.8072
	9	3516022	Loji Air Kuala Kubu Baru	66.8884	0.2798	0.3489	0.8334
	10	3710006	Rmh Pam Bagan Terap	62.2644	0.3168	0.2799	0.8665
Terengganu	1	3933001	Hulu Jabor, Kemaman	74.8046	0.2170	0.2527	0.7281
	2	4131001	Kg. Ban Ho, Kemaman	68.6659	0.3164	0.1157	0.6969
	3	4234109	JPS Kemaman Jambatan	75.8258	0.2385	0.3811	0.7303
	4	4332001	Tebak, Kem.	77.2826	0.3460	0.3036	0.7301
	5	4529001	Rmh Pam Paya Kempian	65.2791	0.3642	0.1477	0.6667
	6	4631001	Almuktafibilah Shah	81.8861	0.3400	0.2600	0.7459
	7	4734079	SM Sultan Omar, Dungun	66.4262	0.3288	0.2152	0.7015
	8	4832077	SK Jerangau	81.4981	0.3736	0.4226	0.7586
	9	4930038	Kg Menerong, Hulu Trg	80.9649	0.3782	0.2561	0.7158
	10	5029034	Kg Dura. Hulu Trg	62.7859	0.3495	0.1103	0.6638
	11	5128001	Sungai Gawi, Hulu Trg	59.3063	0.4001	0.1312	0.6796
	12	5226001	Sg Petualang, Hulu Trg	51.7862	0.2968	0.0704	0.6587
	13	5328044	Sungai Tong, Setiu	63.4136	0.3864	0.0995	0.6540
	14	5331048	Setor JPS K Terengganu	67.0267	0.2844	0.2633	0.6690
	15	5426001	Kg Seladang, Hulu Setiu	76.9088	0.4513	0.1636	0.6834
	16	5428001	Kg Bt. Hampar, Setiu	57.9456	0.2490	0.0380	0.6000
	17	5524002	SK Panchor, Setiu	75.1489	0.4147	0.2580	0.6760



where,

- $C_{avg}$  = Average runoff coefficient;  
 $C_j$  = Runoff coefficient of segment  $i$ ;  
 $A_j$  = Area of segment  $i$  (ha); and  
 $m$  = Total number of segments.

Table 2.5: Recommended Runoff Coefficients for Various Landuses  
(DID, 1980; Chow et al., 1988; QUDM, 2007 and Darwin Harbour, 2009)

Landuse	Runoff Coefficient (C)	
	For Minor System (≤10 year ARI)	For Major System (> 10 year ARI)
Residential		
Bungalow	0.65	0.70
Semi-detached Bungalow	0.70	0.75
Link and Terrace House	0.80	0.90
Flat and Apartment	0.80	0.85
Condominium	0.75	0.80
Commercial and Business Centres	0.90	0.95
Industrial	0.90	0.95
Sport Fields, Park and Agriculture	0.30	0.40
Open Spaces		
Bare Soil (No Cover)	0.50	0.60
Grass Cover	0.40	0.50
Bush Cover	0.35	0.45
Forest Cover	0.30	0.40
Roads and Highways	0.95	0.95
Water Body (Pond)		
Detention Pond (with outlet)	0.95	0.95
Retention Pond (no outlet)	0.00	0.00

Note: The runoff coefficients in this table are given as a guide for designers. The near-field runoff coefficient for any single or mixed landuse should be determined based on the imperviousness of the area.

### 2.3.1.2 Assumptions

Assumptions used in the Rational Method are as follows:

- The peak flow occurs when the entire catchment is contributing to the flow;
- The rainfall intensity is the uniform over the entire catchment area; and
- The rainfall intensity is uniform over a time duration equal to the time of concentration,  $t_c$ .

The Rational Method is *not recommended* for use where:

- The catchment area is greater than 80 ha (TxDOT, 2009);
- Ponding of stormwater in the catchment might affect peak discharge; and
- The design and operation of large and more costly drainage facilities are to be undertaken, particularly if they involve storage.

### 2.3.1.3 Calculation Steps

Steps for estimating a peak flow from a single sub-catchment for a particular ARI using the Rational Method are outlined in Figure 2.4.