SECTOR I

HYDROLOGY

THE STUDY ON INTEGRATED URBAN DRAINAGE IMPROVEMENT FOR MELAKA AND SUNGAI PETANI IN MALAYSIA

FINAL REPORT

VOLUME 3: SUPPORTING REPORT ON DRAINAGE STRUCTURE PLAN

SECTOR I: HYDROLOGY

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HYDROLOGY

1. RAINFALL ANALYSIS

1.1 Rainfall Gauging Data

The hydrograph of the probable flood runoff discharge within a short time duration is essential for formulation of the drainage master plan. The hourly discharge is, however, observed at only one gauging station on Sungai Melaka in the study area. Thus, the data of discharge hydrograph in the study area is scarcely available, and therefore, a proper flood run-off simulation model has to be developed to estimate the probable flood runoff discharge from the observed rainfall data. Hence the rainfall analysis was firstly made, and the probable flood hyetographs were developed.

The rainfall depth is observed and recorded by Department of Irrigation and Drainage (DID) and Malaysian Meteorological Service (MMS). Among the rainfall gauging stations, the following four (4) stations could provide the rainfall intensities for a short term in and around the study area. Out of the four (4) gauging stations, one is operated by DID in Alor Setar in State of Kedah, while other three (3) by MMS at air ports in Alor Setar, Penang and Melaka, respectively. Such rainfall intensities are indispensable to carry out the subject run-off analysis for drainage improvement plan.

Name of Gauging Station	Observed by	Location		Observation Period	
		Latitude	Longitude	From	To
Stor JPS Alor Setar	DID	06°07'00"	100°21'25"	Dec. 1964	Present
Kepala Batas (Alor Setar)	MMS	06°12'05"	100°24'45"	Sep. 1936	Present
Bayan Lepas (Penang)	MMS	05°17'50"	100°16'20"	May 1934	Present
Lanpangan Terbang Melaka	MMS	02°16'00"	100°12'50"	Jan. 1946	Present

The hourly rainfall data observed at the above four (4) gauging stations for the recent five (5) years were collected to clarify the temporal variation of rainfall and the dominant rainfall duration. The annual maximum rainfall intensities for various rainfall duration were also collected from the records of above three (3) gauging station operated by MMS (refer to Table I-1). The period of the collected annual maximum intensities is from 1951 to 1997, and these maximum intensities are used to develop the rainfall intensity-duration curves.

1.2 Rainfall Intensity-Duration Curves

Time length of one sequence of rainfall was examined through observed hourly rainfall recorded for the recent 5 years at the foregoing four (4) gauging stations. As the results, it was clarified that the time length of almost all sequential rainfall is within 12 hours as shown in Fig. I-1. In due consideration of the clarification, rainfall intensity-duration curves were developed on the premises of the maximum rainfall continuation time of 12 hours.

The recurrence probability analysis on the point rainfall intensity for various rainfall duration within 12 hours was made by Gumbel Method with using the aforesaid series of annual maximum rainfall intensities at three (3) gauging stations operated by MMS. As the results, the probable point rainfall intensities for various rainfall duration were estimated as shown in Table I-2 and Fig. I-2.

The rainfall intensity-duration curves express the relation between the above probable rainfall intensities and their corresponding rainfall duration, and thereby, several equations have been proposed to express the relation. In this study, the most conformable equations were selected among the following four (4) prominent equations:

(1) Talbot Type : $I = a / (T + b)$
(2) Sherman Type : $I = a / T^{n}$
(3) Kuno Type : $I = a / (T^{0.5} + b)$
(4) Honer Type : $I = a / (T + b)^{n}$

Where; I : Rainfall Intensity
T : Rainfall Duration
a, b, n : Constants

The constants of the above equations were estimated by a least-square regression method. The estimated value of the constants are as shown in Table I-3. Then, the probable rainfall intensities estimated by the equations were compared with the probable rainfall intensities given from the observed data. As the results, it was confirmed that the equation of Talbot Type is the most conformable as shown in Table I-4.

The rainfall intensity-duration curves at MMS three (3) gauging stations developed by Talbot Type are as shown in Fig. I-3. All curves are resemble, which is probably attributed to that all gauging stations are located in the same meteorological region of east coast. Thus, there is no significant difference among the three kinds of rainfall-duration curves, nevertheless the following curves were applied to each of the study areas, Sungai Petani and Melaka:

(1) Sungai Petani : The study area is located between two gauging stations at Penang (at Bayan Lepas) and Alor Setar, and its rainfall intensity-duration curves could be selected from those developed for two (2) gauging

stations. As shown in Fig. I-3, the rainfall intensity of Alor Setar is slightly lower than that of Penang. Hence, in order to avoid an under-estimation of rainfall intensity, the rainfall intensity-duration curves of Penang was selected as the principal curves for the study area of Sungai Petani.

(2) Melaka : The rainfall gauging station at Lanpangan Terbang Melaka (Melaka Airport) is located within the study area, and its rainfall intensity-duration curves were applied to the study area.

1.3 Model Hyetograph

The model heytographs in various return period were developed to be used for flood run-off simulation taking the following major factors into consideration:

(1) Entire Rainfall Duration

As described in the foregoing sub-section, the maximum time length of one sequence of rainfall assumed to be 12 hours, and therefore, the entire rainfall duration of model hyetograph was set at 12 hours.

