HP 26

HYDROLOGICAL PROCEDURE

ESTIMATION OF DESIGN RAINSTORM IN SABAH AND SARAWAK

(REVISED AND UPDATED 2018)

BERSEKUTU BERTAMBAH MUTU

DEPARTMENT OF IRRIGATION AND DRAINAGE MALAYSIA

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
AM	Annual Maximum
ARF	Areal Reduction Factor
ARI	Annual Recurrence Interval
CCF	Climate Change Factor
CDF	Cumulative Distribution Function
D, d	Duration
D/E	Distribution and Estimation
DBMS	Database Management System
DDF	Depth Duration Frequency
DIAS	Data Integration and Analysis System
DID	Department of Irrigation and Drainage Malaysia
EV	Extreme Value
EV1	Extreme Value Type 1
EXP	Exponential Distribution
GCMs	Global Climate Models
GEV	Generalized Extreme Value
GPA	Generalize Pareto Distribution
H	Heterogeneity Test
H_1	Acceptably Homogenous
H_2	Possibly Heterogeneous
H_3	Definitely Heterogeneous
HP 26	Hydrological Procedure No. 26
i	Rainfall Intensity
IDF	Intensity Duration Frequency
IR	Inception Report
LCK	L-Coefficient of Kurtosis
LCL	Lower Confidence Level
LCS	L-Coefficient of Skewness
LCV	L-Coefficient of Variation
LMOM	L-Moments
LMRD	L-Moments Ratio Diagram
MMD	Malaysia Meteorology Department
MOM	Method of Moment
MSMA	Urban Stormwater Management Manual
NAHRIM	National Hydraulic Research Institute of Malaysia
OSLS	One-Step Least Square
PD/POT	Partial Duration/Peak over Threshold
PWM	Probability-Weighted Moments
RegHCM-SS	Regional Hydroclimate Model for Sabah and Sarawak
RMSE	Root Mean Square Error
SCS	Soil Conservation System
T1	Task 1
T2	Task 2

T3	Task 3
T4	Task 4
T5	Task 5
T6	Task 6
T7	Task 7
T8	Task 8
T9	Task 9
T	Return Period
TOR	Term of Reference
UCL	Upper Confidence Level

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PREFACE

This procedure provides a revised and updated version of the Hydrological Procedure No. 26 (HP 26,1983) for the estimation of design rainstorms in Sabah and Sarawak. The updates were based on extended data records available in the custodian of DID and selected rainfall stations managed by the Malaysian Meteorological Department (MMD).

There were 851 rainfall stations used in Sabah and Sarawak for this revised and updated version of HP26 (2018) which consisted of 473 and 378 automatic and manual (daily) recorded stations respectively. Of the 473 automatic recorded rainfall stations registered and managed by DID, however, only 164 stations had been used in the Intensity-Duration Frequency (IDF) analysis. In addition, ten (10) rainfall stations operated by MMD were used for accomodating the above-mentioned 164 IDF-rainfall stations maintained by DID. Furthermore, only 139 stations of the 378 manual (daily) rainfall stations were used in the estimation of design rainstorms for the long durations (24-hr, 48-hr and 72-hr).

An established approach involving the means of the annual maximum series (AM) was used for the rainfall frequency model determination. The Method of Moment (MOM) was reviewed and the L-Moments (LMOM) approach was introduced to derive the parameter distribution. The parameter of the selected distribution of the AM model was chosen from the most appropriate parameter estimator based on the distribution and estimation procedure (D/E). The most appropriate D/E model for the proposed rainfall frequency model (AM model) was found to be the 2P-EV1/LMOM.

Intensity-Duration Frequency (IDF) relationship (duration, magnitude of design rainstorm-rainfall intensity and return period) was specifically formulated for the gauged sites in Sabah and Sarawak. The IDF parameters (λ, κ, θ and η) derived from these gauged sites, however, were generalized for producing the IDF parameter gridded maps that were presented in 10 and 20 km spatial resolution.

In relation to the temporal storm profiles, the numerical clustering analysis was performed using the 1-day duration rainfall of 165 selected automatic recording stations for creating the hydrologic region and this has resulted in the formation of 9 distinctive regions in Sabah and Sarawak. Moreover, the derivation of temporal storm profiles by means of the alternating block method were developed using 5,940 selected storm events with durations of 0.25-hr to 72-hr from the 132 automatic rain gauge stations

The required Areal Reduction Factor (ARF) for Sabah and Sarawak was derived in accordance to the *United State Weather Bureau* (USWB) method as this method has been widely utilized by practitioners in stormwater designs and applications. The ARF ratio-area-duration relationship has been developed by using the Region 2, and Region 5 and 8 in Sarawak and Sabah respectively. In this context, the hypothetical catchment areas consisted of 100 to 5,000 km^2 and duration of rainfall covers 0.5-hr to 72-hr were applied.

The Climate Change Factor (CCF) was developed to estimate the design rainstorm with considerations of the potential climate change scenarios in Sabah and Sarawak. This study utilized the statistical downscaling of 22 Global Climate Models (GCMs), and dynamic downscaling of Regional Hydroclimate Model of 3 GCMs for Sabah and Sarawak (RegHCM-SS) in relation to the IPCC Special Report on Emissions Scenarios (SRES) A1B. The derived CCF values corresponding to the return periods of 2 to 100 years ARI were generalised in 10 and 20 km spatial resolution gridded maps.

In view of unavoidable study limitations, it is worth noting that there are a few main elements identified. One of these is the adequacy of more than 50 years recorded rainfall data for design rainstorm estimation at high return periods. Theoretically, at least 50 years' available record length is required for the estimation of 100 years ARI. However, only about 87 stations satisfy this condition. In relation to the ARF derivation, only 3 regions were utilised for the analysis and is mainly due to limited number of rainfall stations available, particularly at interior areas. Subsequently, the empirical method (US Weather Bureau method) that was used to derive the fixed-area ARF, is limited to produce only a single value of a given area and duration, and could not estimate the ARF as a function of annual exceedance probability or return period. As for the temporal storm profiles, it apparently shows that rainfall events exceeding return period of 50-years and 100-years are barely available. Under this circumstance, the methodology used probably has limited ability for producing design hyetograph at high return periods for more than 50 years.

In conclusion, the results of analyses in this revised and updated Hydrological Procedure No. 26 (HP26, 2018) can be categorically stated that they serve as a guideline for the estimation of design rainstorms at gauged and ungauged sites in Sabah and Sarawak. The approach and methodology are explained, as well as the worked examples which illustrate the application of methodology are prescribed in this hydrological procedure.

THE REVISED AND UPDATED HYDROLOGICAL PROCEDURE NO. 26 (HP 26)
ESTIMATION OF DESIGN RAINSTORM IN SABAH AND SARAWAK

PART 1 - PROCEDURES AND METHODOLOGY

1. INTRODUCTION

1.1. OVERVIEW

The ultimate objective of the revsionary works carried out is to present this hydrological procedure in its latest version of the revised and updated HP 26 (1983), based on data available in the custodian of the DID with the extended data record up to 2016, as well as utilising a list of selected rainfall stations managed by the Malaysian Meteorological Department (MMD). The revised analyses and calculations adopted the most appropriate and suitable methods that are presented in simple and easy ways, such as the derived graphs, tables and maps.

This procedure introduces a new approach for estimating the design rainstorm in Sabah and Sarawak by means of the intensity-duration-frequency (IDF) formulation at gauged sites. This procedure also enables the estimation of the design rainstorm and intensity at ungauged locations and at specific catchments or river basins. Also included in the procedure are a new derivation of areal reduction factor (ARF), temporal storm profile, and climate change factor (CCF).

This procedure is divided into three main parts:

Part 1 covers Chapter 1 to 3 which consists of the Introduction, Approach and Methodology, and Assessment of the Methodology. These chapters explain the process of data analysis, determination of rainfall frequency model and method of estimating model parameters. Also the methodology assessment, and model robustness study, related to model distribution and estimate procedure (D/E) is given.

Part 2 covers Chapter 4 to 7 which consists of the Estimation of Design Rainstorm and Intensity at gauged and ungauged sites, temporal storm profiles and areal reduction factors (ARF) and developing the climate change factor (CCF). These chapters explain and present the findings for the appropriate topics mentioned.

Part 3 covers Chapter 8 and 9 which consists of worked examples for determining and estimating design rainstorm and rainfall intensity, the application of areal reduction factor (ARF), temporal storm profile and climate change factor at gauged and ungauged site and catchment level.

1.2. PURPOSE OF THE PROCEDURES

Basically, the rainfall frequency procedures involve the estimation of design rainfall depth (rainstorm depth) and rainfall intensity, and also to determine the rarity of observed rainfall events. Design rainstorms are required normally for river flood estimation, where they are an important component in the design of flood mitigation, and are used for the subsequent design of bridges, culverts and others hydraulic related structures. Other application for the design rainstorms covers the designs in the agriculture irrigation system and pumping stations as well as in the sewerage design for built-up areas and drainage for building and also for road infrastructures etc.

Determining the rarity of extreme observed rainfall events, however, are particularly useful for the meteorologist, hydrologist, and people affected by these events. This determination are also often carries important benefits for the assessment of rarity of floods. Thus, the comparison of occurrence likelihood for different rainstorm events for the purpose of optimal drainage designs and flood risk analysis could be determined.

1.3. CONTEXT

This revised and updated Hydrological Procedure No. 26 – Estimation of Design Rainstorm in Sabah and Sarawak (HP26, 2018) replaces the approach and methods presented in HP26 (DID, 1983) where the results have previously been widely used in Sabah and Sarawak for more than 35 years regardless of insufficient record length and the inadequacy of rainfall station density had been used in the published procedure. The said limitations has been resolved by means of additional rainfall stations with adequate record length and data availability utilised throughout Sabah and Sarawak. The new development of temporal storm profile and dedicated areal reduction factor (ARF) based on the accepted homogenous hydrologic regions for Sabah and Sarawak replaces the adopted method and values given in the HP26 (1983). As for quantifying the exacerbation of future climate change condition due to global warming impacts, the load “design safety” factor of climate change namely climate change factor (CCF) was developed. The CCF was purposely prepared for cushioning the potential impacts of climate change scenario that effects frequency, magnitude, intensity and rarity of future extreme rainfall events. Therefore, the CCF is required to be incorporated in the estimated design rainstorm and rainfall intensity. A dedicated chapter about this issue is explained in Chapter 7.

1.4. OUTLINE OF THE ANALYSIS

The procedures analyses were carried out based on available data from the existing network of rainfall stations, respectively in Sabah and Sarawak. Preliminary analysis involved 963 stations where of these, 190 stations and 773 stations are located in Sabah and Sarawak, respectively. All the stations were checked for consistency, adequacy and available records, and possible outliers. Finally, 165 of automatic rainfall stations in the custodian of the DID and 10 stations managed by the Malaysian Meteorological Department (MMD) were utilised in the analysis. Apart from this another 132 manual rainfall stations were used in the estimation of design rainstorm for long durations.

All the works carried out in this procedure such as data mining, rainfall frequency model determination and parent distribution, parameter estimation method, estimation of design storm, IDF construction and formulation, derivation of temporal storm profile, derivation of areal reduction factor, and climate change factor development are explained in Part 1 – Procedures and Methodology described from Chapters 1 to 3.

In order to achieve the objectives of the proposed approach and methodology as described in Chapter 2 and 3 particularly, and also the expected finding as presented in Chapter 4 to 7, the procedure has been organized and designed as depicted in Figure 1.1 – Flowchart summary for the estimation of design rainstorm and related analysis in Sabah and Sarawak. Figure 1.2 shows the location of 174 rain gauges stations that were used in the new published procedure for the IDF model and related rainstorm analysis.

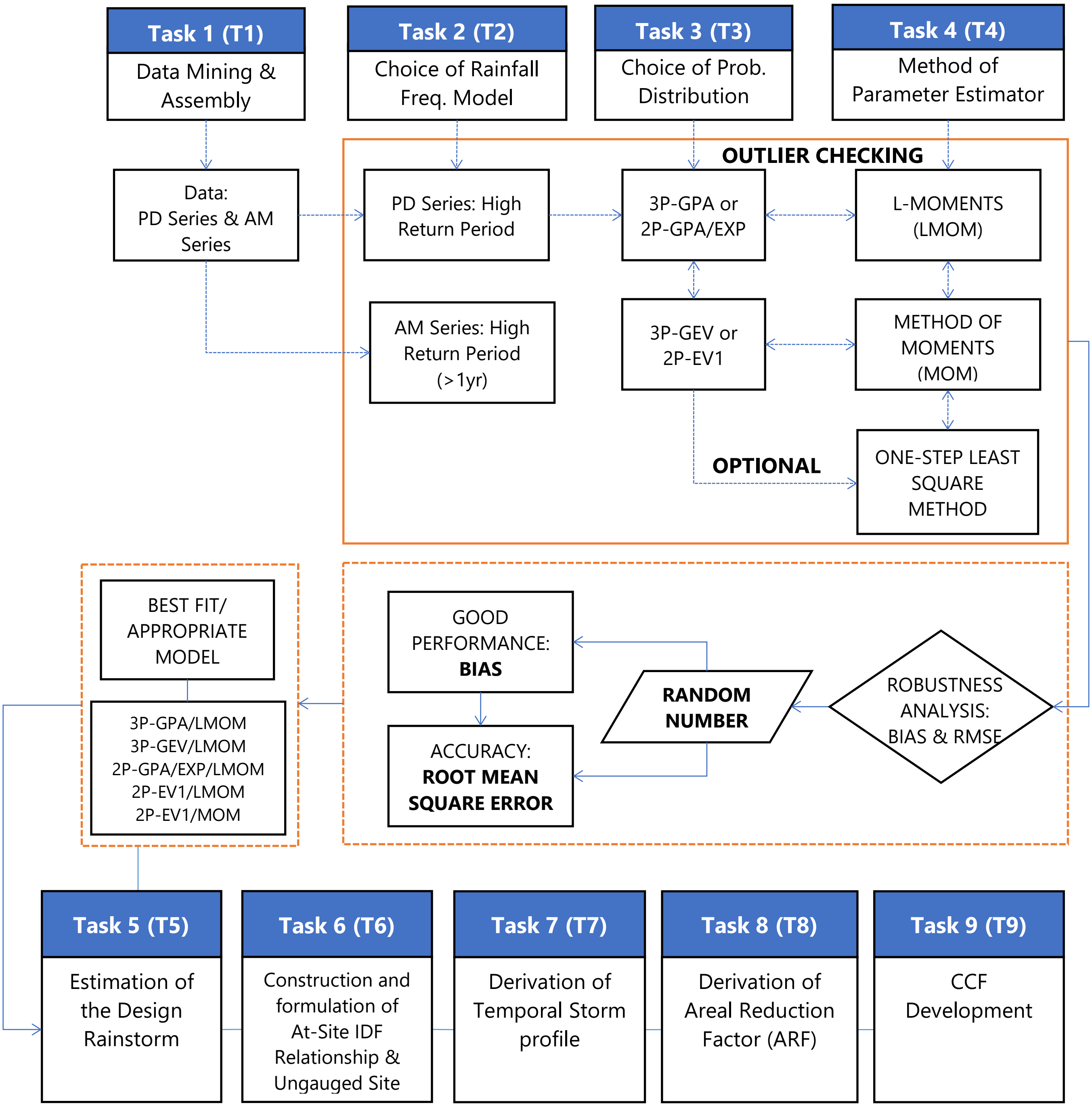


Figure 1.1: Flowchart Summary for The Estimation of Design Rainstorm And Related Analysis.

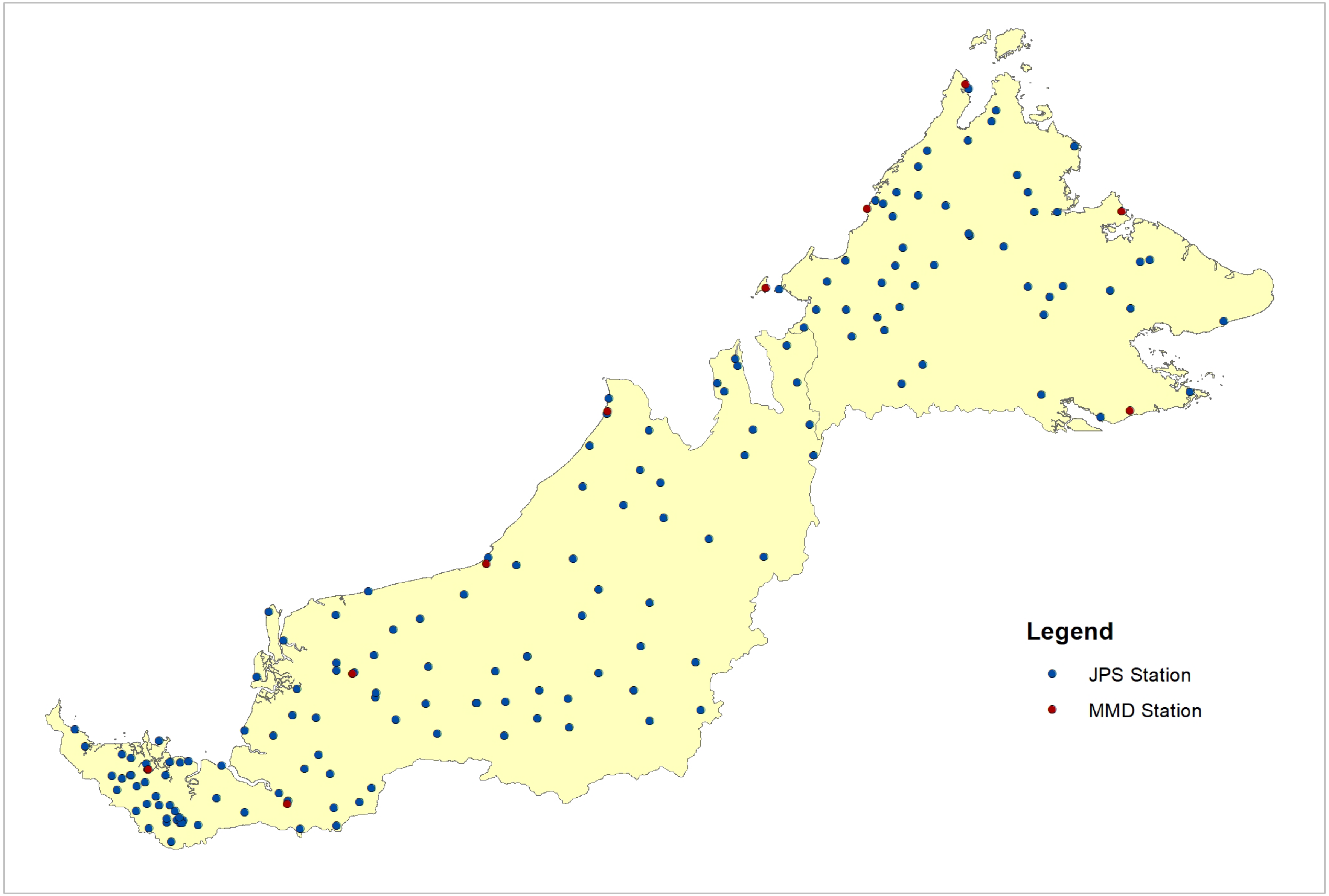


Figure 1.2: Location of Rain Gauge Stations Throughout Sabah and Sarawak.

2. APPROACH AND METHODOLOGY

2.1. DATA ACQUISITION AND MINING

Errors in rainfall data can be inadvertently be introduced at several stages and due to inevitable actions: at the rain gauge, problems can be caused if the gauge is poorly sited, splashing of rainfall in and out, or losses due to high winds and vandalism. Human errors or technical failures are always possible, both in reading the gauge and in archiving the results. Data mining that focus on data checking and screening aimed to identify and investigate suspicious annual maximum series (AM) or partial duration series (PD) of rainfall data.

AM or PD data series abstracted from continuously hourly and daily data would be checked against nearby daily totals. The hourly data would be compare with totals for the day on which the maximum was recorded, from the nearest daily gauges. Any suspicious large hourly totals would be investigated further by inspection of the continuous data from which the AM or PD will abstract. The most suspicious data either from the AM or PD would be statistically tested for the outlier. Thus, the identified outliers (low or high outliers) could be excluded from the analysis. The PD series focused on independency of the data retrieved or abstracted, in order to ensure no overlapping for each of maxima data.

2.2. RAINFALL FREQUENCY MODELS DETERMINATION

Two general approaches are available for modelling flood, rainfall, and many other hydrologic series. One is recognized as an annual maximum series (AM) that considers the largest event in each year; and second is using a partial duration series (PD) or peak-over-threshold (POT) approach in which the analysis includes all peaks above a truncation or threshold level. An objection to using AM series is that it employs only the largest events in each year, regardless of whether the second largest event in a year exceeds the largest events of other years. Moreover, the largest annual maxima in a dry year that is addressed as a storm is misleading. Furthermore, if hydrometric records have insufficient records length, it will affect the accuracy of estimation particularly at high return period. According to Cunnane (1989), the AM series has received widespread attention not due to objective manner but argued in general manner whether it is widely accepted, simple and convenient to apply.

The PD series analyses avoids such problems by considering all dependent peaks, which exceed a specified threshold. Stedinger *et. al*., (1993) cited that arguments in favour of PD series are that relatively long and reliable PD series records are often available, and if the arrival rate for peaks over threshold is large enough (1.65 events/year for the Poisson arrival with exponential exceedance model), PD series analyses should yield more accurate estimates of extreme quantiles than the corresponding annual-maximum frequency analysis. Still, a drawback of the PD series analyses is that one must have criteria to identify only independent peaks (and not multiple peaks corresponding to the same event). However, to avoid counting any multiple peaks in the same event, an independency criterion has to be incorporated to distinguish dependant rainfall events that lead to the same effect. Vaes (2000) has specified that a rainfall volume is independent if in a certain period antecedent and posterior to the considered rainfall volume no larger than or equal rainfall volume occurs. For this period, the maximum between 12-hours and the aggregation period is assumed.

Statistically, if we denote the estimate of R_T obtained by the AM series as $\overline{R}_T$ and that obtained from the same hydrometric record by the PD method as $\overline{R}_T^*$, it is usually observed that these two estimates are unequal. Furthermore the sampling variance of $\overline{R}_T$ is not equal to that of $\overline{R}_T^*$, i.e. var ($\overline{R}_T$) ≠ var ($\overline{R}_T^*$). From a statistical point of view, the method which has the smallest sampling variance enjoys an advantage. Cunnane (1973) examined the relative values of var($\overline{R}_T$) and var($\overline{R}_T^*$) and found that var($\overline{R}_T$) $<$ var($\overline{R}_T^*$) provided $\lambda<1.65$ where λ is the mean number of peaks per year included in the PD series. If $\lambda > 1.65$, the opposite is true. This shows that the AM method is statistically efficient when λ is small and less efficient when λ is large. These results have been re-examined by Yevjevich and Taesombut (1978) who suggested a value of $\lambda > 1.8$ or 1.9 may be required to ensure greater efficiency of PD estimates of $\overline{R}_T$.

