

SULIT



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

JABATAN KEJURUTERAAN AWAM

PEPERIKSAAN AKHIR

SESI II : 2021/2022

DCC50212 / DCC6213 : HYDROLOGY

TARIKH : 29 JUN 2022

MASA : 2.30 PETANG – 4.30 PETANG (2 JAM)

Kertas ini mengandungi **LAPAN (8)** halaman bercetak.

Bahagian A: Struktur (3 soalan)

Bahagian B: Esei (1 soalan)

Dokumen sokongan yang disertakan : MSMA 2nd Edition dan Borang Kadar
Alir disediakan

JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIARAHKAN

(CLO yang tertera hanya sebagai rujukan)

SULIT

SECTION A : 75 MARKS
BAHAGIAN A : 75 MARKAH

INSTRUCTION:

This section consists of **THREE (3)** structured questions. Answer **ALL** questions.

ARAHAN:

Bahagian ini mengandungi **TIGA (3)** soalan berstruktur. Jawab **SEMUA** soalan.

QUESTION 1

SOALAN 1

CLO1

- a) Explain the difference between a river basin and catchment area.

C2

Terangkan perbezaan antara lembangan sungai dan kawasan tadahan.

[5 marks]

[5 markah]

CLO1

- b) Refer to the Figure A1(b), interpret hydrologic cycle according the following terms:

C3

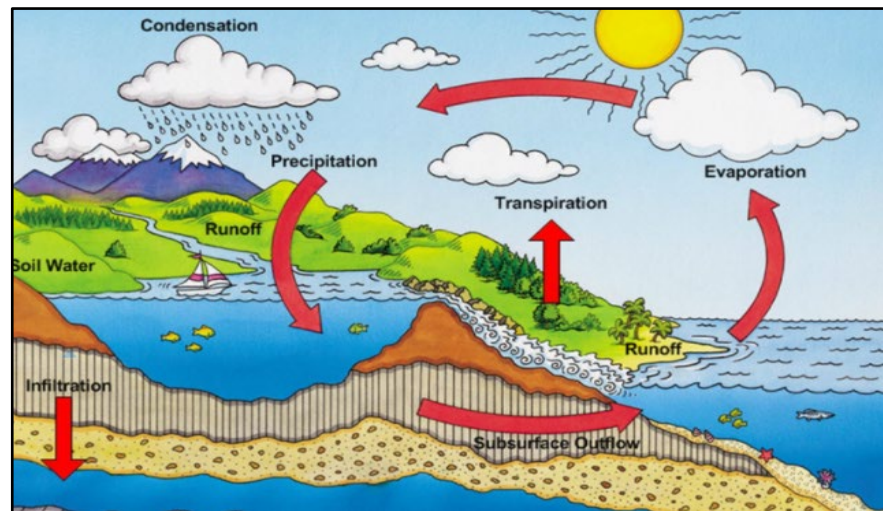


Figure A1(b)/Rajah A1(b)

- i) Interception
- ii) Infiltration
- iii) Evaporation
- iv) Precipitation
- v) Surface Runoff

Merujuk kepada gambarajah A1(b), tafsirkan proses kitaran hidrologi berikut :

- i) Pintasan
- ii) Penyusupan
- iii) Penyejatan
- iv) Curahan
- v) Air Larian Permukaan

[10 marks]
[10 markah]

CLO1
C3

- c) In early Jun 2020, the lake's capacity storage was $24 \times 10^6 \text{ m}^3$. The lake's inflow and outflow during this time are $13.0 \text{ m}^3/\text{s}$ and $22 \text{ m}^3/\text{s}$, respectively. The lake got 125 cm of rain in that month, and the evaporation from the lake was estimated to be 42 mm. An average surface area of 45 km^2 can be calculated. Calculate the lake's water surface elevation at the end of the month. Assume that no contribution to or from groundwater storage exists.

Pada awal Jun 2020 storan sebuah tasik ialah $24 \times 10^6 \text{ m}^3$. Aliran masuk dan aliran keluar tasik ialah $13.0 \text{ m}^3/\text{s}$ dan $22 \text{ m}^3/\text{s}$. Dalam bulan yang sama, tasik tersebut menerima hujan sebanyak 125 cm dan penyejatan dianggarkan 42 mm. Purata luas permukaan tasik 45 km^2 . Kirakan ketinggian permukaan air tasik pada hujung bulan Jun. Anggap tiada sumbangan kepada atau daripada aliran bawah tanah.

[10 marks]
[10 markah]

QUESTION 2**SOALAN 2**

CLO1

C2

- a) Explain the human activities that influences surface runoff below.

Terangkan aktiviti manusia yang boleh mempengaruhi air larian permukaan di bawah.

- i) Urbanization.