(2) Temporal Variation of Rainfall Depth

The temporal variation of rainfall is one of important factors to dominate the storage volume of flood detention pond. The most critical temporal variation of rainfall for flood detention pond is such that the rainfall gradually increases reaching to the peak rainfall at the end of storm rainfall. Such temporal rainfall pattern requires the largest flood detention volume.

The actual temporal variations of peak rainfall depth were examined through hourly rainfall observed at the foregoing four (4) gauging stations. The observation period is five (5) years. As shown in Fig. I-4, more than 5% of rainfall sequences has their peak at the end of the rainfall. Thus, the occurrence of the above critical temporal variation of rainfall was confirmed in the observed rainfall data, and therefore, the pattern was applied to the model hyetographs.

(3) Areal Reduction of Rainfall

During a storm, rainfall is usually distributed unevenly over the catchment area, and tends to decrease with distance from the storm center. That is, as the coverage of drainage area increases, the area average rainfall tends to reduce from the value of point rainfall. However, the subject catchment areas in the Study has a small-size extent of $52km^2$ in maximum as described in the following Subsection 2.1. Such small size catchment area could not effect any significant difference between the point rainfall and the areal average rainfall. In fact, the "Hydrological Procedures No.12" published by DID in 1994 recommends a marginal reduction rate of less than 5% for the catchment area of less than $50km^2$. From these viewpoints, the point rainfall adopted is assumed to represent the areal average rainfall.

The model hyetographs for various recurrence probability was developed, as shown in Figs. I-5 and I-6, on the basis of the above three assumptions and the rainfall intensity-duration curves described in the foregoing subsections.

2. RUN-OFF ANALYSIS

2.1 Basin Run-off Model

The run-off simulation model consists of two items. First component is the basin run-off model to express the flood run-off discharge generated from the rainfall in the sub-basins. Second component is the channel flow model to express the propagation of channel flow discharge from upstream to downstream. The details of the basin runoff model is described in this sub-section, while the channel flow model is described in the following subsection. To facilitate the basin runoff simulation, the study area was divided into 12 groups of major river basins in total (6 for Sengai Petani and 6 for Melaka) as shown in Figs. I-6, and further, each of the groups were divided into 137 sub-basins in total (69 for Sunagi Petani and 68 for Melaka) as shown in Fig. I-7. These basin division are summarized as below:

Study Area of Sungai Petani		
Name of Major River Basins	Catchment Area (km^2)	Number of Sub-basins
1. Lalang	25	11
2. Tukang	8	7
3. Layar Besar	4	4
4. Che Bima	3	3
5. Petani	38	34
6. Pasir	23	10
Total	101	69

Study Area of Melaka		
Name of Major River Basins	Catchment Area (km^2)	Number of Sub-basins
1. Lereh	35	8
2. Malim	52	15
3. Melaka	32	17
4. Cheng	37	10
5. Putat	23	9
6. Others*	13	9
Total	191	68

* Group of drainage area directly flowing into the sea

In due consideration of the on-going drastic change of land use states in the study area, the "Quasi-Liner Runoff Simulation Model" was selected as the basin run-off model. The simulation model has a function to express differences in run-off due to variation in land use. Moreover, the model has a function to express non-liner characteristics of flow over a sloping surface . Because of the function, the model could generate not only peak discharge but also the flood hydrograph. The flood hydrograph is indispensable in this study for estimation on capacity of basin flood detention facilities.

The basic equations of the model are composed of continuity equation (Eq. 1) and storage equation (Eq. 2)

$$dS/dt = re - q \qquad \text{(Eq. 1)}$$

$$S = K \times q \qquad \text{(Eq. 2)}$$

Where; S : Storage depth of basin (mm)
re : Effective rainfall intensity (mm/hr)
q : Runoff depth (mm/hr)
K : Recession constant

The effective rainfall intensity "re" is obtained from the model hyetograph multiplied with runoff coefficient for each land use item. The runoff coefficient was determined with referring to "Urban Drainage Design Standards and Procedures for Peninsular Malaysia" as shown Table I-5.

In the above equations, the recession constant "K" was experimentally estimated from the observed data in several model basins in Japan and simply expressed as below:

$$K = Tc/2 \qquad \text{(Eq. 3)}$$

$$Tc = C \times A^{0.22} \times re^{-0.35} \qquad \text{(Eq. 4)}$$

Where; Tc : Concentration time (hr)
C : Coefficient of basin characteristics
A : Catchment Area (km^2)

The above equation (Eq. 3) was proposed by Yoshino on the basis of experiment on the relationship between actual "K" and flood lag time assuming that the concentration time of Tc corresponds to half of the flood lag time.

The equation (Eq. 4) was proposed by Kadaya on the basis of Kinematic Wave Theory. The equation could present variation of concentration time according to magnitude of effective rainfall. As for the coefficient "C" for basin characteristics in the equation, the "C" for mountainous area was firstly derived as standard value through experiment of 18 model basins. Then the "C" for other land use was estimated from the standard value through Kinematic Wave Theory. The "C" value for each land use categories are as shown in Table I-5. Since the coefficient of "C" is changed according to land use, the equation could also present variation of concentration time according to difference of land use.