2.3. DISTRIBUTION OF RAINFALL FREQUENCY MODELS DETERMINATION

2.3.1. CANDIDATES OF THE AM MODEL

This is a general mathematical form which incorporates the Gumbel's type I, II and III of extreme value distributions for maxima. The GEV distribution's CDF can be written as:

$$F(x) = \exp\left\{-\left[1 - \frac{\kappa(x-\xi)}{\alpha}\right]^{1/\kappa}\right\} \qquad \text{for } \kappa \neq 0 \qquad (2.1)$$

The Gumbel (EV1) distribution is obtained when $\kappa = 0$. For $|\kappa| < 0.3$, the general shape of the GEV distribution is similar to the Gumbel (EV1) distribution, though the right-hand tail is thicker for $\kappa < 0$ and thinner for $\kappa > 0$. The Gumbel (EV1) distribution's CDF can be written as:

$$F(x) = \exp[\,-\exp\{-(-x-\xi)/\alpha\} \qquad \text{for } \kappa = 0 \qquad (2.2)$$

Here ξ is a location parameter, α is a scale parameter, and κ is the important shape parameter. For $\kappa > 0$ the distribution has a finite upper bound at $\xi + \alpha/\kappa$ and corresponds to the EV type III distribution for maxima that are bounded above; for $\kappa < 0$, the distribution has a thicker right-hand tail and corresponds to the EV type II distribution for maxima from thick-tailed distribution like the Generalized Pareto distribution with $\kappa < 0$. The parameters of the GEV distribution in term L-moments are:

$$\kappa = 7.8590c + 2.9554c^2 \qquad (2.3)$$

$$\alpha = \frac{\kappa\lambda_2}{\Gamma(1+\kappa)(1-2^{-\kappa})} \qquad (2.4)$$

$$\xi = \lambda_1 + \frac{\alpha}{\kappa[\Gamma(1+\kappa)-1]}$$

(2.5)

where

$$c = \frac{2\lambda_2}{(\lambda_3 + 3\lambda_2)} - \frac{\ln(2)}{\ln(3)} = \frac{2\beta_1 - \beta_o}{3\beta_2 - \beta_o} - \frac{\ln(2)}{\ln(3)} \qquad (2.6)$$

The parameters of the Gumble (EV1) distribution in term L-moments are:

$$\alpha = \frac{\lambda_2}{ln2} \tag{2.7}$$

$$\xi = \lambda_1 - 0.5772\alpha \tag{2.8}$$

The quantiles of the GEV and Gumble (EV1) distribution can be calculated from Equation (2.9) and (2.10), respectively.

$$X_T = \xi + \frac{\alpha}{\kappa}\left\{1 - \left[-\ln(F)\right]^{\kappa}\right\} \tag{2.9}$$

$$X_T = \xi - \alpha \ln(-log\, F) \tag{2.10}$$

where $F = 1 - \frac{1}{T}$ is the cumulative probability of interest. When data are drawn from a Gumbel distribution ($\kappa = 0$), using the biased estimator b_r^* in Equation (2.12) to calculate the L-moments estimators in Equations (2.13) to (2.16), the resultant estimator of κ has a mean of 0 and variance $Var(\kappa) = \frac{0.563}{n}$. Comparison of the statistic $Z = \hat{\kappa}\sqrt{\frac{n}{0.563}}$ with standard normal quantiles allows construction of a powerful test of whether $\kappa = 0$ or not when fitting with a GEV distribution.

2.3.2. L-MOMENT RATIO DIAGRAM

As cited by Murray C. Peel *et al*. (2001), Hosking (1990) noted the benefits of L-moment ratios over product moment ratios in that the former are more robust in the presence of extreme values and do not have sample size related bounds. This has led to the recommendation that L-moment ratio diagrams should always be used in preference to product moment ratio diagrams in hydrological analysis (Vogel & Fennessey 1993).

L-moment ratio diagrams have been suggested as a useful tool for discriminating between candidate distributions to describe regional data (Murray *et al*, 2001). Generally, the distribution selection process, using L-moment ratio diagrams, involves plotting the sample L-moment ratios as a scatterplot and comparing them with theoretical L-moment ratio curves of candidate distributions. They are constructed by plotting sample L-moment ratios against each other (e.g. L-skewness versus L-CV or L-skewness versus L-kurtosis). Two graphical tools used to assist in distribution selection are the sample average and a line of best-fit through the sample L-moment ratios. Figure 2.1 shows the probability distributions in L-moment ratio diagrams for Sabah and Sarawak.

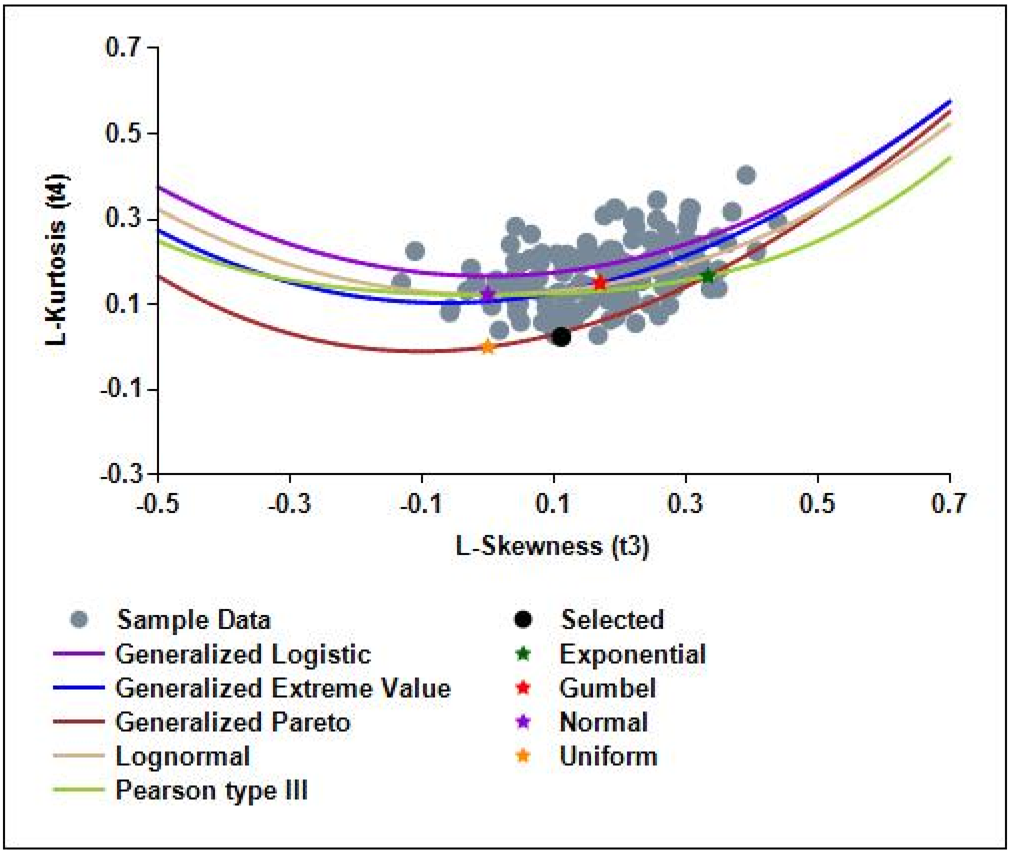


Figure 2.1: Probability Distributions in the L-moment Ratio Diagrams for Sabah and Sarawak.

2.4. PARAMETER ESTIMATION METHOD

Just as the variance, or coefficient of skewness, of a random variable are functions of the moments E(X), $E(X^2)$, and $E(X^3)$, L-moments can be written as functions of probability-weighted moments (PWMs), which can be defined as:

$$\beta_r = E\{X[F(X)]^r\} \tag{2.11}$$

where F(X) is the CDF for X. Probability-weighted moments are the expectation of X times powers of F(X). For r=0, β_o is the population mean μ_X. Estimators of L-moments are mostly simply written as linear function of estimators of PWMs. The first PWM estimator b_o of β_o is the sample mean $\overline{X}$. To estimate other PWMs, one employs the ordered observations, or the order statistics $X_{(n)} \le ..... \le X_{(1)}$, corresponding to the sorted or ranked observation in a sample $(X_i | i = 1,....,n)$. A simple estimator of β_r for $r \ge 1$ is

$$b_r^* = \frac{1}{n}\sum_{j=1}^{n} X_{(j)}\left[1 - \frac{(j-0.35)}{n}\right]^r \tag{2.12}$$

where $1 - \frac{(j-0.35)}{n}$ are estimators of $F(X_{(j)})$. b_r^* is suggested for use when estimating quantiles and fitting a distribution at a single site. Although it is biased, it generally yields smaller mean square error quantiles estimators than the unbiased estimators as in equation below. When unbiasedness is important, one can employ unbiased PWM estimators as:

$$b_o = \overline{X} \tag{2.13}$$

$$b_1 = \sum_{j=1}^{n-1} \frac{(n-j)X_{(j)}}{n(n-1)} \tag{2.14}$$

$$b_2 = \sum_{j=1}^{n-2} \frac{(n-j)(n-j-1)X_{(j)}}{n(n-1)(n-2)} \tag{2.15}$$

$$b_3 = \sum_{j=1}^{n-3} \frac{(n-j)(n-j-1)(n-j-2)X_{(j)}}{n(n-1)(n-2)(n-3)} \tag{2.16}$$

These are examples of the general formula:

$$\hat{\beta}_r = b_r = \frac{1}{n}\sum_{j=1}^{n-r} \frac{\binom{n-j}{r} X_{(j)}}{\binom{n-r}{r}} = \frac{1}{(r+1)}\sum_{j=1}^{n-r} \frac{\binom{n-j}{r} X_{(j)}}{\binom{n}{r+1}} \tag{2.17}$$

for $r = 1,......,n-1$ (which defines PWMs in terms of powers of *(1-F)*; this formula can be derived using the fact that $(r+1)\beta_r$ is the expected value of the largest observation in a sample of size $(r+1)$. The unbiased estimators are recommended for calculating L-moments diagrams and for use with regionalization procedures where unbiasedness is important. For any distribution, L-moments are easily calculated in term of PWMs from:

$$\lambda_1 = \beta_o \tag{2.18}$$

$$\lambda_2 = 2\beta_1 - \beta_o \tag{2.19}$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_o \tag{2.20}$$

$$\lambda_4 = 20\beta_3 - 30\beta_2 + 12\beta_1 - \beta_o \tag{2.21}$$

2.5. ESTIMATION OF DESIGN RAINSTORM AND RAINFALL INTENSITY

The estimated parameters of the chosen probability distributions as carried out in Task 5 (T5), will lead to the possibility of calculating quantile estimation of design storm and rainfall intensity for low and high return period. It can be calculated from the proposed Equation (2.22) associated with return period, *T*, and duration, *d*.

$$i = \frac{\alpha\{\xi - \ln[-\ln(1-1/T)]\}}{(d+\theta)^{\eta}} \tag{2.22}$$

The calculated quantiles estimation at high return period (with respect to *T*=2, 5, 10, 20, 50 and 100-year return period) is definitely to enhance and improve the rainfall intensity design values of the existing HP 26 and integral for the construction of IDF relationship for the entire gauged and ungauged sites of Sabah and Sarawak.

However, Jagtap (2014) indicated that the estimated values for the different return periods are more reasonable and reliable with the increases in the length of records. The uncertainty in the projected extreme events will increase as the return period approaches the length of the data available and will further increase as the return period exceeds the length of the data series. Additionally, Nagy (2017) suggested that at least 50 years of annual maxima data series required to estimate a 100-year design.

2.6. CONSTRUCTION AND FORMULATION OF AT-SITE IDF CURVE

The formulation of a mathematical expression on the at-site IDF relationships is definitely for the benefit of the users and that will assist them to calculate the quantiles estimation in easier and efficient way. To give estimation precisely and for minimizing the error of estimates due to the chosen mathematical expression, we have used general Equation (2.23) to be adopted as general mathematical formulation of the IDF relationship. Under this circumstance, for the specified formulation, the Gumbel (EV1) distribution can be explicitly performed using the Equations (2.22). This proposed IDF formulation is in-line with the formula adopted in HP 1 (DID, 2010).

IDF relationship is a mathematical relationship between the rainfall intensity *i*, the duration *d*, and the return period *T* (or, equivalently, the annual frequency of exceedance, typically referred to as 'frequency' only) (Koutsoyiannis *et al.* 1998).

The general IDF relationship is given in Equation (2.23), which has the advantage of a separable functional dependence of *i* on *T* and *d*.

$$i = \frac{a(T)}{b(d)} \tag{2.23}$$

The function of *b(d)* is $b(d) = (d + \theta)^{\eta}$ where θ and η are parameters to be estimated (θ>0, 0<η<1). The function of *a(T)*; however, could be determined from the probability distribution function of the maximum rainfall intensities *I(d)*. Therefore, if the intensity *I(d)* of a certain duration d has a particular distribution $F_{I(d)}(i;d)$, yields the distribution of variable $X \approx I(d)b(d)$, which is no more than the intensity rescaled by *b(d)*. The function of *a(T*), however, as for simplicity used, can be expressed in Bernard (1932) equation in the form of $a(T) = \lambda T^k$. Finally, the Equation (2.24) can be transformed in general term as follow:

$$i = \frac{\lambda \mathrm{T}^k}{(d + \theta)^{\eta}} \tag{2.24}$$

Equation (2.24) has been used to formulate the gauged IDF relationship and the derived parameters of λ, K, θ and η has been generalized for the construction of ungauged IDF relationship. The required IDF model parameters of λ, K, θ and η are derived using simultaneous solution by means of One-Step Least Square (OSLS) method.

This method is chosen due to its ability to solve functions $a(T)$, and $b(d)$ simultaneously. To this aim, an empirical return period can be assigned using the Gringorten plotting formula $T_{jl} = \frac{n_j + 0.12}{l - 0.44}$ to each data value i_{jl} (j refer to a particular duration *d*, $j = 1,.....k$; l denoting the rank, $l = 1,......n_j$ where n_j is the length of the group j). Each data will have a triplet of numbers (i_{lj}, T_{lj}, d_j) and results the intensity model as $\hat{i}_{jl} = \frac{a(T_{jl})}{b(d_j)}$. The corresponding error could be measured as $e_{jl} = \ln i_{jl} - \ln \hat{i}_{jl} = \ln\left(i_{jl} / \hat{i}_{jl} \right)$.

The overall mean square error is $e^2 = \frac{1}{k}\sum_{j=1}^{k}\frac{1}{n_j}\sum_{l=1}^{n} e_{jl}^2$ which lead into an optimization procedure defined as will minimize $e = f_2(\eta, \theta, \kappa, \alpha, \xi)$. Simultaneous solution to perform the optimization as defined can be executed using the embedded solver tools of common spreadsheet package.

2.7. DEVELOPING THE INTENSITY-DURATION FREQUENCY (IDF) RELATIONSHIP – GAUGED SITES

As explained in Section 2.5, the formulation of IDF relationship was constructed based on Equation (2.24). This equation has been formulated based on formula derived by Koutsoyiannis (1998) and Bernard (1932).

General term of the IDF relationship or recognized as an empirical formula is finally in the form of $i = \frac{\lambda T^k}{(d + \theta)^\eta}$. The required IDF model parameters of λ, K, θ and η were derived using simultaneous solution of the embedded MS Excel SOLVER by means of One-Step Least Square (OSLS) method.

2.8. DESIGN STORM PROFILES (TEMPORAL STORM) DEVELOPMENT

A variety of methods to generate design storm hyetograph exist in the literature, but as cited by Veneziano and Villani (1999), one of the most practical methods is the use of standardized profiles obtained directly from historic rainfall records which is able to reduce a rainfall event to a dimensionless curve by dividing time by the total duration of the event and cumulative rainfall by the total rainfall volume (i.e. as appeared in the existing procedure and has directly been adopted in the MSMA).

The use of standardized rainfall profiles is quite common in the hydrology literature. Prodanovic and Simonovic (2004) cited that the most popular are those of Huff (1967) and SCS (1986). Standardized profiles, also known as mass curve, transform a precipitation event to a dimensionless curve with cumulative fraction of storm time on the horizontal and cumulative fraction of total rainfall on the vertical axis. Since rainfall records are highly variable because of the uncertainty of what actually constitutes a rainfall event, as well as randomness of the rainfall phenomena itself, the standardized profiles method must use some sort of temporal smoothing, or assemble averaging.

The Soil Conservation System (SCS) hypothetical storm method uses standardized rainfall intensities arranged to maximize the peak runoff at a given storm depth. Although primarily it has been used for the design of small dams, it has been applied in many rural and urban areas. The required input parameters are distribution type and total storm depth.

The main appeal of this category of design rainstorm/rainfall intensity hyetographs method is that the resulting output is based on the actual data of intense regional rainfall. Furthermore, as the methods do not rely on IDF data, rainfall exceeding return period of 100-years can be easily used, if available. In the context of available records of rainfall data managed by DID, it apparently shows that the maximum length of historic rainfall records in Sabah and Sarawak are mostly found to be about 20-30 years and 50-60 years, respectively. Under these circumstances, the mentioned methodology probably has limited ability for producing design hyetograph at high return period for more than 50 years. This method also requires large sample data sets for the construction of regional profiles, which in turn generates large uncertainties. Therefore, temporal smoothing needs to be performed and some of the important rainfall features at the locality of interest might be overlooked.

2.8.1. CLUSTERING ANALYSIS

The identification of the spatial pattern of rainfall is usually an essential need for water resources planning and management. However, the rainfall variability from year to year and from place to place is usually difficult to be fully recognized. Therefore, many present-day hydrologic and climatic studies are performed to find and develop methods for the regionalization of hydrologic and climatic variables.

Regional classification of these variables helps scientists to simplify the hydro-climatic convolution and therefore reduce the massive body of information, observation and variables.

Several methods are commonly used for the regionalization of hydro-climatic variables such as rainfall and other components of the water cycle. Cluster analysis is a multivariate analysis technique or procedure in order to organize information of variables to form relatively homogeneous groups, or “cluster”.

The aim of using cluster analysis with hydrologic variables is to group observations or variables into clusters based on the high similarity of hydrologic features, such as geographical, physical, statistical or stochastic properties. In this way, each cluster contains the least variance of variables (smallest dissimilarity). There are several types of cluster analysis such as K-Means Cluster Analysis and Hierarchical Cluster Analysis.

In this study, regions were formed through the K-Means Cluster Analysis method to identify homogeneous groups of cases which are based on selected site characteristics by using an algorithm that can handle a large number of cases. A data vector is associated with each site, and sites are partitioned into groups according to the similarity of their data vectors that can include at-site statistics, site characteristics or combination of these two. However, in this clustering analysis, only site characteristics are selected, and did not involve any at-site statistics measuring the shape of the frequency distribution of rainfall. The site characteristics used in this study are latitude, longitude, mean annual rainfall and elevation. When cluster analysis is based on site characteristics, the at-site statistics are available for use as the basis of an independent test of the homogeneity of the final regions.

Most clustering algorithms measure similarity by the reciprocal of Euclidean distance in a space of site characteristics. This distance measure is affected by the scale of measurement or rescale of the site characteristics in order to have the same amount of variability, as measured by their range or standard deviation across all of the sites in the data set. There is no ‘correct’ number of clusters and no assumption that there are distinct clusters of sites that satisfy the homogeneity condition, but instead a balance must be sought between using regions that are too small or too large. The output from the cluster analysis need not be final because some subjective adjustment can be done in order to improve the physical coherence of the regions and to reduce the heterogeneity of the regions that is measured by the heterogeneity test, H.

The clustering analysis is aimed to form relatively homogenous ‘groups’ or ‘regions’ that are able to accommodate and creates new regions for the storm profiles or storm temporal pattern.

2.8.2. HOMOGENIETY MEASURE (H)

Hosking and J. R. Wallis (1993, 1997) derived the heterogeneity statistics for estimation of the degree of heterogeneity in a group of sites. For heterogeneity test of a group, a four-parameter kappa distribution is fitted to the regional data set generated from series of 500 equivalent region data by numerical simulation. The test compares the variability of the L-Statistics of the actual region to those of the simulated series.

There are three heterogeneity measurements (Hi), namely (H_1), (H_2), and (H_3), which are calculated using the following equation:

$$H_i = (V_i - \mu_v)/\delta_v \quad (2.25)$$

Where μV and σV are the mean and standard deviation of N_{sim} values of V, N_{sim} is the number of simulation data; V_{obs}, is calculated from the regional data and is based on the corresponding V-statistic, defined as follows:

$$V_1 = \sum_{i=1}^{N} (n_i(L - CV_i - \overline{LCV})^2)/\sum_{i=1}^{N} n_i \quad (2.26)$$

$$V_2 = \sum_{i=1}^{N} (n_i[(L - CV_i - \overline{LCV})^2 + (\tau_{3i} - \bar{\tau})^2]^{\frac{1}{2}})/\sum_{i=1}^{N} n_i \quad (2.27)$$

$$V_3 = \sum_{i=1}^{N} (n_i[(\tau_{3i} - \bar{\tau}_3)^2 + (\tau_{4i} - \bar{\tau}_4)^2]^{\frac{1}{2}})/\sum_{i=1}^{N} n_i \quad (2.28)$$

On the basis of Homogeneity measurements, a region is declared acceptably homogenous when H<1, possibly heterogeneous when 1≤H<2 and definitely heterogeneous when H≥2. H values greater than 2 indicates that it lies in the upper threshold for acceptably heterogeneous clusters. Further clustering and subjective adjustments could be necessary for the clusters which are heterogeneous (H>2) (Smithers & Schulze, 2002).

2.9. DEVELOPMENT OF THE AREAL REDUCTION FACTOR (SPATIAL CORRECTION FACTOR)

Sriwardena and Weinmann (1996) described that one of the methods available for deriving the fixed-area areal reduction factors is an empirical method. In empirical methods, recorded rainfall depths at a number of stations within a 'catchments' are used to derive the ARFs empirically.

In this study, the USWB method is used for the derivation of the ARF for Sabah and Sarawak as this method has been widely utilized by local practitioners in stormwater designs and applications, and it was assumed that the ARF is not under the influence of AEP. The ARF estimated from this study is comparable with the ARF derived in *WRP 17* (1986) as a similar method has been adopted to derive the ARF.

The mathematical algorithm for the USWB method is shown in Equation (2.29). The ARF is estimated by taking the ratio of maximum areal rainfall to maximum point rainfall of a particular year and hypothetical area and a single value of ARF is obtained by taking the average over the entire study period.

$$ARF = \frac{N\sum_{i=1}^{N}\sum_{j=i}^{n} w_i \bar{\bar{P}}_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{n} P_{ij}} \qquad (2.29)$$

where *N* refers the number of stations, *n* is the record length (years) and $\bar{\bar{P}}_{ij}$ is the point rainfall for station *i* on the day of the annual maximum areal rainfall in a year *j* (mm), P_{ij} is the annual maximum point rainfall of station *i* in year *j* (mm) and w_i is the thiesen weighted factor for station *i*.

2.10. DEVELOPMENT OF THE CLIMATE CHANGE FACTOR (CCF)

In the context of rainfall, the climate change load factor is defined as the ratio of the projected design rainfall for the future to the control period (historical). The Extreme Value Type 1 (EV1) by means of at-site approaches is used to calculate the return periods of maximum daily rainfall events with return periods of 2, 5, 10, 20, 25, 50 and 100 years. Extreme value analysis is a statistical method that may be used to characterize the probability and magnitude (return level) of events that are more extreme than any that exists in a given data series (Coles, 2001). For example, a 20-year observation record could be used to estimate the return level of an event with a return period of 1 in 100 years.

The estimation of the return levels of rainfall and the derivation of rainfall climate change factor is adopted from NAHRIM (2013) and can be summarized in the flowchart as shown in Figure 2.2.

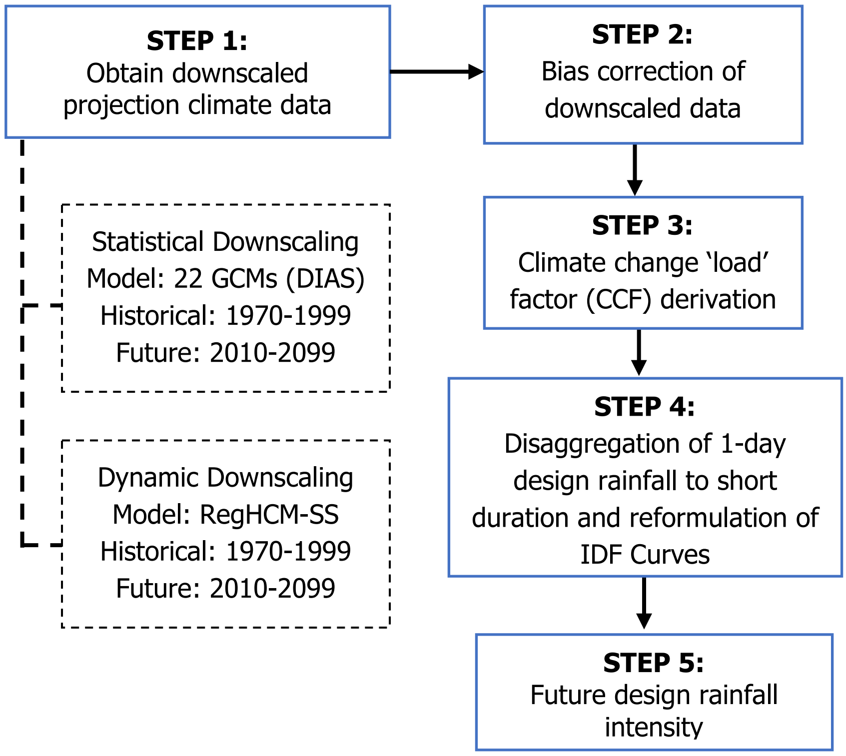


Figure 2.2: Process of the Derivation of Climate Change Load Factor (CCF).