Pembangunan

- ii) Logging

Pembalakan

[5 marks]

[5 markah]

Table 2A(b) shows the current meter gauging data for Sungai Pinji, by using Mean Section Method:

Jadual A2(b) menunjukkan bacaan data bagi Sungai Pinji, dengan menggunakan kaedah keratan min:

Table A2(b) / Jadual A2(b)

Distance from river bank (m) <i>Jarak dari tebing (m)</i>	Vertical depth (m) <i>Kedalaman pugak (m)</i>	Immersion of Current meter depth <i>Kedalaman meter arus</i>	Time <i>Masa (s)</i>	Rotation <i>Putaran</i>
0	0	0	0	0
2.5	0.80	0.6D	16	70
5.5	1.27	0.6D	18	70
8.5	1.40	0.2D	30	70
		0.8D	25	70
10.5	1.25	0.2D	34	70
		0.6D	38	70
		0.8D	30	70
13.5	0	0	0	0

Note: Answer in Appendix 1. All calculation shall be rounded to three decimal places.

Nota: Jawab di Apendik 1. Semua pengiraan hendaklah dibundarkan kepada tiga titik perpuluhan.

CLO1

- b) Determine the velocity if $V = 0.1550N + 0.005$.

C3

Kenalpasti halaju bagi sungai tersebut jika $V = 0.1550N + 0.005$.

[10 marks]

[10 markah]

CLO1

- c) Calculate the discharge of the river.

C3

Kirakan kadar alir bagi sungai tersebut.

[10 marks]

[10 markah]

QUESTION 3

SOALAN 3

CLO2

C3

- a) The following streamflow data in **Table A3(a)** was produced by a storm of 2 hours duration assumed to have a uniform intensity over the catchment. Identify the unit hydrograph for that area if the catchment area is 78km^2 .

*Data aliran sungai dalam **Jadual A3(a)** dihasilkan oleh kejadian hujan bagi tempoh 2 jam yang diandaikan mempunyai keamatan hujan yang seragam di kawasan tadahan tersebut. Tentukan unit hidrograf bagi kawasan tersebut jika keluasan kawasan tadahan ialah 78km^2 .*

[10 marks]

[10 markah]

Table A3(a) / Jadual A3(a)

Time (h) <i>Masa (j)</i>	Total flow, Q (m^3/s) <i>Jumlah aliran, Q (m^3/s)</i>	Base flow (m^3/s) <i>Aliran dasar (m^3/s)</i>
0600	5	5
0800	67	11
1000	96	11
1200	146	14
1400	181	14
1600	109	11

1800	80	11
2000	40	9
2200	5	5

CLO2
C4

- b) **Table A3(b)** shows the ordinate of 2hr-UH for Kinta area. Assume the ordinate 4hr-UH by using S-Curved Method.

Jadual A3(b) menunjukkan ordinat UH-2jam bagi kawasan Kinta. Anggarkan ordinat UH-4jam menggunakan Kaedah Lengkung S.

[15 marks]

[15 markah]

Table A3(b)/Jadual A3(b)

Time (h) <i>Masa (j)</i>	2hr-UH (m^3/s) <i>UH-2jam (m^3/s)</i>
0	0
2	30
4	90
6	140
8	180
10	150
12	100
14	70
16	40
18	10
20	5
22	0

SECTION B : 25 MARKS**BAHAGIAN B : 25 MARKAH****INSTRUCTION:**

This section consists of **ONE (1)** essay questions. Answer **ALL** questions.

ARAHAN:

*Bahagian ini mengandungi **SATU (1)** soalan esei. Jawab **SEMUA** soalan.*

QUESTION 1**SOALAN 1**

CLO2
C4

- a) Compare the concepts the Quantity and Quality Controls in Urban Storm Water Management Manual for Malaysia (MSMA) with **THREE (3)** example of control facilities each for both quantity and quality control system design.

*Bandingkan konsep Kawalan Kuantiti dan Kawalan Kualiti dalam Manual Saliran Mesra Alam Malaysia (MSMA) dengan **TIGA (3)** contoh fasiliti kawalan bagi setiap sistem kawalan kuantiti dan kualiti.*

[10 marks]
[10 markah]

CLO2
C4

- b) A developed area located at Puchong Drop, Kuala Lumpur has a data as shown in **Table B1(b)**. A concrete smooth finish rectangular channel with 400 mm depth and 600 mm width will be placed in that area to accommodate the stormwater discharge for subcatchment A and subcatchment B. Analyze the peak discharge by using rainfall data from Puchong Drop, Kuala Lumpur Rainfall Station.