The 1-day climate change load factor (CCF) associated with the return periods can be defined as a ratio of the design rainfall for the future period to the control period, and it can be written in the form of:

$$\mathrm{CCF}_{1\mathrm{d}}^{\mathrm{T}} = \frac{{}_{SF}R_{1\mathrm{d}}^{\mathrm{T}}}{{}_{SH}R_{1\mathrm{d}}^{\mathrm{T}}} \tag{2.30}$$

where ${}_{SF}R_{1\mathrm{d}}^{\mathrm{T}}$ is simulated future 1-day and ${}_{SH}R_{1\mathrm{d}}^{\mathrm{T}}$ is simulated historical 1-day design of control period with respect to return periods.

This study utilized the statistical downscaling of 22 Global Climate Models (GCMs), and the dynamical downscaling of Regional Hydroclimate Model of 3 GCMs for Sabah and Sarawak (RegHCM-SS) in relation to the IPCC Special Report on Emissions Scenarios (SRES) A1B. The CCF is estimated using simulated historical and future annual maximum daily rainfall data series associated with return periods of 2 to 100 years ARI, and the final CCF values were generalised in 10 and 20 km spatial resolution gridded maps.

3. ASSESSMENT OF THE METHODOLOGY

3.1. ASSESSMENT PROCEDURE

Assessment procedure of the proposed methodology has been conducted as shown in Figure 1.1. The objectives of this assessment procedure to ensure that:

a) Data acquisition and mining which are among others to identify and investigate suspicious annual maximum series (AM) or partial duration series (PD) of rainfall data; identification data independency for PD/POT data series in order to avoid any overlapping each of maxima data; and to ensure clean data set (quantity and quality) for the AM and PD/POT model analysis;

b) To determine the best type of data series that can be used in analysis, two models are identified as Annual Maximum model (AM) and Partial Duration series/Peaks over Threshold model (PD/POT);

c) the most appropriate parent distribution that can be used in analysis of the AM series or the PD/POT data series has to be identified;

d) To determine the best method of parameter estimator is sorted out between between the Method of Moment (MOM) and the L-Moments (LMOM) approach;

e) the best fit or appropriate distribution-estimates (D/E) model; which can be carried out by robustness study in which includes determination of good performance (bias) and accuracy of estimation (rmse) of the model;

f) the estimate the magnitude of design rainstorm corresponds with return period, which includes developing design rain depth-duration and rainfall intensity-duration relationship;

g) the construction and formulation of the Intensity-Duration-Frequency relationships for gauged and ungauged sites are valid.

h) The derivation of the Temporal Storm Profile, Areal Reduction Factor (ARF) and Climate Change Factor (CCF) which includes formation of regions by means of clustering analysis and formulation of empirical ARF ratio-area-duration relations are feasible.

3.2. ROBUSTNESS STUDY AND EFFICIENCY PROCEDURE

The objective quantile estimation method is based on the methods devised for use with truly random samples from stationary populations. Such random samples have the characteristics that different samples, when treated in the same way, generally yield numerically different values of quantile estimates. A procedure for estimating R_T is robust if yields estimates of R_T which are good (low bias, high efficiency) even if the procedure is based on an assumptions which is not true. A procedure is not robust if it yields poor estimates of RT when the procedure's assumption departs even slightly from what is true. Since we do not know the distribution of AM series in nature it is required of us to seek out and find a distribution and an estimating procedure, which together are robust when dealing with distributions that give random samples, which have a storm-like behaviour. It should be pointed out that split samples test based on historical AM rainstorm records are inadequate for testing the robustness of any distribution and estimation (D/E) procedure (Cunnane, 1989).

A suitable method of testing a D/E procedure involves simulating random samples from a parent distribution in which the R-T relationships is known exactly (Hosking et. al., 1985a). To be authentic, in this context, the parent distribution must produce random samples which are rainstorms like in their behaviour. Such a parent distribution would be a GEV and EV1 of the AM model and a GPA and EXP of the PDS/POT model. Then the D/E under test is applied to each sample and $\hat{R}_T$ is obtained from each sample for a selection of T values. This is repeated for M samples (M large) and the Equations (3.1) to (3.4) are used to calculate bias and rmse from the M values of $\hat{R}_T$:

$$mean = \hat{R}_T = \sum_{i=1}^{M} \frac{\left(\hat{R}_T\right)}{M} \tag{3.1}$$

$$St.Dev = S\hat{R}_T = \left[\frac{\sum \left[\left(\hat{R}_T\right)_i - \bar{\hat{R}}_T \right]^2}{M} \right]^{1/2} \tag{3.2}$$

$$Bias = b_T = \hat{R}_T - R_T \tag{3.3}$$

$$RMSE = r_T = \left[\frac{\sum \left[\left(\hat{R}_T \right)_i - R_T \right]^2}{M} \right]^{1/2} \tag{3.4}$$

In these expressions $\hat{R}_T$ is known population value. The sampling distribution of $\hat{R}_T$ is also examined and frequently this can be approximated by a Normal distribution so that 5% and 95% quantiles of the sampling distribution, denoted lower and upper confidence levels, LCL and UCL, can be obtained from Equations (3.5) and (3.6):

$$LCL = \overline{\hat{R}_T} - 1.645 S\hat{R}_T \tag{3.5}$$

$$UCL = \overline{\hat{R}_T} + 1.645 S\hat{R}_T \tag{3.6}$$

All these quantities can be made dimensionless by dividing by population value R_T. This practice is usually followed to enable inter-comparison of D/E procedures.

3.3. RAINFALL MODEL DETERMINATION, PARENT DISTRIBUTION AND PARAMETER ESTIMATION

There are 15 selected rainfall stations used in the analysis, and two models namely the AM model and the PDS/POT model have been assessed. The L-Moment ratio diagram (LMRD) used to determine the parent distribution results in the 3P-Generalized Pareto (GPA) and the Generalized Extreme Value (EV1). Subsequently, assessment of the AM and PDS/POT models was carried out by means of robustness analysis related to standard error, bias and root mean square error (*rmse*) associated with return period (*T*) *T*=2, 5, 10, 20, 25, 50 and 100 years. This assessment is for comparing the most efficient model of the PDS/POT model that is represented by 3P-Generalized Pareto (GPA) and 2P-GPA/Exponential distribution (EXP) against the AM model of 3P-Generalized Extreme Value (GEV) and 2P-Extreme Value Type 1 (EV1/Gumbel) distributions. Furthermore, the choice of 3P and 2P frequency distributions was carried out by means of the hypothesis shape parameter of 3P (k=0) distribution which means a special case of 3P-GEV and 3P-GPA distributions are tested. The conclusions are as follows:

i. The most appropriate distribution for the proposed rainfall frequency models (AM model and PDS/POT model) are most likely represented by the 2P-EV1/LMOM and 2P-GPA-EXP/LMOM;

ii. Relatively, the 2P-EV1/LMOM shows good performance compare to the 2P-GPA-EXP/LMOM as indicated by robustness study and efficiency procedure (in terms of *rmse*, *bias*, and *standard deviation*) and this led to the decision to use the 2P-EV1/LMOM in analysis.

Subsequent to the conclusion mentioned, further analysis in Section 3.1 (f) and (g) has been carried out using the AM model of 2P-EV1/LMOM distribution for 174 rainfall sites throughout Sabah and Sarawak.

PART 2 – ANALYSIS AND RESULTS

4. ESTIMATION OF DESIGN RAINSTORM AND INTENSITY AT GAUGED SITES

4.1. DEVELOPING THE INTENSITY-DURATION FREQUENCY (IDF) RELATIONSHIP

A total of 174 stations were used in the IDF analysis. Ten (10) rainfall stations operated by Malaysia Meteorology Department (MMD) were utilised in addition to the observed 164 rainfall stations maintained by DID. The chosen stations have an average record length of more than 34 years where the longest record is 66 years. These stations are used to fill the gap for stations located in remote areas and improve the accuracy of the interpolated IDF Parameter at the ungauged sites. The final four parameters derived from 174 rain gauge stations in Sabah and Sarawak, are tabulated in Tables 4.1 and 4.2, respectively which represents the IDF relationship associated with return periods T = 2, 5, 10, 20, 50 and 100 years.

Table 4.1: List of Derived IDF Parameters of High ARI for Sabah.

No.	Station ID	Station Name	λ	κ	θ	η
1	96465 (MMD)	Labuan	93.0111	0.1524	0.4415	0.8175
2	96471 (MMD)	Kota Kinabalu	101.8615	0.1675	0.6103	0.8534
3	96477 (MMD)	Kudat	55.3968	0.1830	0.2104	0.6913
4	96481 (MMD)	Tawau	71.5413	0.1672	0.3193	0.8793
5	96491 (MMD)	Sandakan	74.8844	0.1797	0.2643	0.6961
6	0850051RF (4278004)	Kuhara	70.9720	0.1536	0.4175	0.9223
7	0790011RF (4474002)	Kalabakan	65.8850	0.1494	0.3178	0.8807
8	0890011RF (4486001)	Semporna Airport	70.6422	0.1773	0.3591	0.8542
9	0750031RF (4563001)	Pensiangan	58.5605	0.1388	0.2376	0.7959
10	0750011RF (4764002)	Sapulut	75.5886	0.1660	0.4475	0.8610
11	1490021RF (4955001)	Sindumin	101.4679	0.1605	0.5229	0.8531
12	1460261RF (4959001)	Kemabong	47.4246	0.1711	0.2548	0.8479
13	1460271RF (4961001)	Bonor	69.4661	0.1332	0.4050	0.8671
14	1460171RF (5061001)	Kalampun	80.6466	0.1576	0.5881	0.9224
15	1040151RF (5074001)	Ulu Kuamut	72.8998	0.1582	0.3706	0.8172
16	0950011RF (5088002)	Tungku	76.3082	0.2017	0.5466	0.9164
17	1480041RF (5156001)	Mesapol	87.9903	0.1507	0.3794	0.8629
18	1460141RF (5158001)	Pangi Dam Site	61.3233	0.1452	0.3705	0.8732
19	1460031RF (5163002)	Sook	74.9797	0.1527	0.4374	0.8947
20	1010041RF (5181001)	Limkabong	59.0822	0.1960	0.1843	0.7904
21	1040061RF (5269001)	Tongod	85.8492	0.1845	0.4761	0.9053
22	1040021RF (5274001)	Kuamut Met. Stn.	71.5654	0.1552	0.2051	0.8043

No.	Station ID	Station Name	λ	κ	θ	η
23	1040181RF (5275001)	Balat	62.8835	0.1601	0.2472	0.7874
24	1450011RF (5353001)	Mempakul	92.7614	0.1541	0.4805	0.8330
25	1460011RF (5357003)	Beaufort JPS	82.5504	0.1404	0.2132	0.8379
26	1460061RF (5361002)	Keningau Met. Stn.	54.5199	0.1692	0.3344	0.8926
27	1460161RF (5364002)	Tulid	64.6170	0.1482	0.4231	0.8745
28	1040161RF (5372001)	Tangkulap	71.9506	0.1701	0.2676	0.8137
29	1460071RF (5462001)	Apin Apin	55.9527	0.1792	0.3706	0.8978
30	1460281RF (5465001)	Sinua At Sabah	63.8033	0.1635	0.3512	0.8553
31	1040111RF (5482001)	Bilit	66.1458	0.2100	0.3399	0.7014
32	1420011RF (5558001)	Bongawan	95.3959	0.1533	0.4864	0.8632
33	1040101RF (5582001)	Sukau	62.7799	0.2000	0.3054	0.6979
34	1460291RF (5663001)	Tambunan Agr. Stn.	45.2804	0.1419	0.2159	0.8545
35	1160071RF (5671002)	Telupid	58.8599	0.1898	0.1858	0.7047
36	1160171RF (5768001)	Tampias	52.8947	0.1474	0.1569	0.7730
37	1390011RF (5862002)	Ulu Moyog	75.2134	0.1477	0.2057	0.7491
38	1160201RF (5875001)	Beluran	81.4749	0.1925	0.5206	0.7379
39	1380021RF (5961001)	Kiansam	82.5791	0.1777	0.4099	0.7948
40	1380041RF (5961002)	Inanam Met. Stn.	89.3380	0.1877	0.6006	0.8215
41	1160101RF (5966001)	Ranau Agr. Stn.	52.4534	0.1645	0.2534	0.7812
42	1160141RF (5973001)	Trusan Sapi Met. Stn.	78.7037	0.1875	0.3313	0.7424
43	1360021RF (6062001)	Kiulu (Tuaran)	71.2387	0.1547	0.3897	0.8189
44	1340011RF (6064001)	Dalas	68.5212	0.1367	0.2801	0.8191
45	1160221RF (6073001)	Basai	69.6909	0.1763	0.2550	0.7219
46	1160181RF (6168001)	Merungin	44.6620	0.1674	0.0838	0.7233
47	1200041RF (6172001)	Bukit Mondou	64.1015	0.1797	0.2703	0.6969
48	1340041RF (6264001)	Tamu Darat Agr. Stn.	66.2701	0.1504	0.2889	0.7929
49	1320011RF (6365001)	Rosok	61.7721	0.1872	0.2647	0.7464
50	1270021RF (6468001)	Tandek P.H.	47.7904	0.1998	0.0641	0.5922
51	1270031RF (6476001)	Trusan Sugut	58.8315	0.2007	0.1916	0.6525
52	1260021RF (6670001)	Kobon	57.3372	0.1830	0.2036	0.6315
53	1260031RF (6770001)	Pitas	59.0912	0.1783	0.2388	0.6474
54	1310021RF (6868001)	Kudat JPS	54.9907	0.1776	0.2540	0.6838

Table 4.2: List of Derived IDF Parameters of High ARI for Sarawak.

No.	Station ID	Station Name	λ	κ	θ	η
1	96413 (MMD)	Kuching	84.6865	0.1820	0.4599	0.7092
2	96418 (MMD)	Sri Aman	81.6399	0.1479	0.3601	0.8505
3	96421 (MMD)	Sibu	82.5196	0.1696	0.3291	0.8476
4	96441 (MMD)	Bintulu	88.6821	0.1412	0.4249	0.7983
5	96449 (MMD)	Miri	81.3086	0.1646	0.4021	0.7907
6	1790061RF (905039)	Bunan Gega	74.5208	0.1600	0.3508	0.8503
7	1790071RF (1003031)	Tebedu	58.6267	0.1630	0.1982	0.8164
8	1790081RF (1004001)	Krusen	70.5645	0.1669	0.3331	0.8090
9	1790091RF (1005079)	Bukit Matuh	60.5487	0.1627	0.1790	0.8152
10	1790101RF (1005080)	Sungai Busit	64.9958	0.1913	0.2424	0.7672
11	1790111RF (1006028)	Sungai Bedup	63.7794	0.1635	0.2388	0.7965
12	1790121RF (1006033)	Sungai Merang	60.1405	0.1834	0.1833	0.7749
13	1790131RF (1006037)	Sungai Teb	56.0356	0.1660	0.1550	0.7619
14	1790141RF (1007040)	Balai Ringin	77.2972	0.1684	0.4464	0.8333
15	1770081RF (1015001)	Batu Lintang	62.2552	0.1613	0.2796	0.8097
16	1770021RF (1018002)	Lubok Antu	60.7630	0.1671	0.2556	0.8233
17	1810071RF (1102019)	Padawan	58.2932	0.1906	0.2275	0.7064
18	1790151RF (1105027)	Serian	67.8353	0.1618	0.2675	0.7736
19	1790161RF (1105035)	Semuja Nonok	73.4404	0.1693	0.3398	0.8205
20	1790171RF (1105050)	Tebakang	61.6503	0.1845	0.2934	0.7757
21	1770091RF (1111008)	Pantu	78.1097	0.1866	0.3336	0.8269
22	1770101RF (1118002)	Bekatan	70.0769	0.1578	0.4382	0.8513
23	1800051RF (1203002)	Kampung Gayu	53.7233	0.1715	0.0772	0.6798
24	1800061RF (1204001)	Plaman Nyabet	65.3263	0.1733	0.2315	0.7221
25	1800011RF (1204024)	Dragon School	58.1570	0.1696	0.1708	0.6903
26	1800081RF (1205006)	Tarat	56.6654	0.1909	0.0867	0.6801
27	1790181RF (1208001)	Kampung Sangkalan Pasir	79.0179	0.1557	0.4408	0.8220
28	1770011RF (1214001)	Sri Aman	76.5907	0.1414	0.3857	0.8563
29	1770111RF (1220025)	Nanga Delok	61.0550	0.1795	0.3077	0.8386
30	1810081RF (1301001)	Kampung Monggak	56.0552	0.1740	0.0897	0.6118
31	1810091RF (1302078)	Kampung Git	65.2652	0.2076	0.2657	0.6602
32	1800091RF (1303014)	Semonggok	57.5385	0.1974	0.2231	0.6493
33	1770121RF (1313006)	Stumbin	68.8947	0.1501	0.2846	0.8287
34	1770131RF (1321001)	Nanga Mujan	68.5728	0.1448	0.2821	0.8501
35	1810101RF (1400001)	Kampung Opar	66.8415	0.1981	0.2800	0.6265
36	1810021RF (1401005)	Bau	62.6059	0.2059	0.1817	0.6390
37	1810111RF (1402001)	Siniawan Water Works	57.4203	0.2045	0.1930	0.6158
38	1810121RF (1402002)	Siniawan	66.0186	0.1901	0.2181	0.6486
39	1810011RF (1403001)	Kuching Airport	81.8540	0.1854	0.4976	0.7003
40	1800101RF (1404049)	Paya Paloh	87.7813	0.1937	0.6240	0.7394
41	1750031RF (1415001)	Nanga Lubau	70.1770	0.1589	0.3401	0.8381
42	1770141RF (1417001)	Nanga Entalau	83.3883	0.1485	0.4904	0.8491
43	1840011RF (1502001)	Sebubut	59.9318	0.2031	0.0651	0.6227

No.	Station ID	Station Name	λ	κ	θ	η
44	1810131RF (1503004)	Kuching Saberkas	68.1837	0.1913	0.2946	0.6837
45	1800111RF (1505081)	Ketup	95.3220	0.1976	0.7655	0.7355
46	1800031RF (1506001)	Semera	83.2267	0.1870	0.5320	0.7307
47	1800041RF (1506034)	Asa Jaya	87.3387	0.1925	0.6120	0.7253
48	1780021RF (1509009)	Sebuyau	79.9417	0.1707	0.4067	0.7820
49	1730141RF (1544001)	Long Singut	64.8400	0.1329	0.3096	0.7882
50	1850011RF (1601001)	Sungai Rayu	64.0479	0.1982	0.1844	0.6393
51	1750041RF (1616021)	Nanga Tiga	79.0119	0.1594	0.4370	0.8438
52	1860011RF (1698007)	Lundu	83.5400	0.1848	0.5634	0.6626
53	1820011RF (1704013)	Telok Assam	93.3816	0.1775	0.6216	0.7465
54	1740041RF (1713005)	Saratok	63.2456	0.1532	0.1804	0.7979
55	1730151RF (1726041)	Nanga Bangkit	75.9190	0.1324	0.3077	0.8193
56	1730161RF (1731001)	Nanga Balang	64.4526	0.1359	0.1684	0.7609
57	1740051RF (1811007)	Kabong	91.6755	0.1652	0.5393	0.8010
58	1730171RF (1816029)	Pakan	83.3283	0.1505	0.4176	0.8709
59	1730181RF (1823001)	Nanga Jagau	79.5152	0.1496	0.4107	0.8778
60	1730191RF (1834001)	Gaat Balleh	93.4239	0.1496	0.5411	0.8433
61	1730201RF (1836042)	Nanga Entawau	89.9724	0.1378	0.4507	0.8333
62	1730211RF (1843001)	Long Busang	67.1898	0.1498	0.3375	0.8205
63	1870011RF (1897016)	Sematan	64.8548	0.1762	0.2458	0.6235
64	1740061RF (1914001)	Asun SRK	80.5993	0.1474	0.4318	0.8696
65	1730221RF (1947001)	Long Unai	59.3990	0.1527	0.2078	0.7948
66	1730231RF (2021001)	Renan Kemiding	89.6967	0.1643	0.5572	0.9049
67	1730241RF (2021036)	Kanowit	87.4288	0.1698	0.4725	0.8981
68	1730251RF (2025012)	Song	56.8382	0.1546	0.1782	0.8307
69	(2029001)	Kapit JKR	64.0098	0.1886	0.3780	0.8092
70	1730261RF (2029002)	Kapit New Head Works	67.2686	0.1544	0.2578	0.8100
71	1730271RF (2031034)	Nanga Mujong	87.8941	0.1417	0.4509	0.8489
72	1730281RF (2036001)	Tunoh Scheme	73.4616	0.1287	0.3529	0.8325
73	1730291RF (2115008)	Sarikei	62.4503	0.1595	0.2124	0.7925
74	1730301RF (2134001)	Nanga Tiau	87.7627	0.1350	0.5081	0.8309
75	1730311RF (2141048)	Long Jawe	73.8966	0.1278	0.3570	0.8298
76	1730321RF (2212001)	Belawai	84.7995	0.1832	0.6072	0.8016
77	1730331RF (2218017)	Sibu JKR WW	69.3052	0.1786	0.3874	0.8183
78	1730341RF (2219001)	Sibu New Airport	72.8049	0.1414	0.2593	0.8026
79	1730351RF (2230143)	Nanga Merit	77.3708	0.1634	0.3572	0.8498
80	(2239147)	Batu Keling	56.5154	0.1655	0.2908	0.8501
81	(2318007)	Sibu Airport	79.8182	0.1703	0.3154	0.8784
82	1710011RF (2321001)	Stapang	84.7977	0.1932	0.4881	0.8456
83	1700051RF (2325039)	Sungai Arau	84.1264	0.1598	0.5515	0.8846
84	1730361RF (2333001)	Punah Bah	90.3548	0.1351	0.5587	0.8489
85	1730371RF (2346001)	Long Lidam	58.5166	0.1462	0.2495	0.8302
86	1730381RF (2442001)	Long Laku	57.1354	0.1287	0.2341	0.7946
87	1730391RF (2514004)	JPS Daro	76.2630	0.2169	0.6473	0.8047

No.	Station ID	Station Name	λ	κ	θ	η
88	1700061RF (2522038)	Bukit Engkerbai	72.1195	0.1719	0.3057	0.8143
89	1670021RF (2625051)	Nanga Lemai	69.9463	0.1541	0.2521	0.7946
90	1720011RF (2712001)	Tekajong	84.8929	0.1757	0.4665	0.7632
91	1730401RF (2718022)	Sungai Kut	75.0424	0.2087	0.5346	0.7216
92	1730021RF (2737103)	Belaga	57.7723	0.1627	0.2228	0.7925
93	1650011RF (2828025)	Tatau Town	78.5852	0.1882	0.4370	0.7959
94	1730411RF (2843001)	Long Jek	58.3989	0.1431	0.2871	0.8110
95	1700021RF (2920005)	Mukah JKR	88.8303	0.1863	0.6051	0.7465
96	1730421RF (2939045)	Long Sambop	74.0499	0.1415	0.3546	0.8191
97	1640041RF (3130002)	Bintulu Airport	92.3308	0.1474	0.5171	0.8185
98	1640051RF (3132023)	Sebauh	64.6642	0.1512	0.2571	0.8055
99	1640031RF (3137021)	Tubau	74.4625	0.1687	0.3196	0.8066
100	1550111RF (3152011)	Lio Matu	55.6012	0.1472	0.1653	0.7980
101	1550121RF (3347003)	Long Akah	74.5485	0.1473	0.3508	0.8006
102	1550131RF (3444018)	Long Pilah	81.1265	0.1605	0.3969	0.8155
103	1550141RF (3541033)	Long Jegan	78.6554	0.1465	0.4437	0.8337
104	1580031RF (3737045)	Sungai Lebai	78.8467	0.1542	0.4654	0.8846
105	1550151RF (3744009)	Long Lama	78.3231	0.1469	0.2540	0.8159
106	1550161RF (3842034)	Long Teru	69.5497	0.1648	0.2646	0.8272
107	1550171RF (3950020)	Long Seridan	69.3172	0.1437	0.3181	0.8060
108	1520021RF (3956001)	Ba Kelalan	46.1621	0.1557	0.2549	0.8127
109	1570021RF (4038006)	Bekenu	66.8622	0.1733	0.4414	0.8164
110	1550061RF (4143004)	Marudi	57.2942	0.1671	0.1886	0.7902
111	1540091RF (4151017)	Long Napir	55.3904	0.1354	0.1995	0.8019
112	1520031RF (4255006)	Long Semado	49.0084	0.1446	0.2900	0.8242
113	1560021RF (4339005)	Miri Airport	80.1511	0.1689	0.5051	0.8057
114	1560041RF (4440060)	Miri DID	67.2645	0.1868	0.3714	0.7970
115	1540101RF (4449012)	Nanga Medamit	88.4002	0.1549	0.3886	0.8619
116	1540021RF (4548004)	Ukong	72.5809	0.1495	0.2235	0.8030
117	1520041RF (4554001)	Long Sukang	53.0810	0.1671	0.3400	0.8541
118	1530011RF (4650023)	Pandaruan	88.6347	0.1745	0.3895	0.8508
119	1540111RF (4749001)	Limbang DID	75.6279	0.1650	0.3053	0.8486
120	1500011RF (4854009)	Lawas Airfield	93.2855	0.1547	0.4079	0.8532

4.2. ESTIMATION OF DESIGN RAINSTORM FROM IDF RELATIONSHIP

The design rainstorm of gauged sites can be easily obtained by extracting the derived IDF parameters from the listed sites as shown in Tables 4.1 and 4.2. Thus, the formation of design rainfall intensity-duration-frequency (IDF) can be performed using Equation (2.24). For instance, the required four IDF parameters for Site 089001RF (4486001) at Semporna Airport, Sabah can be derived and are κ=0.1773, λ=70.6422, θ=0.3591 and η=0.8542 and the summary for the Semporna Airport IDF values are given in Table 4.3. The required design rainstorm can be obtained by transforming the estimated IDF values (divided by duration) as tabulated in Table 4.4, and the depth-duration-frequency (DDF) curve corresponding with return period *T*=2, 5, 10, 20, 25, 50 and 100 years is shown in Figure 4.1.

Table 4.3: Estimated Design Rainfall Intensity-Frequency-Duration (IDF) for Site 089001RF (4486001) at Semporna Airport, Sabah.

Intensity (mm/hr)	**Return Period, *T* (yr)**						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	122.00	143.52	162.28	183.52	190.92	215.88	244.12
0.5	90.94	107.00	120.98	136.80	142.32	160.94	181.98
1	61.46	72.30	81.76	92.45	96.18	108.76	122.98
3	28.38	33.38	37.75	42.68	44.40	50.21	56.78
6	16.45	19.35	21.88	24.74	25.74	29.11	32.92
12	9.33	10.97	12.40	14.03	14.59	16.50	18.66
24	5.22	6.14	6.95	7.86	8.17	9.24	10.45
48	2.91	3.42	3.87	4.37	4.55	5.15	5.82
72	2.06	2.42	2.74	3.10	3.23	3.65	4.12

Table 4.4: Estimated Design Rainstorm for Site 089001RF (4486001) at Semporna Airport, Sabah.

Rain Depth (mm)	**Return Period, *T* (yr)**						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	30.50	35.88	40.57	45.88	47.73	53.97	61.03
0.5	45.47	53.50	60.49	68.40	71.16	80.47	90.99
1	61.46	72.30	81.76	92.45	96.18	108.76	122.98
3	85.14	100.14	113.25	128.04	133.20	150.63	170.34
6	98.70	116.10	131.28	148.44	154.44	174.66	197.52
12	111.96	131.64	148.80	168.36	175.08	198.00	223.92
24	125.28	147.36	166.80	188.64	196.08	221.76	250.80
48	139.68	164.16	185.76	209.76	218.40	247.20	279.36
72	148.32	174.24	197.28	223.20	232.56	262.80	296.64

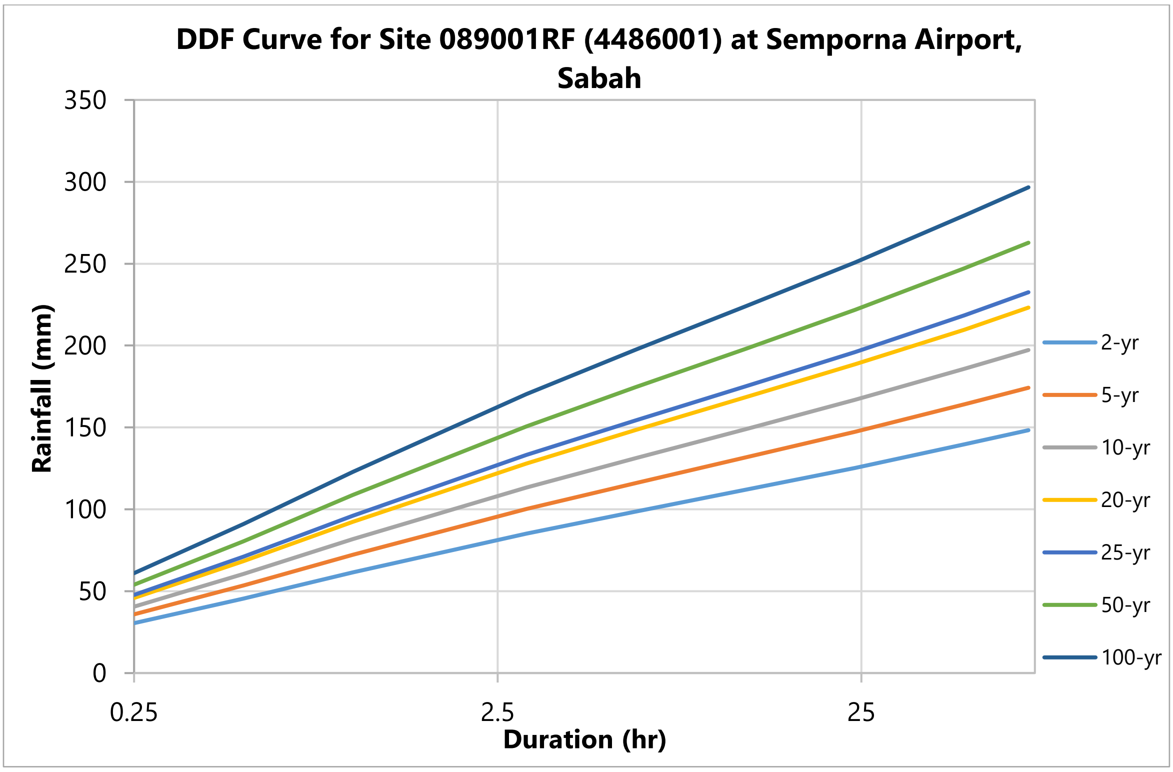


Figure 4.1: Depth-Duration-Frequency Curve for Site 089001RF (4486001) at Semporna Airport, Sabah.

4.3. ESTIMATION OF DESIGN RAINSTORM FOR LONG DURATION

The estimated design rainstorm values for longer durations of 24-hr, 48-hr and 72-hr associated with return period *T*= 2, 5, 10, 20, 25, 50 and 100 years were also analysed using the 2P-Extreme Value Type 1 (EV1) distribution/LMOM based on the AM model procedure. The annual maximum data series for 1, 2 and 3-day were extracted from the daily stations, however, this extracted values are likely less than the true value due to the fixed beginning and ending observation time which is at 0800 hours. The adjustment factor of daily to hourly data set needs to be applied prior to any further analysis. Thus, forty-nine (49) rainfall stations in Sabah and Sarawak were used to determine the required adjustment factor for 1, 2 and 3-day as the analysis results can be seen in Table 4.5 along with the adopted values of a study in Peninsular Malaysia for HP26 (1983). Therefore, the 1, 2 and 3-day annual maximum data series were adjusted with these values prior to the quantile of design rainstorm estimation.

Table 4.5: The Adjustment Factor for Various Durations.

Duration (day)	Adjustment Factor	
	HP 26 (2018)	HP 26 (1983)
1	1.08	1.14
2	1.03	1.08
3	1.01	1.06

As listed in Appendix B, the analysis of design rainstorm estimation has utilised about 139 daily rainfall stations, of which 18 sites are located in Sabah and the 121 sites are in Sarawak. The estimated design rainstorm for 24-hr, 48-hr and 72-hr corresponding to return period *T*=2, 5, 10, 20, 25, 50 and 100 years along with lower and upper confidence limits (LCL and UCL) are tabulated in APPENDIX C. The denoted lower and upper confidence limits, LCL and UCL are obtained from Equation (3.5) and (3.6) where the 5% and 95% quantiles of the sampling distribution can be approximated by a Normal distribution.

4.4. COMPARISON OF THE NEW IDF – DESIGN RAINSTORM WITH THOSE FROM HP 26 (1983)

4.4.1. ESTIMATED DESIGN INTENSITY FOR SHORT DURATION

The IDF curves published in HP 26 (1983) were derived and extrapolated using the Gumbel frequency distribution plotting paper. There were 16 stations managed by DID and MMD with a record period ranging from 7 to 30 years as listed in Table 4.6 as having being used in the frequency analysis. Site 1403001 at Kuching, Sarawak and Site 5880001 and 5960002 located at Sandakan and Kota Kinabalu in Sabah are found to have the longest record length, whereas the shortest period of length of record were observed at Site 6868001 at Kudat, Sabah and Site 4650023 at Limbang, Sarawak. The adequacy of record length, and errors due to rainfall recorded chart and data digitizing were amongst the drawbacks that could possibly be reason for the inaccurate quantile estimates not only for short duration particularly, but also for long duration (e.g. 15-min to 60-min, 24 to 72-hrs).

Site 1403001 at Kuching and Site 5960002 at Kota Kinabalu has been chosen in assessing the said drawbacks. At this juncture, both sites do possess a sufficient length of record of about 66 years as per the 2017 data record, whereas respectively, they are approximately 30 and 28 years as published in 1983. As for

HP26 (1983), the design rainfall intensity for the two stations were estimated by digitising from the published curves, whereas the 2P- EV1/LMOM has been used for estimating the required design rainfall intensity from the most recent rainfall data set.

Table 4.6: List of Stations Used in HP 26 (1983).

No.	State	Station ID	Station Name	Record (Year)	Type of Recorder
1	Sabah	2478002	Tawau	11	Kent Weekly (DID)
2	Sabah	5252002	Labuan	13	Casella Weekly (MMS)
3	Sabah	5274001	Kuamat	12	Hattori Longterm (DID)
4	Sabah	5361002	Keningau	16	Kent Weekly (DID)
5	Sabah	5880001	Sandakan	24	Casella Weekly (MMS)
6	Sabah	5960002	Kota Kinabalu	24	Casella Weekly (MMS)
7	Sabah	6064001	Ranau	21	Hattori Longterm (DID)
8	Sabah	6868001	Kudat	8	Hattori Longterm (DID)
9	Sarawak	1214001	Simanggang	18	Hattori Daily (DID)
10	Sarawak	1403001	Kuching	30	Casella Weekly (MMS)
11	Sarawak	2029001	Kapit	10	Kent Daily (DID)
12	Sarawak	2318007	Sibu	19	Kent Daily (DID)
13	Sarawak	2737003	Belaga	16	Kent Weekly (DID)
14	Sarawak	3130002	Bintulu	28	Casella Daily (MMS)
15	Sarawak	4339005	Miri	28	Casella Daily (MMS)
16	Sarawak	4650023	Limbang	7	Kent Weekly (DID)

Table 4.7: Estimated Design Intensity (mm/hr) for Site 1403001 (96413*) at Kuching, Sarawak.

Duration (hr)	New IDF				HP 26 (1983)			
	2	5	10	20	2	5	10	20
0.25	139.85	159.31	172.20	184.56	140.0	167.0	185.0	200.0
0.5	109.30	125.53	136.28	146.58	108.0	132.0	147.0	165.0
1	80.16	96.73	107.70	118.22	75.0	98.0	114.0	132.0
3	37.11	47.17	53.84	60.23	40.0	55.0	66.0	76.0
6	23.08	30.76	35.84	40.72	26.0	35.0	42.0	50.0
12	13.49	18.66	22.09	25.38	16.5	22.0	27.0	33.0
24	8.14	11.55	13.81	15.97	9.8	13.8	16.8	20.0
48	5.15	7.12	8.42	9.67	5.4	8.1	10	12.0
72	3.95	5.47	6.47	7.44	4	6	7.2	8.5

*MMD station ID where new IDF is derived using this site data set.

Table 4.8: Estimated Design Intensity (mm/hr) for Site 5960002 (96471*) at Kota Kinabalu, Sabah.

Duration (hr)	New IDF				HP26 (1983)			
	2	5	10	20	2	5	10	20
0.25	132.33	157.42	174.04	189.98	127.0	160.0	180.0	200.0
0.5	107.00	129.18	143.87	157.96	100.0	128.0	147.0	166.7
1	75.65	92.58	103.79	114.54	73.0	92.0	108.0	124.0
3	36.54	45.97	52.21	58.19	38.0	48.0	56.0	68.0
6	21.00	27.24	31.37	35.34	22.0	28.0	33.0	40.0
12	11.56	15.08	17.41	19.64	12.0	16.0	18.5	22.0
24	6.59	8.42	9.64	10.80	6.8	9.0	10.5	12.5
48	3.84	4.88	5.56	6.22	4.0	5.5	6.5	8.0
72	2.85	3.63	4.14	4.64	3.0	4.0	5.0	6.5

*MMD station ID where new IDF is derived using this site data set.

Table 4.7 and 4.8 show the estimated values of design rainfall intensity for Site 1403001 and Site 5960002 at Kuching and Kota Kinabalu, respectively. Overall, the estimated design rainfall intensity with the new data set has a lower magnitude as much as -30% and -40% lesser as compared to those derived with the HP26 (1983) for the site 1403001 and 596002, respectively. In relation to short duration of 15 to 60-min, decreases from 12.6% to 16.9% were found, whereas for the long duration, values has decreased some 25% to 40%. It is worth noting that lowest decreasing intensity indicated for the return period *T*=20 years ARI which is lower by as much as -40%. The differences could possibly be attributed either to length of record or due to digitizing of curves.

The drawback of the rainfall recorded chart is well illustrated in Figure 4.2 and 4.3, with the new and existing HP26 (1983)'s IDF for Site 1403001 and 5960002, respectively. Thoughtfully, it can be noted that the contraction starts and widens at the end for short duration of 15 to 60-min and long duration of 24 to 72-hrs., which may possibly be a consequence of under and over estimates. The drawback in the HP 26 (1983) has been overcome by means formulation of the IDF relationship as discussed in Section 2.6. The new IDF for Kuching, Sarawak and Kota Kinabalu, Sabah are depicted in Figures 4.4 and 4.5, respectively.

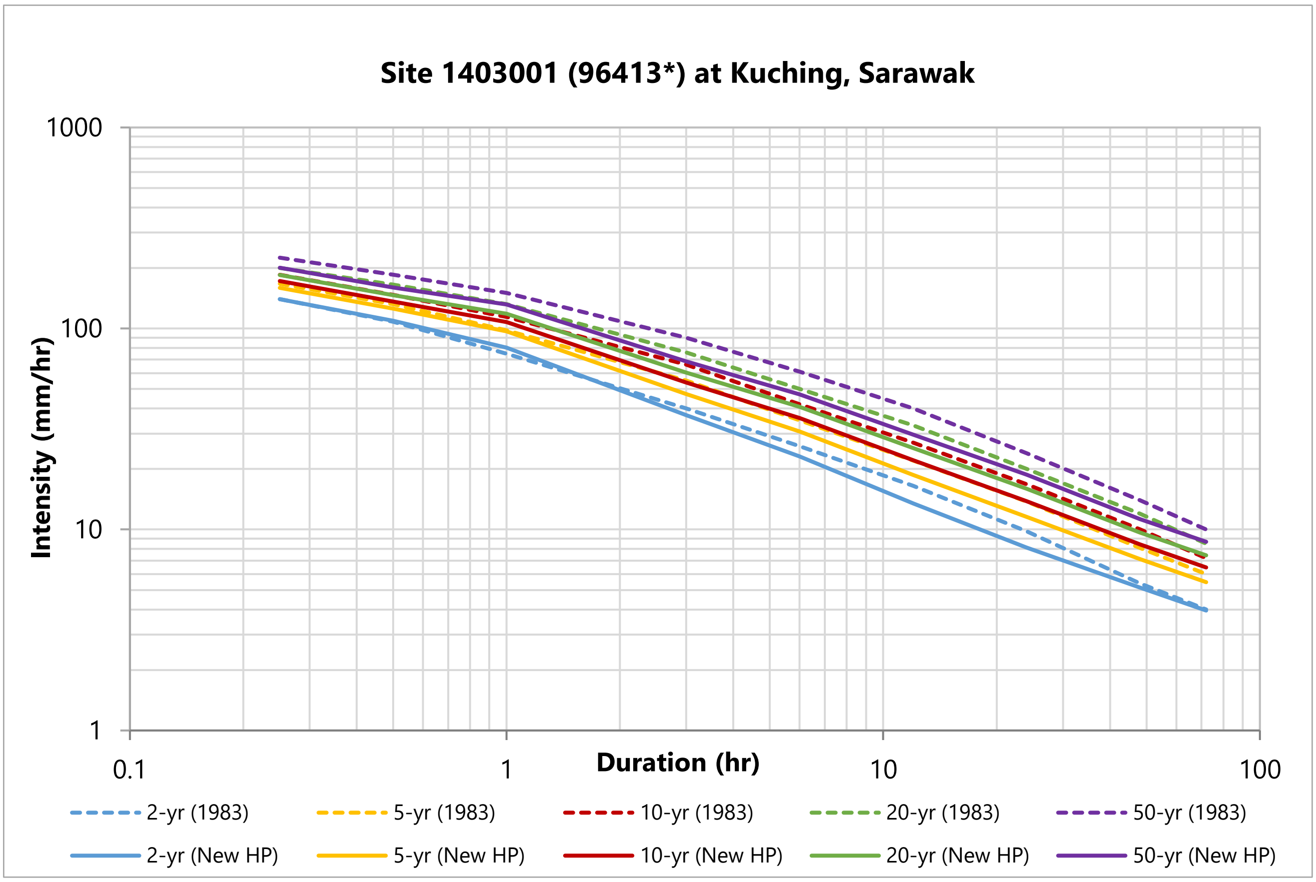


Figure 4.2: Comparison of New IDF and IDF HP 26 (1983) for Site Kuching, Sarawak.

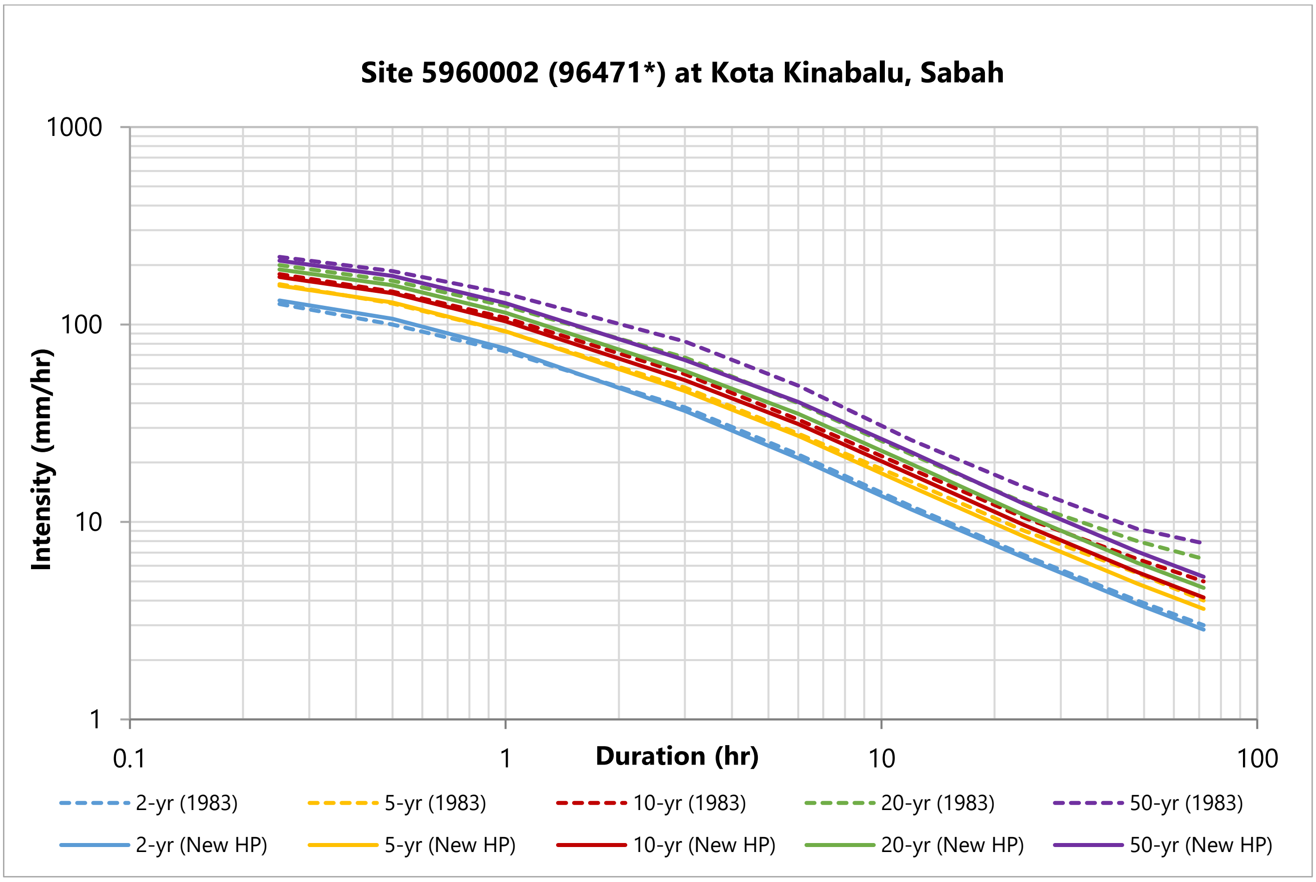
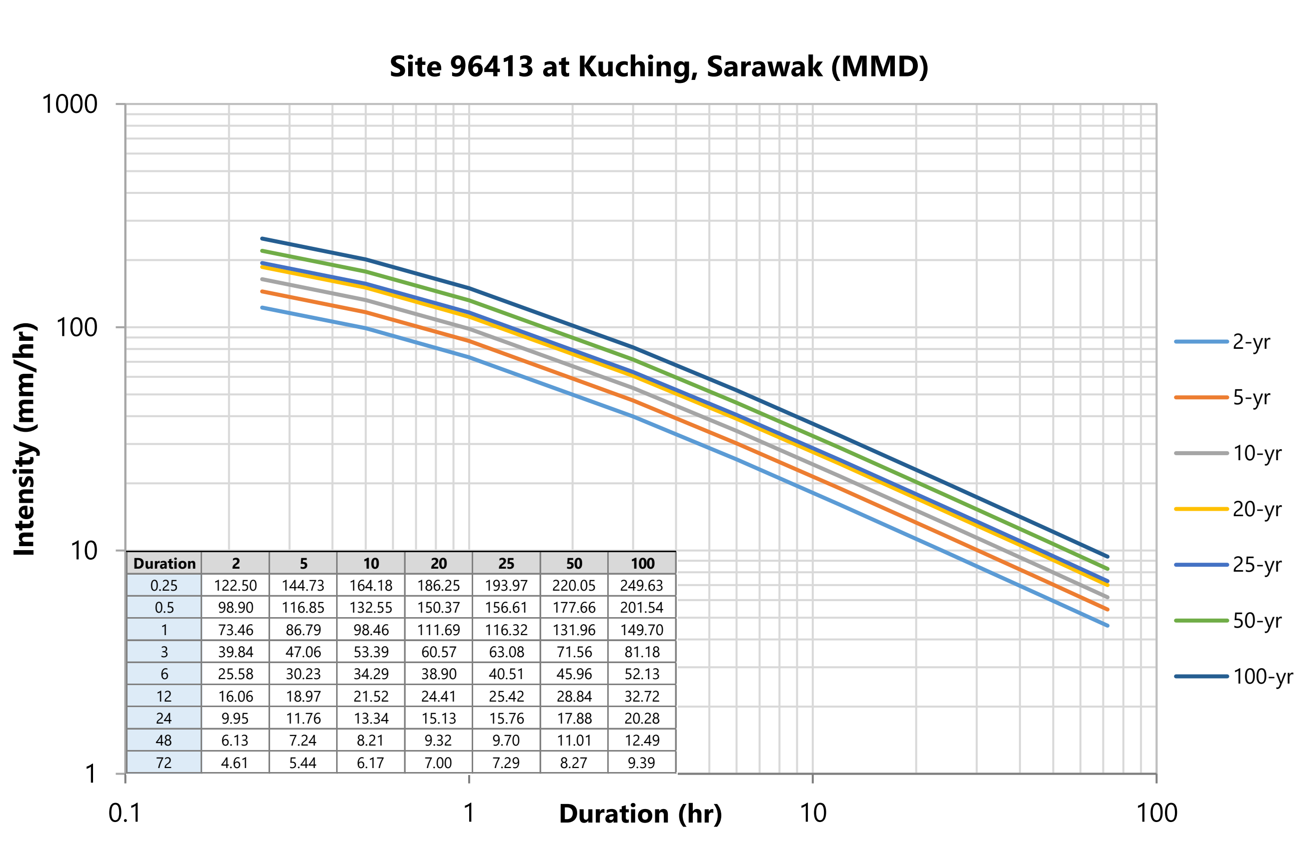