*Sebuah kawasan membangun yang terletak di Puchong Drop, Kuala Lumpur mempunyai data seperti yang ditunjukkan dalam **Jadual B1(b)**. Kemasan licin saluran konkrit segi empat dengan kedalaman 400 mm dan lebar 600 mm akan ditempatkan di kawasan itu untuk menampung aliran ribut hujan bagi sub tadahan A dan sub tadahan B. Analisa kadaralir puncak dengan menggunakan data hujan dari Stesen Hujan Puchong Drop, Kuala Lumpur.*

[15 marks]
[15 markah]

Table B1(b)/Jadual B1(b)

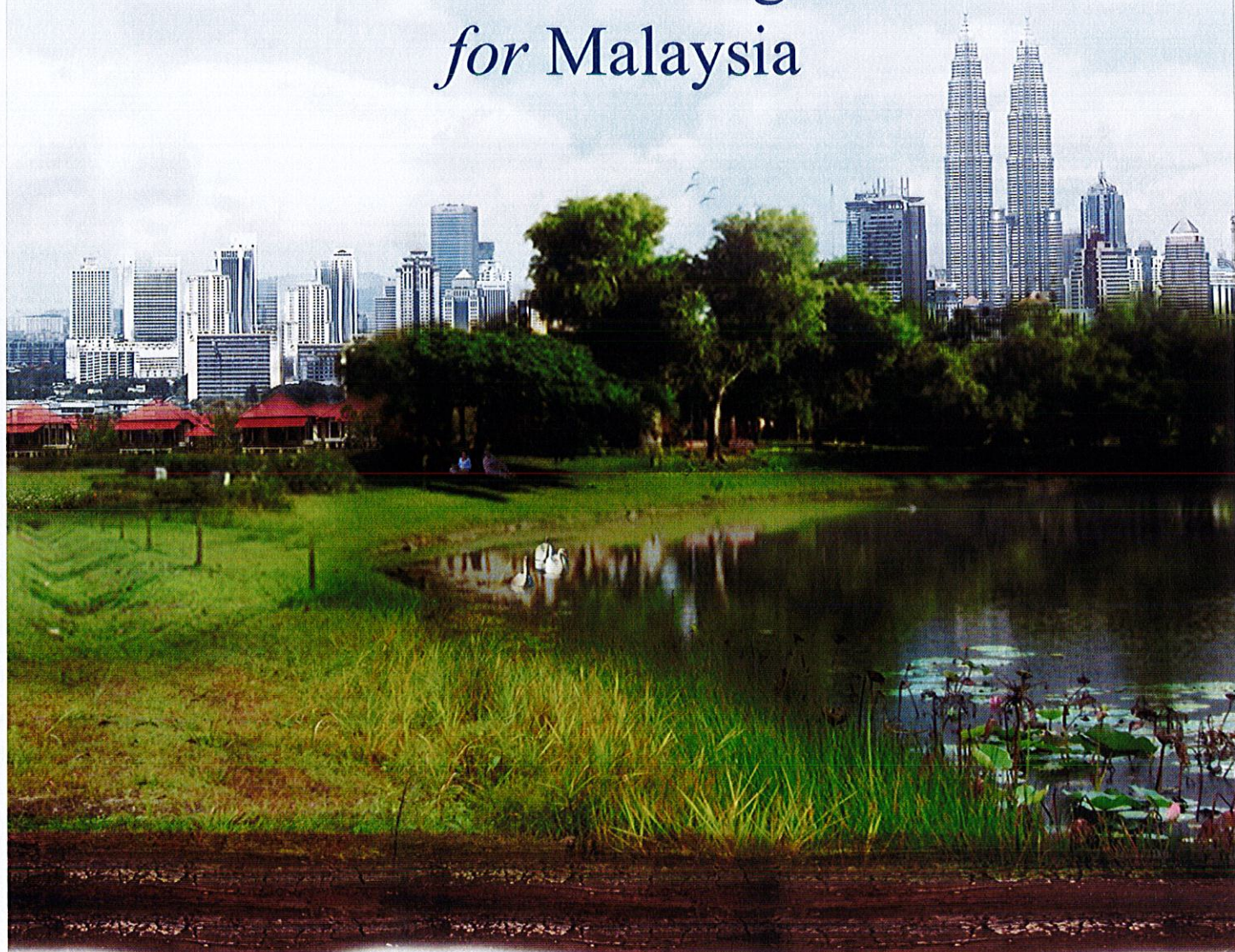
Data <i>Data</i>	Sub catchment A <i>Sub tadahan A</i>		Sub catchment B <i>Sub tadahan B</i>	
Drainage system <i>Sistem Saliran</i>	Major (20 year ARI) <i>Major (20 tahun ARI)</i>		Major (20 year ARI) <i>Major (20 tahun ARI)</i>	
Land use <i>Kegunaan tanah</i>	Link and Terrace House <i>Rumah berangkai dan teres</i>	Average Grassed cover <i>Litupan rumput sederhana</i>	Industrial Area <i>Kawasan perindustrian</i>	Bare soil <i>Tanah terdedah</i>
Area (ha) <i>Luas (ha)</i>	23.8	7.11	15.45	6.96
Overland sheet flow (m) <i>Aliran atas permukaan (m)</i>	60.6		72.9	
Land Slope (%) <i>Kecerunan tanah (%)</i>	2.8		10.9	
Length of channel (m) <i>Panjang saluran (m)</i>	271		830	
Channel slope (m/m) <i>Kecerunan saluran (m/m)</i>	0.02		0.06	