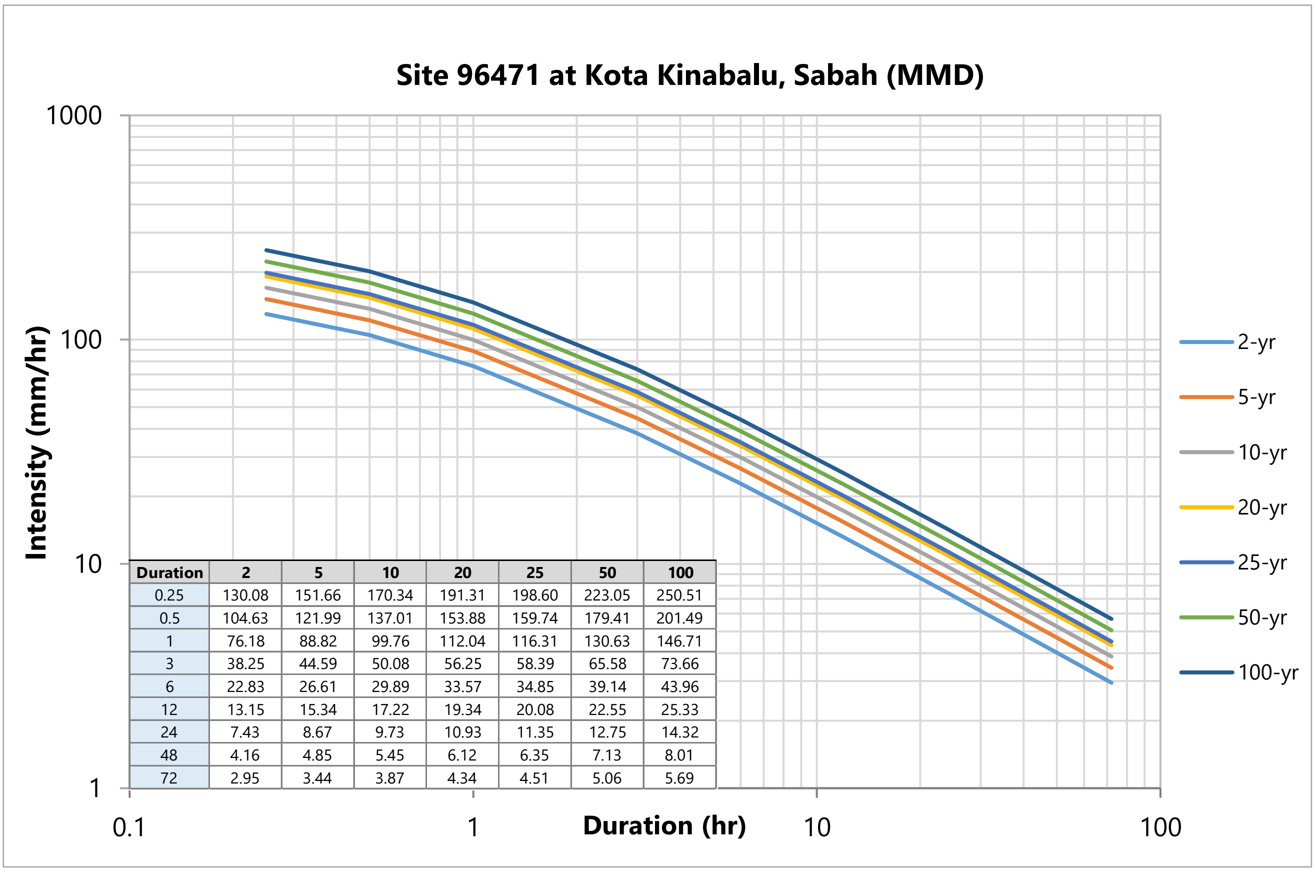
Figure 4.3: Comparison of New IDF and IDF HP 26 (1983) for Site Kota Kinabalu, Sabah.

*MMD station ID where new IDF is derived using this site data set.



Duration	2	5	10	20	25	50	100
0.25	122.50	144.73	164.18	186.25	193.97	220.05	249.63
0.5	98.90	116.85	132.55	150.37	156.61	177.66	201.54
1	73.46	86.79	98.46	111.69	116.32	131.96	149.70
3	39.84	47.06	53.39	60.57	63.08	71.56	81.18
6	25.58	30.23	34.29	38.90	40.51	45.96	52.13
12	16.06	18.97	21.52	24.41	25.42	28.84	32.72
24	9.95	11.76	13.34	15.13	15.76	17.88	20.28
48	6.13	7.24	8.21	9.32	9.70	11.01	12.49
72	4.61	5.44	6.17	7.00	7.29	8.27	9.39

Figure 4.4: Design Rainfall Intensity-Frequency-Duration (IDF) Curve for Kuching, Sarawak.



Duration	2	5	10	20	25	50	100
0.25	130.08	151.66	170.34	191.31	198.60	223.05	250.51
0.5	104.63	121.99	137.01	153.88	159.74	179.41	201.49
1	76.18	88.82	99.76	112.04	116.31	130.63	146.71
3	38.25	44.59	50.08	56.25	58.39	65.58	73.66
6	22.83	26.61	29.89	33.57	34.85	39.14	43.96
12	13.15	15.34	17.22	19.34	20.08	22.55	25.33
24	7.43	8.67	9.73	10.93	11.35	12.75	14.32
48	4.16	4.85	5.45	6.12	6.35	7.13	8.01
72	2.95	3.44	3.87	4.34	4.51	5.06	5.69

Figure 4.5: Design Rainfall Intensity-Frequency-Duration (IDF) Curve for Kota Kinabalu, Sabah.

4.4.2. ESTIMATED DESIGN INTENSITY FOR LONG DURATION

The results of Gumbel Frequency Analysis for manual stations published in HP 26 (1983) were derived based on 54 and 101 rainfall stations in Sabah and Sarawak, respectively. Seven (7) durations of 1, 2, 3, 5, 7, 14 and 30 days corresponding to the ARI of 2, 5, 10 and 20 years had been prepared in that analysis. The available length of record of the stations used in the HP 26 (1983) are mostly of length less than 30 years and 23 stations even had length of data shorter than 10 years.

In contrast, as described in Section 4.3, the new estimated quantile of design rainstorm for long durations had utilised 139 daily rainfall stations, and which are from the 18 and 121 sites in Sabah and Sarawak, respectively. These rainfall sites were chosen on the consideration the data quality along with an adequate length of record that range from 25 to 65 years.

The analysis attempts to review the integrity and robustness of the quantile estimation between two approaches along with the restriction mentioned by utilizing 55 rainfall sites. The estimated quantile values were performed using the Extreme Value Type 1 (EV1) distribution for data durations of 24-hr, 48-hr and 72-hr corresponding with return period T= 2, 5, 10 and 20 years ARI. The 5% lower and 95% upper confidence limits are constructed in order to distinguish between the two approaches.

Overall, the quantile estimates produced by the current study (HP26, 2018) is approximated being lower by some 9% to 24% than the previous study. The difference is recognised due to the 1, 2 and 3-day adjustment factor adopted in the current and previous analysis, as stated in section 4.3. It is worth noting that the said adjustment factors for the current study are explicitly based on rainfall data set from Sabah and Sarawak, which is most likely to be able to produce better estimates. The contrasting results may arisen due to the dataset, data availability and adequacy of length of record for both studies including the technique and methodology used.

For more specific comparison, three rainfall stations that are Site 1770091RF (1111008) at Pantu, Site 1790061RF (905039) at Bunan Gega and 1770011RF (1214001) at Sri Aman located in Sarawak are selected for further assessment. These three sites have record length of 48, 47 and 62 years respectively, as compared to 14, 11 and 38 years used in HP 26 (1983). The sample size was separated into two data sets covering the full years of record length (48, 47 and 62 years) and the reference period of 14, 11 and 38 years respectively. The quantile of design rainstorm estimates, and the 5% lower and 95% upper confidence limit denoted by LCL and UCL are recalculated for representing both studies and the intended data periods. Table 4.9, 4.10 and 4.11 show the assessment results for Pantu, Bunan Gega and Sri Aman respectively. It shows that variances for the estimated design rainstorm of HP 26 (1983) and the "newly calculated HP 26 (1983)" are found to be in the range of -33% to 18%.

As described in the published HP 26 (1983), the major limitation with the uncertainty of quantile estimation is due to the short period record length used in analysis. However, this uncertainty normally can be expressed with two control lower and upper confidence limit curves plotted on either side of the plotted line as explained in Section 3.2 and expressed in Equations (3.5) and (3.6) and is also briefly described in Section 4.3. For example, Tables 4.9, 4.10 and 4.11 show the estimated uncertainty by means of upper confidence limit and lower confidence limit of quantile values for the respective sites. Comparatively, better performance is shown by the newly estimated quantile values (2018) as compared to the "newly calculated HP 26 (1983)" values. In this case, better performance means the estimated lower and upper limits of design rainstorm associated with return period T=2, 5, 10 and 20 years ARI for the current study are relatively smaller than the newly calculated HP26 (1983).

The assessment result for Site 1770091RF (1111008) at Pantu and Site 1790061RF (905039) at Bunan Gega as shown in Tables 4.9 and 4.10 indicate that the difference is within the range of -52% to -6%. Relatively, the analysis for Site 1770011RF (1214001) at Sri Aman falls within -4% to +5%. It can be concluded that the length of record used in new calculated values for Site 1770091RF (1111008) at Pantu and Site 1790061RF (905039) at Bunan Gega can lead to better results and accuracies as compared to the new calculated HP 26 (1983). Nevertheless, the result for Site 1770011RF (1214001) at Sri Aman showed that the length of record with the HP 26 (1983) is considered satisfactory to be used in quantiles estimation at return period *T*=2 to 20 years ARI.

Table 4.9: Comparison of Estimated Design Rainstorm from HP 26 (1983), New Calculated HP 26 (1983) and New Estimated Values (2018) for Site 1770091RF (1111008) at Pantu, Sarawak.

Station ID	Station Name	Type	Analysis	Duration (hr)	Design Rainstorm (mm)			
					2	5	10	20
1770091RF (1111008)	Pantu	HP 26 (1983)	**Estimated Design Rainstorm**	24	125.5	153.4	171.9	189.7
				48	170.6	204.9	227.6	249.4
				72	196.0	236.3	262.9	288.4
		New Calculated HP 26 (1983)	Upper Confidence Limit	24	138.70	190.35	225.34	259.09
				48	180.17	248.57	294.90	339.59
				72	212.26	286.43	336.68	385.15
			Estimated Design Rainstorm	24	131.25	177.30	207.79	237.03
				48	170.32	231.29	271.66	310.38
				72	201.58	267.70	311.48	353.47
			Lower Confidence Limit	24	123.81	164.26	190.24	214.97
				48	160.47	214.02	248.42	281.18
				72	190.89	248.97	286.28	321.80
		New Estimated Values (2018)	Upper Confidence Limit	24	139.5	188.2	221.2	253.0
				48	165.1	218.3	254.3	289.1
				72	188.4	245.7	284.5	321.9
			Estimated Design Rainstorm	24	132.5	175.9	204.6	232.2
				48	157.5	204.9	236.3	266.4
				72	180.2	231.2	265.0	297.5
			Lower Confidence Limit	24	125.5	163.6	188.1	211.4
				48	149.8	191.4	218.2	243.7
				72	171.9	216.8	245.6	273.0

Table 4.10: Comparison of Estimated Design Rainstorm from HP 26 (1983), New Calculated HP 26 (1983) and New Estimated Values (2018) for Site 1790061RF (905039) at Bunan Gega, Sarawak.

Station ID	Station Name	Type	Analysis	Duration (hr)	Design Rainstorm (mm)			
					2	5	10	20
1790061RF (905039)	Bunan Gega	HP 26 (1983)	**Estimated Design Rainstorm**	24	124.8	160.1	183.3	205.5
				48	169.9	219.0	251.5	282.7
				72	199.6	255.8	293.0	328.6
		New Calculated HP 26 (1983)	Upper Confidence Limit	24	122.44	157.47	181.21	204.10
				48	159.26	208.93	242.57	275.03
				72	182.57	242.50	283.10	322.26
			Estimated Design Rainstorm	24	117.40	148.63	169.30	189.14
				48	152.11	196.38	225.70	253.82
				72	173.94	227.36	262.74	296.67
			Lower Confidence Limit	24	112.35	139.78	157.40	174.18
				48	144.95	183.84	208.82	232.61
				72	165.31	212.23	242.37	271.07
		New Estimated Values (2018)	Upper Confidence Limit	24	120.05	147.83	166.65	184.80
				48	151.49	186.76	210.65	233.69
				72	171.33	210.85	237.62	263.44
			Estimated Design Rainstorm	24	116.05	140.81	157.21	172.94
				48	146.41	177.85	198.66	218.63
				72	165.64	200.87	224.19	246.57
			Lower Confidence Limit	24	112.04	133.80	147.77	161.07
				48	141.32	168.94	186.68	203.57
				72	159.95	190.89	210.76	229.69

Table 4.11: Comparison of Estimated of Design Rainstorm from HP 26 (1983), New Calculated HP 26 (1983) and New Estimated Values (2018) for Site 1770011RF (1214001) at Sri Aman, Sarawak.

Station ID	Station Name	Type	Analysis	Duration (hr)	Design Rainstorm (mm)			
					2	5	10	20
1770011RF (1214001)	Sri Aman	HP 26 (1983)	**Estimated Design Rainstorm**	24	134.7	165.1	185.3	204.5
				48	156.4	190.8	213.6	235.4
				72	176.8	218.3	245.7	272.0
		New Calculated HP 26 (1983)	Upper Confidence Limit	24	134.30	166.73	188.70	209.89
				48	156.14	192.90	217.81	241.83
				72	177.41	217.56	244.76	271.00
			Estimated Design Rainstorm	24	129.62	158.54	177.68	196.04
				48	150.84	183.61	205.32	226.13
				72	171.63	207.42	231.12	253.85
			Lower Confidence Limit	24	124.95	150.35	166.66	182.19
				48	145.54	174.33	192.82	210.43
				72	165.85	197.28	217.48	236.71
		New Estimated Values (2018)	Upper Confidence Limit	24	129.9	160.8	181.8	202.1
				48	151.3	189.2	214.9	239.7
				72	170.9	212.8	241.2	268.6
			Estimated Design Rainstorm	24	125.4	153.0	171.3	188.8
				48	145.8	179.6	202.0	223.5
				72	164.9	202.2	227.0	250.7
			Lower Confidence Limit	24	121.0	145.2	160.8	175.6
				48	140.3	170.0	189.1	207.3
				72	158.8	191.6	212.7	232.8

4.4.3. SUMMARY

In conclusion, the statistical analysis can be useful for investigating the adequacy issue of the length of record and the effect of sample size had on the determining of quantile estimation of design rainfall particularly for minimizing the uncertainty effect. Obeyade (1983) mentioned that at least 25-30 years of records are required to estimate design values for both short and long duration. Hogg (1991), demonstrated that 20 years of data are not sufficient to estimate the 10-year return period event, while Hogg (1992) concluded that even a 40-year period of record is still insufficient to estimate the 100-year return period event. Hogg (1992) suggested that a regional approach may improve the frequency analysis of extreme rainfall. Suffice to say that theoretically, at least a 50-year length of record length is required for the estimation of 100 years ARI.

5. ESTIMATION OF DESIGN RAINSTORM AND INTENSITY AT UNGAUGED SITE

5.1. DEVELOPING THE INTENSITY-DURATION FREQUENCY (IDF) RELATIONSHIP

The four IDF parameters or coefficients derived from gauged sites namely λ, Κ, θ and η as explained in Section (4.1) and (4.2), can be further analysed for generating the gridded maps of λ, Κ, θ and η. The said four parameters which is can be separately generalized has the ability for providing the intended IDF relationship at ungauged sites as required. A few advantages of using this approach among others are:

i. The ungauged parameters are directly transformed from gauged sites.
ii. Ungauged IDF relationship can be directly formulated at any point from the four parameters isopleths maps.
iii. IDF curve can be easily derived at any point of interest within the gridded parameters boundary.
iv. The required design rainstorm can be easily calculated in correspondence with any return period and duration (15 minutes to 72 hours).

The generalized values of λ, Κ, θ and η have been prepared in 10 and 20 km spatial resolution gridded maps where each grid is assigned by grid ID, longitude, latitude and the said IDF parameter values. The utilization of both spatial resolution gridded maps, however, needs to be prudently selected subject to the size of the study or catchment area. The said generalized values of λ, Κ, θ and η in 10 and 20 km spatial resolution gridded maps are provided in the electronic copy on the CD-ROM attached to this document**.** The sample of generalised value λ, Κ, θ and η extracted from 20 km spatial resolution gridded maps are illustrated in Figures 5.1 -5.4 while the derived design rainfall intensity and IDF curve at an ungauged site identified by Grid ID 39 (marked in yellow) are shown in Table 5.1 and Figure 5.5 respectively. The four IDF parameters at Grid ID 39 as extracted from 20 km gridded maps are λ=66.1870, K=0.1930, θ=0.2825 and η=0.6661. An example of a typical application of the 10 and 20 km gridded maps of IDF parameters at ungauged sites is given in Part 3 of the Worked Example. Sample of catchment scale analysis for Saribas and Baram River Basins cover a catchment area of 2,027 km^2 and 23,220 km^2 respectively using 10km and 20km IDF gridded maps are also demonstrated.

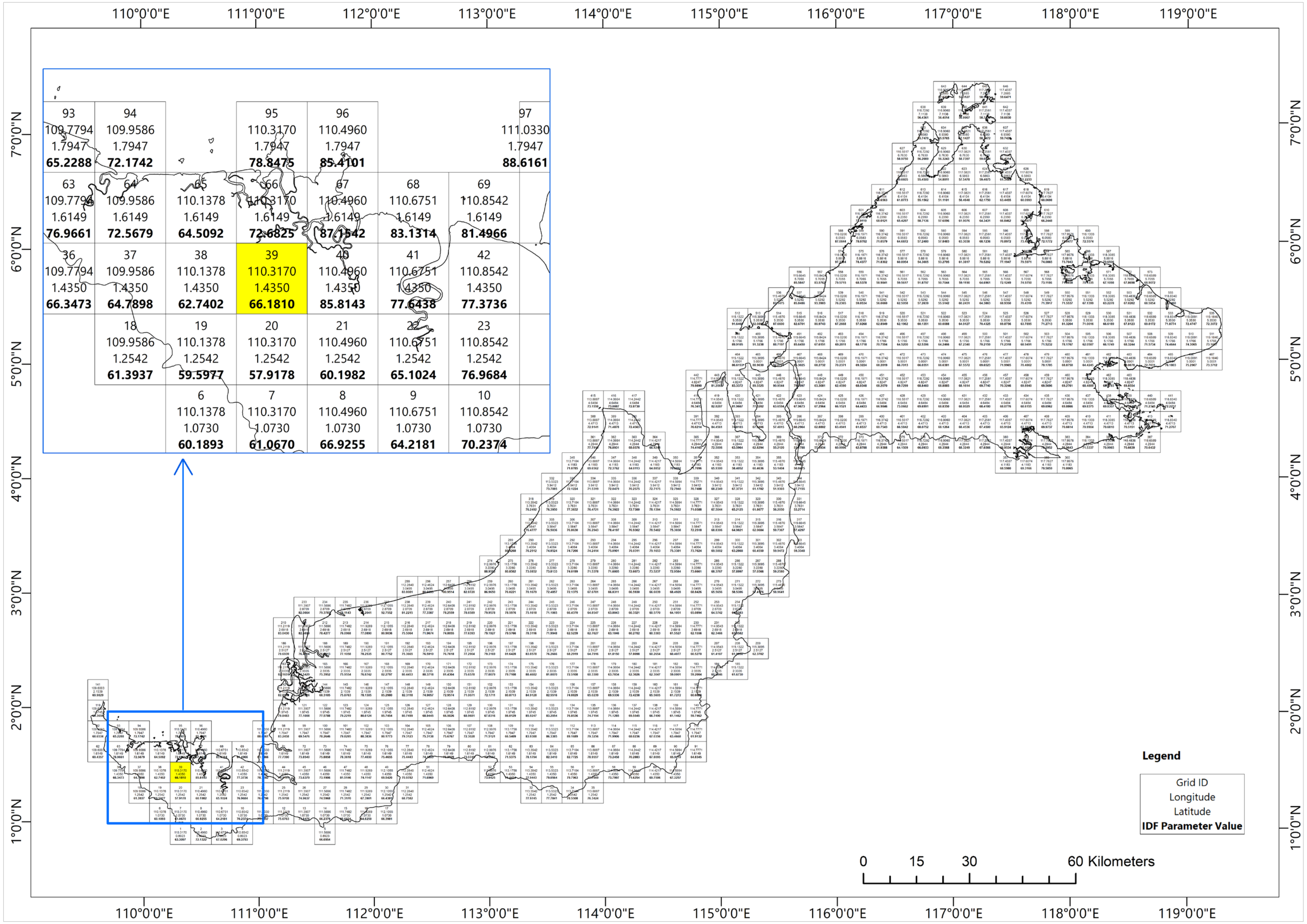


Figure 5.1: 20 km Spatial Resolution Isopleth Map of IDF Generalised Parameter λ.

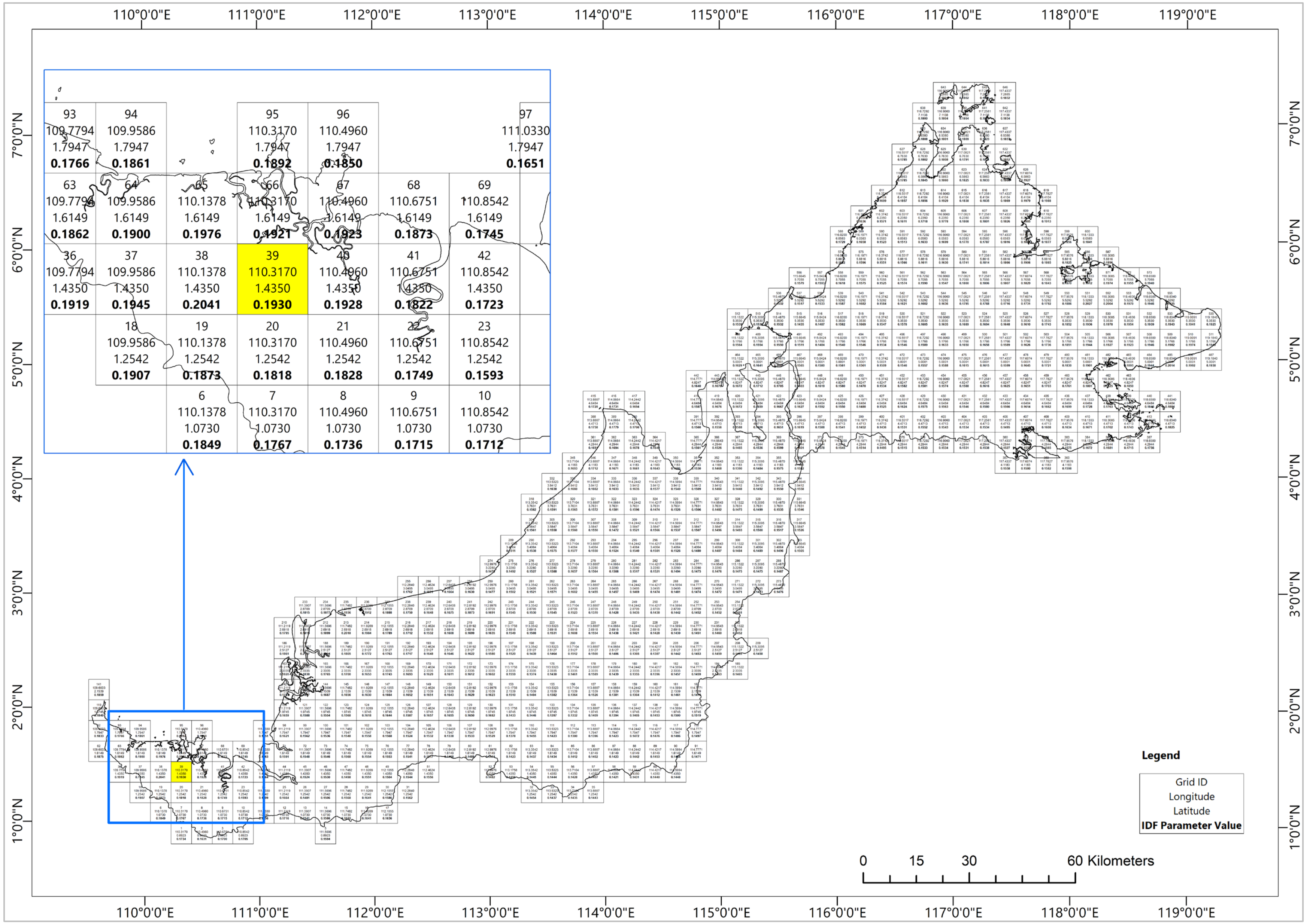


Figure 5.2: 20 km Spatial Resolution Isopleth Map of IDF Parameter K.

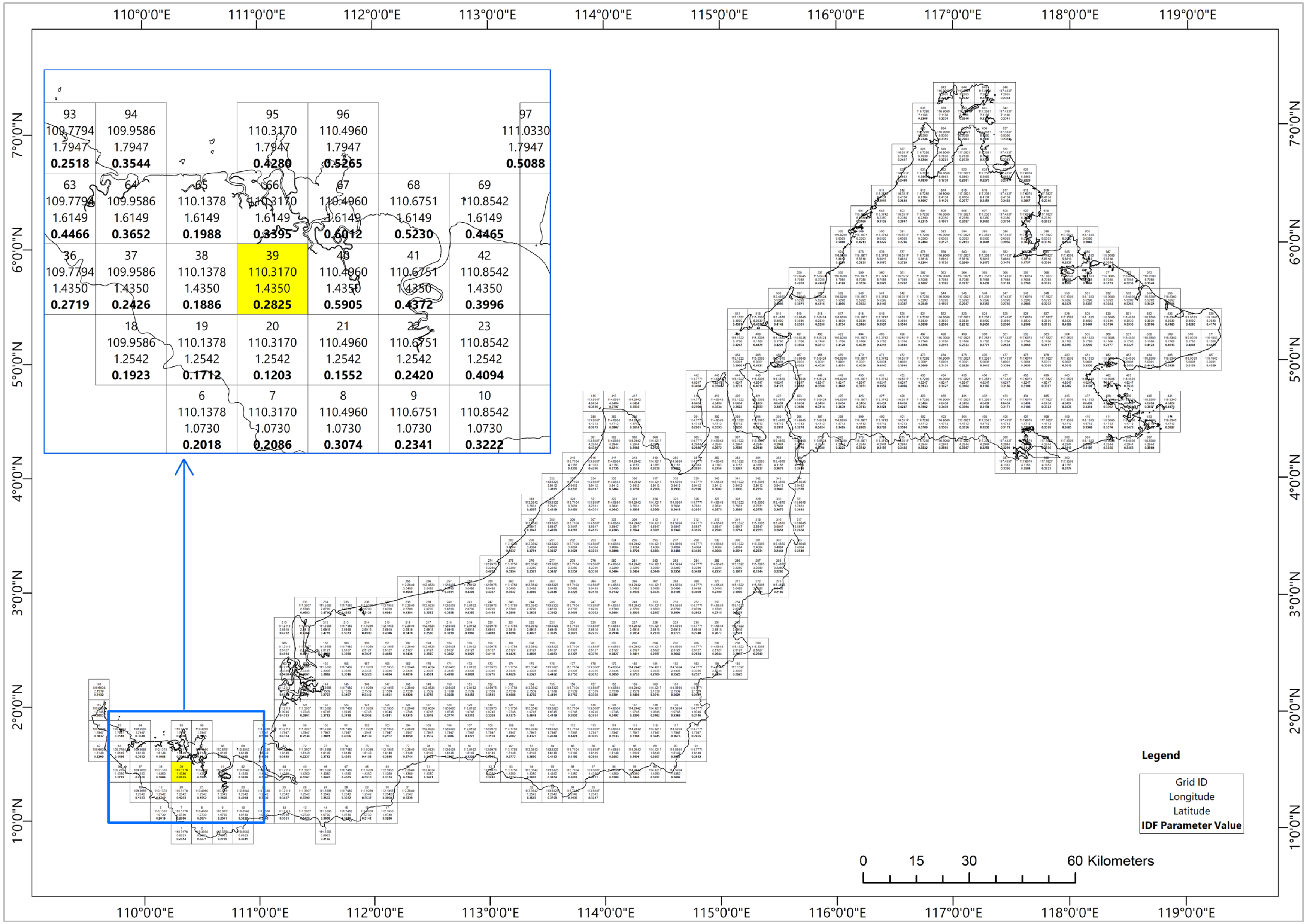


Figure 5.3: 20 km Spatial Resolution Isopleth Map of IDF Parameter θ.

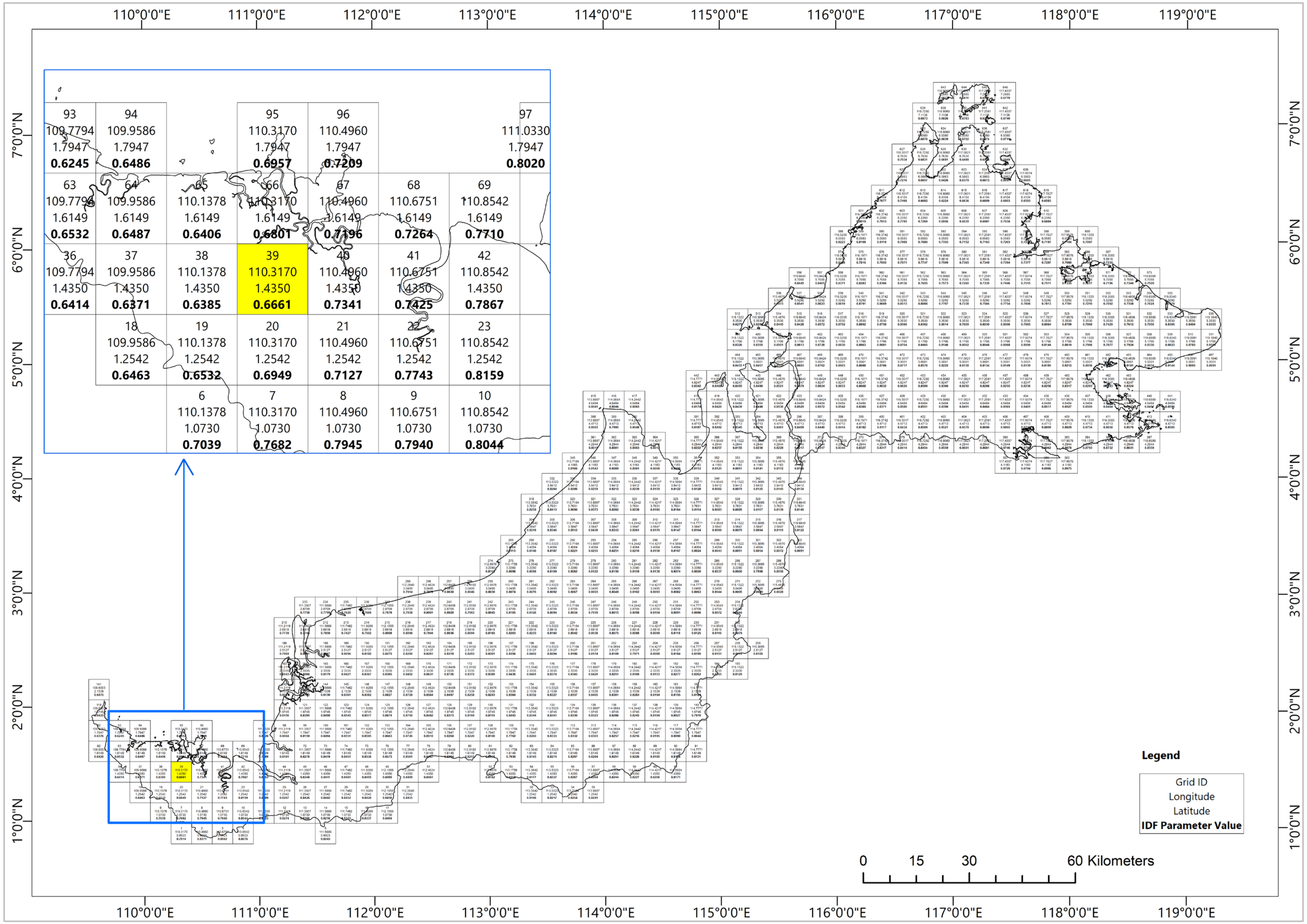


Figure 5.4: 20 km Spatial Resolution Isopleth Map of IDF Parameter η.

Table 5.1: Derived Design Rainfall Intensity (mm/hr) for Grid ID 39.

Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	115.11	137.38	157.05	179.53	187.43	214.26	244.92
0.5	89.08	106.31	121.53	138.93	145.04	165.80	189.53
1	64.10	76.50	87.45	99.97	104.37	119.30	136.38
3	34.28	40.91	46.76	53.45	55.81	63.80	72.93
6	22.24	26.55	30.35	34.69	36.22	41.40	47.33
12	14.23	16.98	19.42	22.20	23.17	26.49	30.28
24	9.04	10.79	12.33	14.10	14.72	16.82	19.23
48	5.72	6.82	7.80	8.92	9.31	10.64	12.17
72	4.37	5.22	5.96	6.82	7.12	8.13	9.30

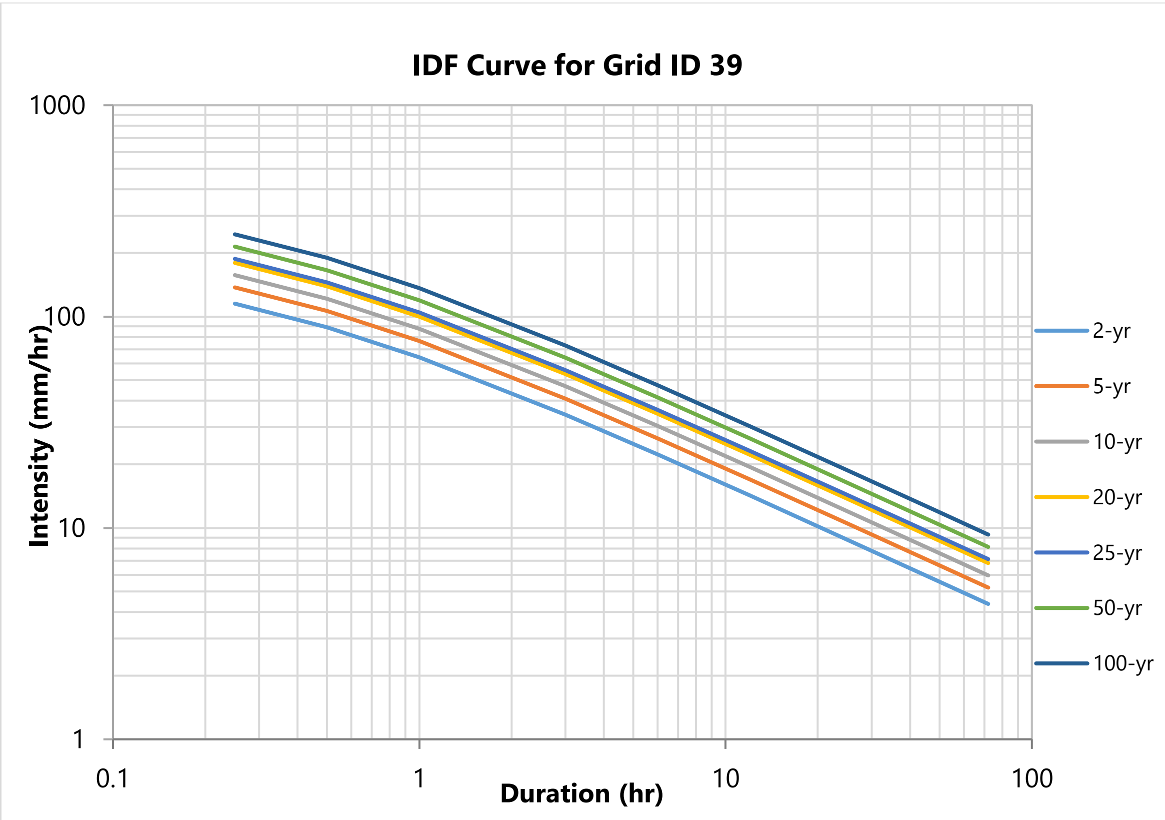


Figure 5.5: Derived IDF Curve for Grid ID 39.

5.2. ESTIMATION OF DESIGN RAINSTORM FROM IDF RELATIONSHIP

As stated in Section (4.2) and (5.1), the design rainstorm of ungauged sites, can also be easily obtained once the IDF parameters are extracted either from 10km or 20km gridded parameter maps. Furthermore, the formation of design rainfall intensity-duration-frequency (IDF) can be performed using Equation (2.24) where a typical calculation example for an ungauged site of Grid ID 39 has been demonstrated in Table 5.1. It can be transformed directly from the derived intensity (mm/hr) into rain depth (mm) corresponding with return period T=2, 5, 10, 20, 25, 50 and 100 years ARI. The required design rainstorm estimation (rain depth) and depth-duration-frequency (DDF) curve for Grid ID 39 are given in Table 5.2 and Figure 5.6 respectively.

Table 5.2: Estimated Design Rainstorm for Grid ID 39.

Rain Depth (mm)	**Return Period, *T* (yr)**						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	28.78	34.35	39.26	44.88	46.86	53.57	61.23
0.5	44.54	53.16	60.77	69.47	72.52	82.90	94.77
1	64.10	76.50	87.45	99.97	104.37	119.30	136.38
3	102.84	122.73	140.28	160.35	167.43	191.40	218.79
6	133.44	159.30	182.10	208.14	217.32	248.40	283.98
12	170.76	203.76	233.04	266.40	278.04	317.88	363.36
24	216.96	258.96	295.92	338.40	353.28	403.68	461.52
48	274.56	327.36	374.40	428.16	446.88	510.72	584.16
72	314.64	375.84	429.12	491.04	512.64	585.36	669.60

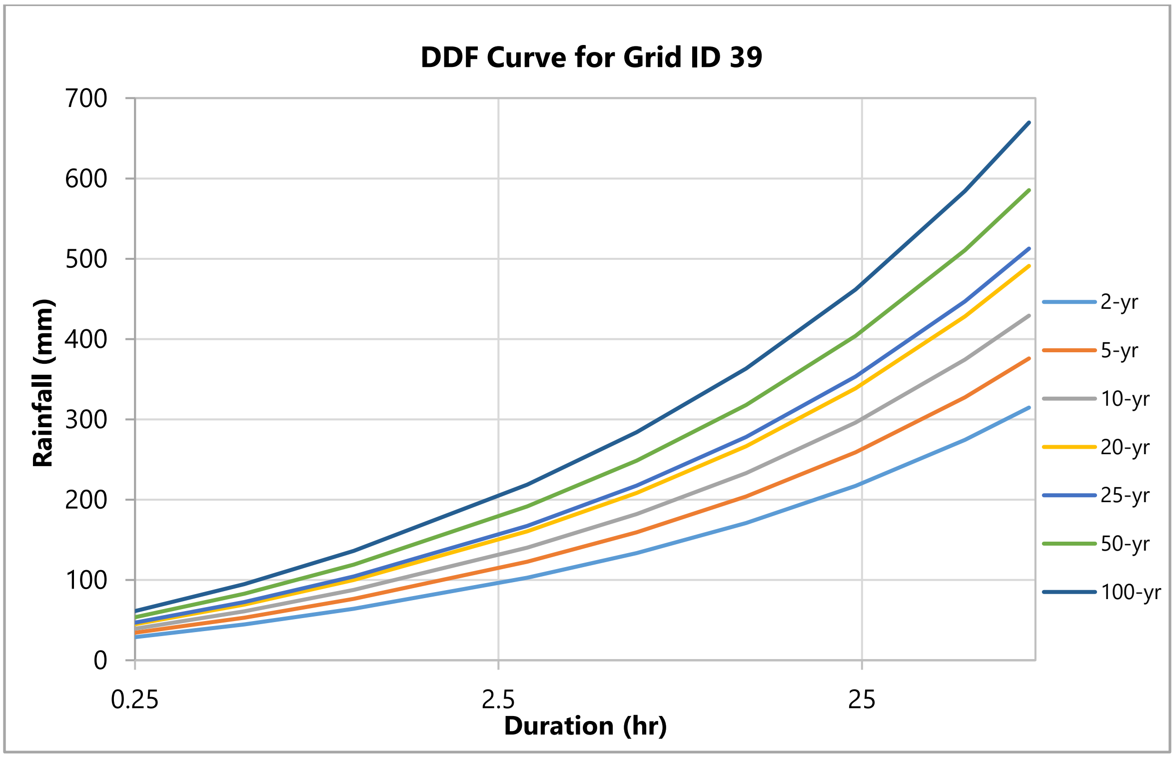


Figure 5.6: Depth-Duration-Frequency Curve for Grid ID 39.

6. TEMPORAL STORM PROFILES AND AREAL REDUCTION FACTOR (ARF)

6.1. DEVELOPING THE REGION OF TEMPORAL STORM PROFILES

6.1.1. FORMATION OF REGION BY CLUSTERING ANALYSIS

The numerical clustering analysis was performed using 1-day duration rainfall of 165 selected automatic recording rainfall stations operated by DID. In the environmental application study, four variables of site characteristics were considered that are latitude, longitude, elevation and mean annual rainfall. The potential right numbers of cluster "region" has been assigned to the 165 selected automatic rainfall stations throughout Sabah and Sarawak with a primary target being to obtain an acceptable hydrologic homogenous region by means of the Heterogeneity measures (H). The basis of Heterogeneity measurements lies where a region is declared acceptably homogenous when H<1 (H_1), possibly heterogeneous when 1≤H<2 (H_2) and definitely heterogeneous when H≥2 (H_3). The obtained clusters which are derived using Ward's method were adjusted by K–means algorithm of Hartigan & Wong (1979), which yield clusters that were a little more compact in the space of cluster variables.

6.1.2. RESULTS OF CLUSTERING ANALYSIS

A few attempts have been conducted for the said clustering analysis which is particularly for choosing the right numbers of acceptably hydrologic regions. It was initiated with 3 designated regions, and further attempts with 5, 8, 9, 10 and 12 regions were employed. The final outcome of analysis shows good performance resulted from 9 clusters that are consisted of 4 and 5 Regions located in Sabah and Sarawak respectively. The 9 acceptably regions are indicated by the numbers of acceptably homogenous (H_1) and possibly heterogeneous (H_2) regions which represents 7 out of 9 derived clusters. Only 2 regions are identified as definitely heterogeneous (H_3) when H≥2 which are Regions 1 and 4 in Sabah. One recognised, both Region 1 (in Tawau Division) and 4 (mountainous area) have limited number of rainfall stations. Although a few efforts to reproduce the required acceptably regions were performed, but, the best result is still shown by the 9 clusters. This could possibly be attributed by non-similarity site characteristics of the regions. For instance, Region 4 is located at mountainous area (high elevation), as well as insufficient number of rainfall stations. Region 1 which mostly covers Tawau Division has suffered with sufficient rainfall density in the area. The final 9 regions created in clustering analysis are shown in Figure 6.1.

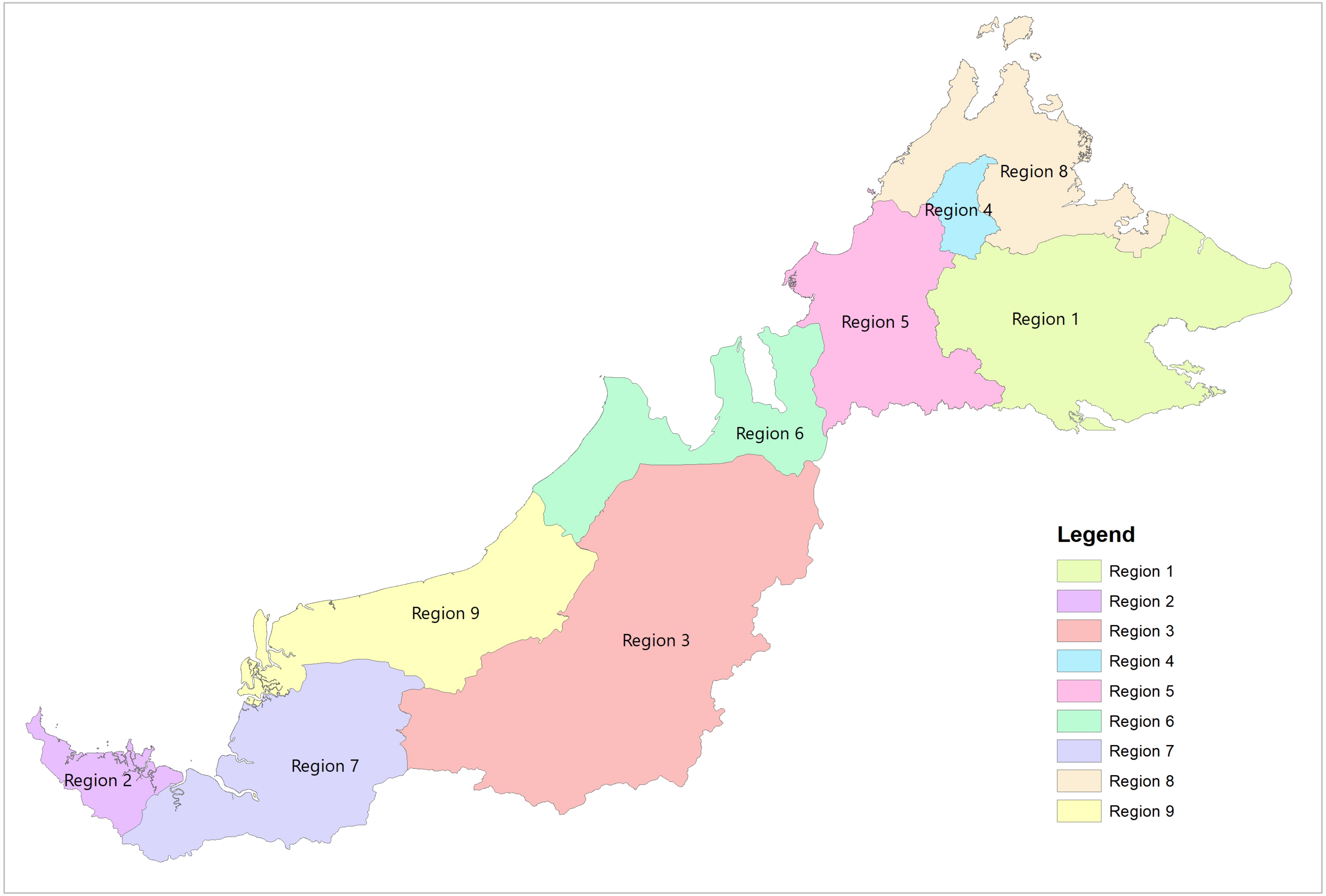


Figure 6.1: Final Region Created

6.2. DEVELOPING THE TEMPORAL PATTERN (STORM PROFILES)

About 5,940 number of storm events from the 132 automatic gauged stations were considered in the analysis, with durations ranging from 0.25-hr to 72-hrs. The 5 highest rainfall depths were selected and identified from the annual maximum rainfall data series at each station. Furthermore, the extraction of actual rainfall depth is conducted based on the designated block (time interval) as shown in Table 6.1.