SOALAN TAMAT



Government of Malaysia
Department of Irrigation and Drainage

Urban Stormwater Management Manual *for Malaysia*



MSMA 2nd 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 (>10%), $L \leq 50$ m</i> <i>for Moderate Slope (<5%), $L \leq 100$ m</i> <i>for Mild Slope (<1%), $L \leq 200$ 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

λ , κ , θ and η = 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.

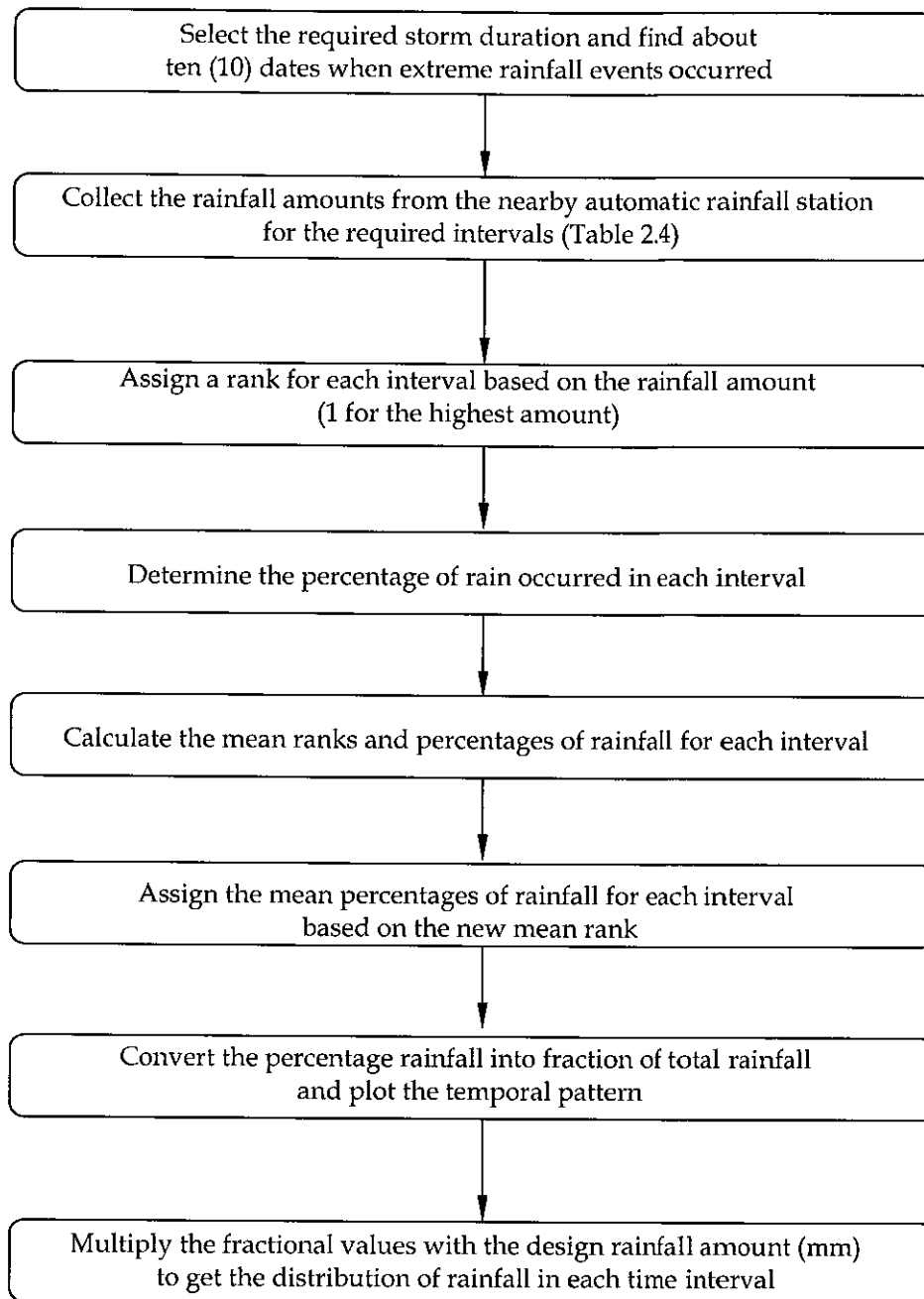


Figure 2.3: Typical Steps for the Development of Design Rainfall Temporal Pattern

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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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			
				λ	κ	θ	η
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.