Table 6.1: Designated Block Used in the Temporal Pattern Analysis.

No.	Duration	No. of Block	Duration for Each Block
1	15min	3	5min
2	30min	6	5min
3	1hr	12	5min
4	3hr	12	15min
5	6hr	12	30min
6	12hr	12	60min
7	24hr	24	1hr
8	48hr	24	2hr
9	72hr	24	3hr

Based on the final region created in clustering analysis, as shown in Figure 6.1, the required storm profiles are modelled as region-based model by using Alternating Block Method. The Alternating Block Method, introduced by Chow et al. (1988), redistributes the incremental rainfall values in a quasi-symmetrical form, where the block of maximum incremental depth is positioned at the middle of the required duration and the remaining blocks of rainfall are arranged in descending order, alternately to the right and to the left of the central block. This method is able to reduce uncertainty of the block diagram standardized values. The results of Alternating Block Method for each region by means of normalization are tabulated in Tables 6.2 – 6.10. The block diagram of temporal storm profiles can be seen in Appendix D as illustrated in Figure D1 to D9.

Table 6.2: Normalized Temporal Pattern for Region 1.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.288	0.147	0.049	0.039	0.035	0.041	0.009	0.011	0.022
2	0.401	0.161	0.071	0.059	0.049	0.046	0.021	0.019	0.025
3	0.311	0.170	0.083	0.076	0.077	0.052	0.025	0.023	0.027
4		0.200	0.089	0.095	0.088	0.087	0.027	0.025	0.034
5		0.164	0.092	0.105	0.108	0.099	0.032	0.027	0.035
6		0.158	0.099	0.112	0.114	0.142	0.033	0.034	0.036
7			0.101	0.116	0.119	0.149	0.040	0.039	0.039
8			0.096	0.108	0.111	0.124	0.045	0.045	0.042
9			0.090	0.099	0.098	0.094	0.048	0.052	0.045
10			0.084	0.089	0.084	0.076	0.057	0.054	0.050
11			0.077	0.062	0.075	0.048	0.070	0.072	0.059
12			0.069	0.040	0.042	0.042	0.074	0.080	0.063
13							0.077	0.080	0.098
14							0.072	0.077	0.059
15							0.059	0.065	0.050
16							0.056	0.053	0.048
17							0.047	0.050	0.044
18							0.040	0.045	0.040
19							0.039	0.035	0.038
20							0.032	0.029	0.036
21							0.029	0.026	0.035
22							0.027	0.024	0.027
23							0.024	0.022	0.025
24							0.017	0.013	0.023

Table 6.3: Normalized Temporal Pattern for Region 2.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.321	0.136	0.053	0.046	0.056	0.039	0.029	0.030	0.026
2	0.354	0.168	0.072	0.063	0.069	0.074	0.029	0.031	0.031
3	0.325	0.179	0.082	0.075	0.082	0.085	0.033	0.033	0.033
4		0.183	0.086	0.089	0.088	0.089	0.034	0.034	0.036
5		0.178	0.095	0.103	0.091	0.095	0.038	0.036	0.039
6		0.156	0.098	0.108	0.097	0.100	0.039	0.037	0.040
7			0.098	0.108	0.102	0.103	0.043	0.043	0.041
8			0.096	0.104	0.092	0.100	0.047	0.044	0.042
9			0.093	0.099	0.091	0.092	0.048	0.047	0.046
10			0.084	0.087	0.087	0.086	0.048	0.048	0.049
11			0.076	0.069	0.081	0.078	0.050	0.051	0.052
12			0.067	0.049	0.064	0.059	0.054	0.059	0.054
13							0.059	0.064	0.058
14							0.050	0.051	0.053
15							0.048	0.048	0.050
16							0.048	0.047	0.048
17							0.047	0.044	0.045
18							0.045	0.044	0.042
19							0.043	0.040	0.041
20							0.038	0.037	0.039
21							0.036	0.035	0.039
22							0.033	0.034	0.036
23							0.032	0.032	0.033
24							0.029	0.031	0.027

Table 6.4: Normalized Temporal Pattern for Region 3.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.324	0.136	0.052	0.037	0.023	0.013	0.005	0.009	0.007
2	0.351	0.169	0.067	0.049	0.041	0.024	0.012	0.012	0.010
3	0.325	0.181	0.081	0.074	0.066	0.048	0.014	0.015	0.019
4		0.184	0.091	0.089	0.075	0.081	0.017	0.020	0.021
5		0.173	0.093	0.107	0.110	0.113	0.021	0.022	0.024
6		0.157	0.102	0.117	0.148	0.150	0.027	0.026	0.033
7			0.105	0.129	0.168	0.206	0.030	0.036	0.037
8			0.097	0.116	0.143	0.138	0.037	0.047	0.041
9			0.091	0.090	0.076	0.108	0.041	0.050	0.044
10			0.086	0.088	0.067	0.057	0.048	0.062	0.056
11			0.076	0.063	0.050	0.046	0.051	0.064	0.073
12			0.059	0.041	0.033	0.016	0.135	0.077	0.080
13							0.211	0.175	0.170
14							0.080	0.065	0.076
15							0.051	0.062	0.064
16							0.043	0.055	0.045
17							0.038	0.047	0.043
18							0.032	0.041	0.038
19							0.028	0.029	0.034
20							0.021	0.025	0.024
21							0.018	0.020	0.022
22							0.016	0.016	0.021
23							0.013	0.014	0.010
24							0.011	0.011	0.008

Table 6.5: Normalized Temporal Pattern for Region 4.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.293	0.137	0.048	0.029	0.057	0.041	0.025	0.017	0.016
2	0.354	0.162	0.060	0.049	0.069	0.068	0.028	0.021	0.022
3	0.353	0.184	0.076	0.073	0.076	0.078	0.034	0.027	0.028
4		0.186	0.087	0.098	0.080	0.081	0.036	0.030	0.031
5		0.169	0.104	0.109	0.099	0.087	0.037	0.034	0.036
6		0.162	0.106	0.123	0.113	0.132	0.039	0.038	0.040
7			0.109	0.130	0.116	0.133	0.041	0.043	0.042
8			0.104	0.113	0.099	0.088	0.045	0.045	0.046
9			0.103	0.108	0.080	0.081	0.048	0.047	0.048
10			0.087	0.075	0.076	0.079	0.050	0.049	0.049
11			0.065	0.062	0.074	0.070	0.051	0.058	0.057
12			0.051	0.031	0.061	0.062	0.058	0.075	0.068
13							0.058	0.080	0.078
14							0.053	0.067	0.059
15							0.050	0.051	0.055
16							0.048	0.048	0.049
17							0.046	0.046	0.048
18							0.044	0.044	0.042
19							0.040	0.041	0.041
20							0.039	0.037	0.039
21							0.037	0.030	0.035
22							0.034	0.029	0.028
23							0.033	0.025	0.024
24							0.026	0.018	0.019

Table 6.6: Normalized Temporal Pattern for Region 5.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.287	0.156	0.053	0.043	0.042	0.029	0.010	0.012	0.015
2	0.391	0.164	0.068	0.060	0.057	0.054	0.017	0.019	0.020
3	0.322	0.171	0.075	0.083	0.078	0.069	0.025	0.028	0.021
4		0.178	0.085	0.086	0.090	0.091	0.025	0.029	0.023
5		0.170	0.097	0.097	0.102	0.101	0.030	0.029	0.029
6		0.161	0.107	0.108	0.106	0.115	0.035	0.030	0.032
7			0.108	0.114	0.122	0.154	0.046	0.033	0.038
8			0.099	0.103	0.105	0.107	0.050	0.033	0.046
9			0.091	0.094	0.095	0.093	0.058	0.044	0.049
10			0.084	0.083	0.085	0.090	0.058	0.056	0.052
11			0.069	0.078	0.069	0.055	0.062	0.080	0.066
12			0.064	0.051	0.049	0.042	0.069	0.089	0.086
13							0.069	0.092	0.103
14							0.064	0.082	0.076
15							0.060	0.070	0.058
16							0.058	0.046	0.050
17							0.052	0.039	0.047
18							0.049	0.033	0.042
19							0.043	0.032	0.035
20							0.034	0.029	0.031
21							0.028	0.029	0.025
22							0.025	0.028	0.021
23							0.019	0.024	0.020
24							0.014	0.014	0.015

Table 6.7: Normalized Temporal Pattern for Region 6.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.325	0.143	0.056	0.034	0.024	0.019	0.016	0.019	0.012
2	0.349	0.162	0.069	0.055	0.039	0.038	0.023	0.020	0.018
3	0.326	0.188	0.080	0.076	0.062	0.054	0.024	0.022	0.032
4		0.196	0.085	0.098	0.089	0.076	0.027	0.027	0.034
5		0.163	0.096	0.105	0.109	0.124	0.030	0.028	0.035
6		0.148	0.101	0.113	0.137	0.151	0.031	0.030	0.038
7			0.104	0.121	0.140	0.153	0.035	0.033	0.039
8			0.098	0.105	0.127	0.148	0.037	0.039	0.041
9			0.092	0.100	0.106	0.095	0.037	0.042	0.045
10			0.085	0.082	0.083	0.055	0.053	0.044	0.046
11			0.072	0.068	0.051	0.049	0.069	0.059	0.046
12			0.062	0.043	0.033	0.038	0.089	0.111	0.062
13							0.123	0.144	0.139
14							0.077	0.060	0.061
15							0.054	0.046	0.046
16							0.042	0.043	0.045
17							0.037	0.042	0.043
18							0.037	0.037	0.041
19							0.031	0.032	0.038
20							0.031	0.030	0.038
21							0.029	0.027	0.034
22							0.027	0.023	0.032
23							0.023	0.022	0.021
24							0.018	0.020	0.014

Table 6.8: Normalized Temporal Pattern for Region 7.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.322	0.136	0.051	0.022	0.029	0.014	0.014	0.026	0.028
2	0.341	0.164	0.060	0.040	0.044	0.044	0.025	0.028	0.031
3	0.337	0.184	0.079	0.074	0.055	0.050	0.029	0.030	0.032
4		0.188	0.086	0.100	0.081	0.084	0.033	0.030	0.033
5		0.173	0.101	0.115	0.116	0.103	0.035	0.032	0.036
6		0.155	0.104	0.125	0.140	0.159	0.036	0.033	0.037
7			0.104	0.128	0.154	0.193	0.037	0.035	0.039
8			0.103	0.120	0.137	0.129	0.039	0.038	0.039
9			0.095	0.106	0.091	0.087	0.040	0.042	0.043
10			0.086	0.084	0.067	0.066	0.042	0.042	0.044
11			0.073	0.057	0.046	0.046	0.050	0.045	0.050
12			0.058	0.029	0.040	0.025	0.081	0.064	0.053
13							0.110	0.165	0.109
14							0.072	0.045	0.050
15							0.050	0.043	0.046
16							0.042	0.042	0.044
17							0.040	0.041	0.043
18							0.038	0.036	0.039
19							0.036	0.033	0.038
20							0.035	0.032	0.037
21							0.034	0.031	0.034
22							0.032	0.030	0.033
23							0.028	0.030	0.031
24							0.022	0.027	0.031

Table 6.9: Normalized Temporal Pattern for Region 8.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.302	0.152	0.058	0.052	0.056	0.044	0.026	0.029	0.024
2	0.384	0.169	0.075	0.069	0.071	0.062	0.029	0.033	0.027
3	0.314	0.172	0.079	0.080	0.079	0.081	0.032	0.033	0.031
4		0.181	0.084	0.090	0.089	0.088	0.036	0.034	0.033
5		0.170	0.092	0.096	0.092	0.093	0.037	0.039	0.034
6		0.156	0.102	0.107	0.103	0.110	0.041	0.041	0.041
7			0.105	0.109	0.103	0.116	0.045	0.044	0.045
8			0.094	0.097	0.096	0.095	0.045	0.045	0.046
9			0.087	0.093	0.091	0.091	0.046	0.047	0.049
10			0.080	0.080	0.089	0.088	0.050	0.047	0.050
11			0.077	0.070	0.072	0.070	0.051	0.050	0.053
12			0.067	0.057	0.059	0.062	0.055	0.052	0.058
13							0.058	0.055	0.060
14							0.051	0.051	0.057
15							0.051	0.049	0.051
16							0.049	0.047	0.050
17							0.045	0.047	0.048
18							0.045	0.044	0.046
19							0.042	0.042	0.042
20							0.038	0.040	0.038
21							0.037	0.035	0.033
22							0.034	0.034	0.032
23							0.030	0.033	0.028
24							0.027	0.029	0.024

Table 6.10: Normalized Temporal Pattern for Region 9.

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.296	0.147	0.052	0.037	0.024	0.037	0.012	0.015	0.018
2	0.355	0.167	0.074	0.050	0.049	0.062	0.027	0.023	0.022
3	0.349	0.175	0.083	0.067	0.068	0.076	0.029	0.032	0.025
4		0.175	0.086	0.086	0.084	0.077	0.031	0.033	0.028
5		0.170	0.092	0.111	0.113	0.091	0.033	0.036	0.032
6		0.166	0.098	0.120	0.128	0.140	0.033	0.038	0.036
7			0.101	0.131	0.144	0.149	0.037	0.040	0.037
8			0.093	0.113	0.115	0.092	0.041	0.043	0.041
9			0.087	0.107	0.100	0.079	0.043	0.046	0.042
10			0.085	0.079	0.082	0.077	0.049	0.049	0.049
11			0.082	0.060	0.060	0.066	0.056	0.057	0.056
12			0.067	0.039	0.033	0.054	0.072	0.058	0.075
13							0.110	0.102	0.117
14							0.063	0.058	0.075
15							0.054	0.050	0.051
16							0.046	0.046	0.045
17							0.042	0.043	0.042
18							0.040	0.040	0.037
19							0.035	0.038	0.037
20							0.033	0.037	0.033
21							0.032	0.035	0.030
22							0.030	0.033	0.028
23							0.028	0.030	0.023
24							0.024	0.018	0.021

6.3. AREAL REDUCTION FACTOR (SPATIAL CORRECTION FACTOR)

A pre-requisite criterion for deriving the areal reduction factor (ARF) is to obtain sufficient rainfall density within a “catchment” required or recognized as a “hypothetical catchment area”, which in this case, the said catchments of 100km^2, 300km^2, 500km^2, 1,000km^2, 3,000km^2 and 5,000km^2 were assigned. In order to satisfy this criteria, 2 regions in Sabah and 1 region in Sarawak with acceptably homogenous and possibly heterogeneous have been selected where the required hypothetical catchment areas with sufficient rainfall density are located within these 3 regions.

Twenty (20) rainfall stations in Region 2 of Sarawak and 13 rainfall stations in Regions 5 and 8 of Sabah have been selected for the ARF derivation in this study. Twenty (20) years of rainfall data has been retrieved from the selected rainfall stations for the analysis. The rainfall stations located within the respective hypothetical area was then be used to determine its representative Thiessen polygon and the areal rainfall for that particular hypothetical area will be estimated by summing up the multiplication of point rainfall with Thiessen weighted factor for all the rainfall stations located within the hypothetical area. The maximum areal rainfall event for the hypothetical area is identified and the ARF is estimated by dividing the maximum areal rainfall to the maximum point rainfall recorded by the rainfall stations located within the hypothetical area.

In this study, the US Weather Bureau method (USWB) was adopted for the derivation of the ARF for Sabah and Sarawak as this method has been widely utilized by local practitioners in hydraulic related designs and applications, and the ARF is assumed not under the influence of AEP. The ARF estimated from this study is comparable with the ARF derived in *WRP 17* (1986) as similar method has been adopted to derive the ARF. Caution is made here that the ARF cannot be compared directly if the derivation methodology is not identical.

Table 6.11 indicates the fitted power equation for various durations while Tables 6.12 and 6.13 indicate the derived ARF for Sabah and Sarawak, respectively. The fitted ARF curves of respective duration are shown in Figures 6.2 and 6.3. The power function fits reasonably well to the series of data points to define the relationship of ARF and hypothetical area. The practitioners could interpolate from the values presented in Tables 6.12 and 6.13 to obtain the ARF for other rainfall durations that are not derived in this study (between 30-min to 72-hr) or can be easily calculated using the fitted power equation provided.

Table 6.11: Fitted Power Equations For Various Durations.

State	Duration	Equation	R^2
Sabah	30-min	$y = 3.6522x^{-0.307}$	0.9298
	1-hr	$y = 3.8384x^{-0.308}$	0.9459
	3-hr	$y = 3.9491x^{-0.304}$	0.9620
	6-hr	$y = 3.9192x^{-0.296}$	0.9741
	12-hr	$y = 3.8991x^{-0.291}$	0.9668
	24-hr	$y = 3.1667x^{-0.248}$	0.9194
	48-hr	$y = 3.2426x^{-0.251}$	0.9295
	72-hr	$y = 3.3019x^{-0.248}$	0.9198
Sarawak	30-min	$y = 1.4445x^{-0.191}$	0.8294
	1-hr	$y = 1.4421x^{-0.186}$	0.8540
	3-hr	$y = 1.7559x^{-0.200}$	0.9325
	6-hr	$y = 2.0499x^{-0.212}$	0.9823
	12-hr	$y = 2.1610x^{-0.210}$	0.9784
	24-hr	$y = 1.8888x^{-0.167}$	0.9829
	48-hr	$y = 1.8639x^{-0.154}$	0.9809
	72-hr	$y = 1.8097x^{-0.142}$	0.9896

Table 6.12: ARF Derived for Sabah Region.

Area (km²)	50	100	150	200	300	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500
30-min	1.000	0.888	0.784	0.718	0.634	0.542	0.438	0.387	0.354	0.331	0.313	0.298	0.286	0.276	0.267	0.260
1-hr	1.000	0.929	0.820	0.751	0.663	0.566	0.457	0.404	0.369	0.345	0.326	0.311	0.298	0.288	0.279	0.270
3-hr	1.000	0.974	0.861	0.789	0.697	0.597	0.484	0.428	0.392	0.366	0.346	0.330	0.317	0.306	0.296	0.288
6-hr	1.000	1.000	0.889	0.817	0.724	0.623	0.507	0.450	0.413	0.387	0.366	0.350	0.337	0.325	0.315	0.306
12-hr	1.000	1.000	0.907	0.834	0.742	0.639	0.522	0.464	0.427	0.400	0.379	0.363	0.349	0.337	0.327	0.318
24-hr	1.000	1.000	0.914	0.851	0.770	0.678	0.571	0.517	0.481	0.455	0.435	0.419	0.405	0.393	0.383	0.374
48-hr	1.000	1.000	0.945	0.880	0.796	0.702	0.592	0.536	0.499	0.473	0.452	0.435	0.421	0.409	0.399	0.389
72-hr	1.000	1.000	0.958	0.892	0.807	0.711	0.599	0.542	0.505	0.478	0.457	0.440	0.426	0.413	0.403	0.393

Table 6.13: ARF Derived for Sarawak Region.

Area (km²)	50	100	150	200	300	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500
30-min	0.684	0.599	0.555	0.525	0.486	0.441	0.386	0.357	0.338	0.324	0.313	0.304	0.296	0.290	0.284	0.279
1-hr	0.697	0.612	0.568	0.538	0.499	0.454	0.399	0.370	0.351	0.336	0.325	0.316	0.308	0.302	0.296	0.291
3-hr	0.803	0.699	0.645	0.609	0.561	0.507	0.441	0.407	0.384	0.367	0.354	0.343	0.334	0.326	0.320	0.314
6-hr	0.894	0.772	0.709	0.667	0.612	0.549	0.474	0.435	0.409	0.390	0.375	0.363	0.353	0.345	0.337	0.330
12-hr	0.950	0.822	0.755	0.710	0.652	0.586	0.507	0.465	0.438	0.418	0.402	0.389	0.379	0.369	0.361	0.354
24-hr	0.983	0.875	0.818	0.780	0.729	0.669	0.596	0.557	0.531	0.511	0.496	0.483	0.473	0.464	0.455	0.448
48-hr	1.000	0.917	0.862	0.824	0.774	0.716	0.643	0.604	0.578	0.559	0.543	0.530	0.520	0.510	0.502	0.495
72-hr	1.000	0.941	0.888	0.853	0.805	0.749	0.679	0.641	0.615	0.596	0.581	0.568	0.557	0.548	0.540	0.533

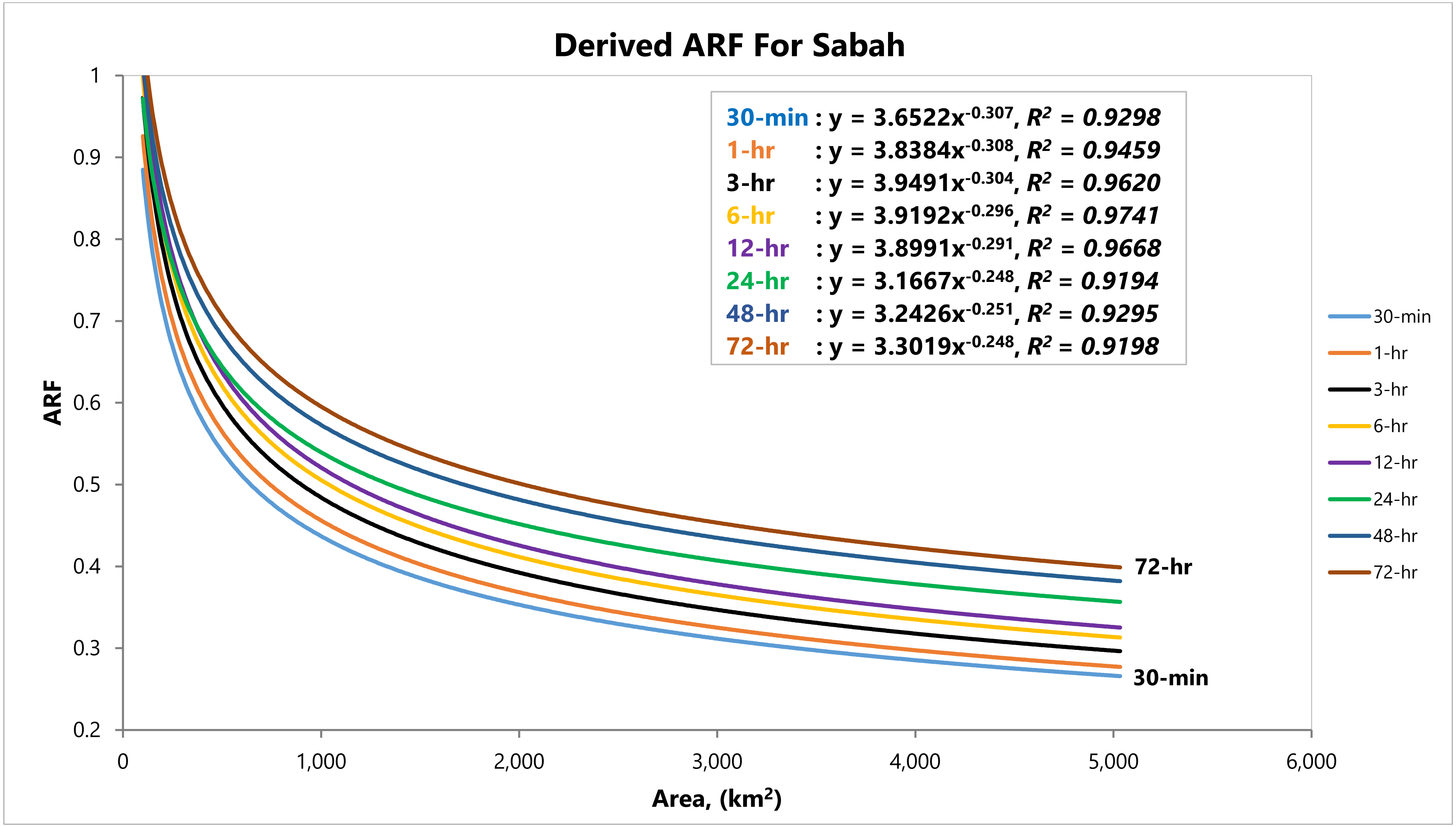


Figure 6.2: Derived ARF for Sabah.

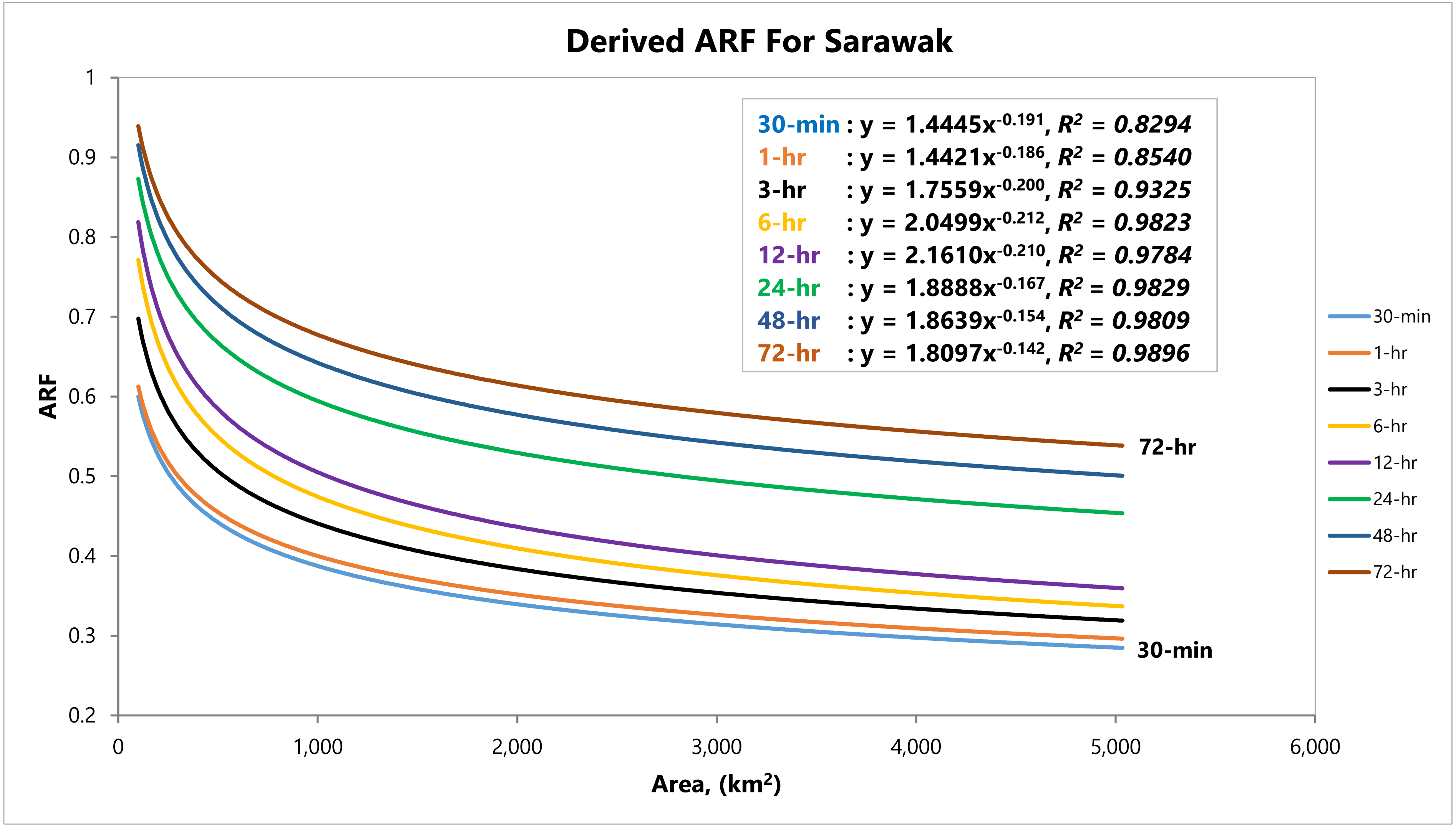


Figure 6.3: Derived ARF for Sarawak.

7. CLIMATE CHANGE FACTOR (CCF)

A total of 165 rainfall stations were selected for the analysis wherein 49 stations and 116 stations are in Sabah and Sarawak, respectively. The 1-day CCF for these stations were calculated for ARI of 2, 5, 10, 20, 25, 50 and 100 years. The CCF of ungauged locations can be estimated from the interpolation of CCF at gauged locations. The 1-day CCF for selected rainfall stations are listed in Tables 7.1 and 7.2. The interpolated CCF values are presented in 10 and 20 km spatial resolution gridded maps and are stored as an electronic copy in the CD-ROM attached to this document**.**

Table 7.1: 1-day CCF for Selected Rainfall Stations in Sabah.

No.	Station ID	Station Name	Climate Change Factor, CCF						
			Return Period, T						
			2	5	10	20	25	50	100
1	0850051RF (4278004)	Kuhara	1.16	1.22	1.24	1.26	1.26	1.27	1.29
2	0790011RF (4474002)	Kalabakan	1.13	1.19	1.21	1.23	1.24	1.25	1.27
3	0890011RF (4486001)	Semporna Airport	1.14	1.20	1.22	1.24	1.25	1.26	1.27
4	0750031RF (4563001)	Pensiangan	1.09	1.13	1.16	1.18	1.20	1.20	1.23
5	0750011RF (4764002)	Sapulut	1.09	1.13	1.17	1.19	1.19	1.21	1.22
6	1490021RF (4955001)	Sindumin	1.10	1.17	1.19	1.20	1.21	1.23	1.24
7	1460261RF (4959001)	Kemabong	1.09	1.13	1.16	1.19	1.19	1.21	1.23
8	1460271RF (4961001)	Bonor	1.08	1.13	1.16	1.18	1.19	1.20	1.22
9	1460171RF (5061001)	Kalampun	1.08	1.13	1.16	1.18	1.19	1.20	1.22
10	1040151RF (5074001)	Ulu Kuamut	1.10	1.17	1.19	1.21	1.22	1.23	1.25
11	0950011RF (5088002)	Tungku	1.14	1.20	1.22	1.24	1.25	1.26	1.28
12	1480041RF (5156001)	Mesapol	1.09	1.16	1.18	1.20	1.21	1.22	1.24
13	1460141RF (5158001)	Pangi Dam Site	1.08	1.14	1.17	1.19	1.19	1.21	1.22
14	1460031RF (5163002)	Sook	1.07	1.12	1.15	1.18	1.18	1.20	1.21
15	1010041RF (5181001)	Limkabong	1.13	1.19	1.21	1.23	1.24	1.25	1.27
16	1040061RF (5269001)	Tongod	1.13	1.18	1.21	1.23	1.23	1.25	1.26
17	1040021RF (5274001)	Kuamut Met. Stn.	1.14	1.20	1.22	1.25	1.23	1.27	1.28
18	1040181RF (5275001)	Balat	1.12	1.18	1.20	1.22	1.24	1.24	1.26
19	1450011RF (5353001)	Mempakul	1.09	1.16	1.18	1.20	1.21	1.23	1.24
20	1460011RF (5357003)	Beaufort JPS	1.09	1.13	1.17	1.19	1.20	1.21	1.23
21	1460061RF (5361002)	Keningau Met. Stn.	1.08	1.13	1.16	1.18	1.19	1.21	1.22
22	1460161RF (5364002)	Tulid	1.07	1.12	1.15	1.17	1.17	1.19	1.20
23	1040161RF (5372001)	Tangkulap	1.10	1.18	1.19	1.21	1.22	1.24	1.25
24	1460071RF (5462001)	Apin Apin	1.13	1.16	1.18	1.17	1.20	1.22	1.20
25	1460281RF (5465001)	Sinua At Sabah	1.13	1.16	1.19	1.19	1.21	1.23	1.20
26	1040111RF (5482001)	Bilit	1.13	1.19	1.21	1.23	1.24	1.25	1.26
27	1420011RF (5558001)	Bongawan	1.08	1.13	1.16	1.18	1.19	1.21	1.22
28	1040101RF (5582001)	Sukau	1.13	1.19	1.21	1.23	1.24	1.26	1.27

No.	Station ID	Station Name	Climate Change Factor, CCF						
			Return Period, T						
			2	5	10	20	25	50	100
29	1460291RF (5663001)	Tambunan Agr. Stn.	1.07	1.11	1.14	1.16	1.17	1.18	1.20
30	1160071RF (5671002)	Telupid	1.09	1.16	1.18	1.20	1.21	1.22	1.24
31	1160171RF (5768001)	Tampias	1.08	1.14	1.17	1.19	1.20	1.21	1.23
32	1390011RF (5862002)	Ulu Moyog	1.06	1.11	1.14	1.16	1.17	1.18	1.19
33	1160201RF (5875001)	Beluran	1.12	1.17	1.21	1.23	1.23	1.25	1.26
34	1380021RF (5961001)	Kiansam	1.07	1.11	1.15	1.17	1.17	1.19	1.20
35	1380041RF (5961002)	Inanam Met. Stn.	1.07	1.12	1.15	1.16	1.17	1.18	1.20
36	1160101RF (5966001)	Ranau Agr. Stn.	1.09	1.13	1.17	1.19	1.20	1.21	1.22
37	1160141RF (5973001)	Trusan Sapi Met. Stn.	1.12	1.17	1.20	1.23	1.23	1.25	1.26
38	1360021RF (6062001)	Kiulu (Tuaran)	1.11	1.13	1.15	1.15	1.16	1.17	1.21
39	1340011RF (6064001)	Dalas	1.13	1.16	1.18	1.18	1.20	1.22	1.21
40	1160221RF (6073001)	Basai	1.12	1.16	1.20	1.22	1.22	1.24	1.25
41	1160181RF (6168001)	Merungin	1.09	1.14	1.17	1.19	1.20	1.21	1.23
42	1200041RF (6172001)	Bukit Mondou	1.12	1.17	1.20	1.22	1.23	1.24	1.26
43	1340041RF (6264001)	Tamu Darat Agr. Stn.	1.09	1.14	1.17	1.19	1.19	1.20	1.22
44	1320011RF (6365001)	Rosok	1.09	1.14	1.17	1.19	1.20	1.21	1.22
45	1270021RF (6468001)	Tandek P.H.	1.11	1.17	1.19	1.21	1.21	1.23	1.24
46	1270031RF (6476001)	Trusan Sugut	1.12	1.18	1.20	1.22	1.22	1.24	1.25
47	1260021RF (6670001)	Kobon	1.11	1.18	1.20	1.22	1.22	1.24	1.24
48	1260031RF (6770001)	Pitas	1.11	1.18	1.19	1.21	1.21	1.23	1.24
49	1310021RF (6868001)	Kudat JPS	1.11	1.17	1.19	1.20	1.21	1.22	1.23

Table 7.2: 1-day CCF for Selected Rainfall Stations in Sarawak.

No.	Station ID	Station Name	Climate Change Factor, CCF						
			Return Period, T						
			2	5	10	20	25	50	100
1	1790061RF (905039)	Bunan Gega	1.10	1.14	1.16	1.18	1.18	1.20	1.21
2	1790071RF (1003031)	Tebedu	1.13	1.17	1.19	1.21	1.21	1.23	1.24
3	1790081RF (1004001)	Krusen	1.08	1.13	1.15	1.16	1.17	1.18	1.19
4	1790091RF (1005079)	Bukit Matuh	1.08	1.11	1.13	1.14	1.14	1.16	1.16
5	1790101RF (1005080)	Sungai Busit	1.09	1.13	1.15	1.17	1.17	1.19	1.20
6	1790111RF (1006028)	Sungai Bedup	1.10	1.14	1.16	1.18	1.18	1.20	1.20
7	1790121RF (1006033)	Sungai Merang	1.12	1.17	1.19	1.21	1.22	1.23	1.25
8	1790131RF (1006037)	Sungai Teb	1.09	1.13	1.14	1.16	1.16	1.17	1.18
9	1790141RF (1007040)	Balai Ringin	1.10	1.13	1.15	1.17	1.17	1.18	1.19
10	1770081RF (1015001)	Batu Lintang	1.14	1.20	1.23	1.25	1.26	1.28	1.29
11	1770021RF (1018002)	Lubok Antu	1.14	1.20	1.24	1.27	1.27	1.29	1.31
12	1810071RF (1102019)	Padawan	1.08	1.13	1.15	1.16	1.17	1.18	1.19
13	1790151RF (1105027)	Serian	1.09	1.13	1.15	1.17	1.17	1.18	1.20
14	1790161RF (1105035)	Semuja Nonok	1.10	1.14	1.16	1.17	1.18	1.19	1.20
15	1790171RF (1105050)	Tebakang	1.08	1.12	1.14	1.16	1.16	1.18	1.18

No.	Station ID	Station Name	Climate Change Factor, CCF						
			Return Period, T						
			2	5	10	20	25	50	100
16	1770091RF (1111008)	Pantu	1.12	1.16	1.19	1.20	1.21	1.22	1.24
17	1770101RF (1118002)	Bekatan	1.14	1.20	1.24	1.26	1.27	1.29	1.31
18	1800051RF (1203002)	Kampung Gayu	1.08	1.12	1.14	1.16	1.17	1.18	1.19
19	1800061RF (1204001)	Plaman Nyabet	1.09	1.13	1.15	1.17	1.17	1.18	1.20
20	1800011RF (1204024)	Dragon School	1.06	1.10	1.12	1.14	1.14	1.16	1.17
21	1800081RF (1205006)	Tarat	1.06	1.10	1.11	1.12	1.13	1.14	1.15
22	1790181RF (1208001)	Kampung Sangkalan Pasir	1.10	1.14	1.16	1.18	1.19	1.20	1.21
23	1770011RF (1214001)	Sri Aman	1.14	1.21	1.23	1.25	1.25	1.27	1.29
24	1770111RF (1220025)	Nanga Delok	1.14	1.19	1.24	1.26	1.27	1.29	1.31
25	1810081RF (1301001)	Kampung Monggak	1.08	1.13	1.15	1.17	1.17	1.19	1.19
26	1810091RF (1302078)	Kampung Git	1.09	1.13	1.15	1.17	1.17	1.19	1.20
27	1800091RF (1303014)	Semongok	1.08	1.12	1.15	1.16	1.17	1.18	1.19
28	1790231RF(1306055)	Lubok Ipoi	1.09	1.13	1.15	1.17	1.17	1.18	1.19
29	1770121RF (1313006)	Stumbin	1.14	1.20	1.22	1.25	1.25	1.27	1.28
30	1770131RF (1321001)	Nanga Mujan	1.14	1.19	1.23	1.26	1.27	1.29	1.30
31	1810101RF (1400001)	Kampung Opar	1.07	1.10	1.11	1.13	1.13	1.14	1.15
32	1810021RF (1401005)	Bau	1.08	1.12	1.13	1.14	1.15	1.15	1.16
33	1810111RF (1402001)	Siniawan Water Works	1.07	1.10	1.11	1.13	1.13	1.14	1.15
34	1810121RF (1402002)	Siniawan	1.07	1.10	1.11	1.13	1.13	1.14	1.15
35	1810011RF (1403001)	Kuching Airport	1.11	1.16	1.18	1.20	1.21	1.22	1.23
36	1800101RF (1404049)	Paya Paloh	1.08	1.12	1.15	1.17	1.17	1.19	1.20
37	1750031RF (1415001)	Nanga Lubau	1.13	1.20	1.23	1.26	1.26	1.28	1.30
38	1770141RF (1417001)	Nanga Entalau	1.13	1.20	1.23	1.26	1.27	1.29	1.31
39	1860021RF (1499051)	Stungkor	1.08	1.13	1.15	1.16	1.17	1.18	1.19
40	1840011RF (1502001)	Sebubut	1.06	1.10	1.12	1.14	1.14	1.15	1.16
41	1810131RF (1503004)	Kuching Saberkas	1.12	1.17	1.20	1.22	1.22	1.24	1.25
42	1800111RF (1505081)	Ketup	1.07	1.11	1.13	1.14	1.14	1.16	1.16
43	1800031RF (1506001)	Semera	1.08	1.12	1.14	1.16	1.16	1.18	1.18
44	1800041RF (1506034)	Asa Jaya	1.07	1.12	1.14	1.15	1.16	1.17	1.18
45	1780021RF (1509009)	Sebuyau	1.10	1.14	1.17	1.19	1.20	1.21	1.23
46	1730141RF (1544001)	Long Singut	1.08	1.13	1.16	1.17	1.18	1.19	1.20
47	1850011RF (1601001)	Sungai Rayu	1.08	1.13	1.15	1.17	1.17	1.19	1.20
48	1750041RF (1616021)	Nanga Tiga	1.13	1.20	1.23	1.26	1.26	1.29	1.30
49	1860011RF (1698007)	Lundu	1.08	1.13	1.15	1.16	1.17	1.18	1.19
50	1820011RF (1704013)	Telok Assam	1.08	1.13	1.16	1.18	1.18	1.20	1.21
51	1740041RF (1713005)	Saratok DID	1.12	1.19	1.22	1.24	1.24	1.26	1.28
52	1730151RF (1726041)	Nanga Bangkit	1.13	1.18	1.22	1.24	1.25	1.27	1.29
53	1730161RF (1731001)	Nanga Balang	1.11	1.14	1.18	1.20	1.21	1.22	1.24
54	1740051RF (1811007)	Kabong	1.12	1.18	1.21	1.23	1.24	1.26	1.28
55	1730171RF (1816029)	Pakan	1.13	1.19	1.23	1.25	1.26	1.28	1.30
56	1730181RF (1823001)	Nanga Jagau	1.14	1.20	1.23	1.25	1.26	1.28	1.30
57	1730191RF (1834001)	Gaat Balleh	1.10	1.14	1.17	1.19	1.20	1.21	1.23

No.	Station ID	Station Name	Climate Change Factor, CCF						
			Return Period, T						
			2	5	10	20	25	50	100
58	1730201RF (1836042)	Nanga Entawau	1.09	1.13	1.16	1.18	1.19	1.21	1.22
59	1730211RF (1843001)	Long Busang	1.06	1.11	1.13	1.14	1.15	1.16	1.18
60	1870011RF (1897016)	Sematan	1.07	1.12	1.14	1.16	1.16	1.17	1.18
61	1740061RF (1914001)	Asun SRK	1.13	1.18	1.21	1.24	1.25	1.26	1.28
62	1730221RF (1947001)	Long Unai	1.08	1.14	1.16	1.18	1.18	1.20	1.21
63	1730231RF (2021001)	Renan Kemiding	1.17	1.25	1.29	1.33	1.34	1.36	1.39
64	1730241RF (2021036)	Kanowit Water Works	1.17	1.25	1.30	1.33	1.34	1.37	1.39
65	1730251RF (2025012)	Song	1.14	1.19	1.22	1.24	1.25	1.27	1.29
66	1730261RF (2029002)	Kapit New Head Works	1.12	1.16	1.20	1.22	1.23	1.25	1.26
67	1730271RF (2031034)	Nanga Mujong	1.11	1.14	1.18	1.21	1.21	1.23	1.24
68	1730281RF (2036001)	Tunoh Scheme	1.09	1.13	1.16	1.18	1.18	1.20	1.21
69	1730291RF (2115008)	Sarikei DID	1.14	1.19	1.22	1.24	1.25	1.27	1.29
70	1730301RF (2134001)	Nanga Tiau	1.09	1.13	1.16	1.18	1.19	1.20	1.21
71	1730311RF (2141048)	Long Jawe	1.08	1.13	1.15	1.17	1.18	1.19	1.21
72	1730321RF (2212001)	Belawai	1.14	1.20	1.23	1.25	1.26	1.27	1.29
73	1730351RF (2230143)	Nanga Merit	1.11	1.15	1.19	1.21	1.21	1.23	1.25
74	(2239147)	Batu Keling	1.08	1.13	1.15	1.18	1.18	1.20	1.21
75	(2318007)	Sibu Airport	1.15	1.21	1.23	1.25	1.26	1.27	1.29
76	1710011RF (2321001)	Stapang	1.15	1.21	1.24	1.26	1.27	1.29	1.31
77	1700051RF (2325039)	Sungai Arau	1.14	1.20	1.23	1.25	1.26	1.28	1.30
78	1730361RF (2333001)	Punan Bah	1.09	1.14	1.17	1.19	1.19	1.21	1.22
79	1730371RF (2346001)	Long Lidam	1.08	1.13	1.15	1.17	1.18	1.19	1.21
80	1730601RF (2412001)	Paloh Bangau	1.14	1.20	1.22	1.24	1.25	1.27	1.28
81	1730381RF (2442001)	Long Laku	1.07	1.11	1.15	1.17	1.17	1.19	1.20
82	1730391RF (2514004)	JPS Daro	1.19	1.25	1.28	1.29	1.30	1.32	1.33
83	1700061RF (2522038)	Bukit Engkerbai	1.12	1.18	1.21	1.23	1.23	1.25	1.27
84	1670021RF (2625051)	Nanga Lemai	1.14	1.22	1.25	1.27	1.27	1.30	1.31
85	1720011RF (2712001)	Tekajong	1.18	1.24	1.27	1.29	1.30	1.31	1.33
86	1730401RF (2718022)	Sungai Kut	1.15	1.20	1.22	1.24	1.24	1.26	1.27
87	(2723002)	Mukah-Balingian OPS4	1.15	1.21	1.24	1.27	1.27	1.29	1.31
88	1650011RF (2828025)	Tatau Town	1.12	1.16	1.20	1.22	1.23	1.24	1.26
89	1730411RF (2843001)	Long Jek	1.08	1.12	1.15	1.17	1.18	1.19	1.20
90	1700021RF (2920005)	Mukah JKR	1.14	1.21	1.24	1.26	1.27	1.29	1.30
91	1730421RF (2939045)	Long Sambop	1.09	1.14	1.17	1.19	1.19	1.21	1.22
92	1640041RF (3130002)	Bintulu Airport	1.10	1.14	1.18	1.20	1.21	1.22	1.24
93	1640051RF (3132023)	Sebauh	1.10	1.13	1.18	1.20	1.20	1.22	1.23
94	1640031RF (3137021)	Tubau	1.08	1.12	1.15	1.18	1.18	1.20	1.21
95	1550111RF (3152011)	Lio Matu	1.10	1.15	1.18	1.20	1.21	1.23	1.24
96	1640061RF (3234022)	Labang	1.09	1.12	1.17	1.19	1.19	1.21	1.22
97	1550121RF (3347003)	Long Akah	1.14	1.22	1.26	1.29	1.30	1.32	1.34
98	1550131RF (3444018)	Long Pilah	1.10	1.17	1.20	1.22	1.23	1.25	1.26
99	1550141RF (3541033)	Long Jegan	1.09	1.15	1.17	1.20	1.20	1.22	1.23

No.	Station ID	Station Name	Climate Change Factor, CCF						
			Return Period, T						
			2	5	10	20	25	50	100
100	1580031RF (3737045)	Sungai Lebai	1.09	1.14	1.16	1.18	1.19	1.21	1.22
101	1550151RF (3744009)	Long Lama	1.09	1.15	1.18	1.20	1.20	1.22	1.23
102	1550161RF (3842034)	Long Teru	1.08	1.14	1.17	1.19	1.20	1.21	1.23
103	1550171RF (3950020)	Long Seridan	1.12	1.20	1.23	1.25	1.26	1.27	1.29
104	1520021RF (3956001)	Ba Kelalan	1.11	1.17	1.19	1.21	1.22	1.23	1.25
105	1570021RF (4038006)	Bekenu	1.14	1.22	1.26	1.29	1.30	1.32	1.34
106	1550061RF (4143004)	Marudi	1.11	1.18	1.21	1.24	1.24	1.26	1.28
107	1540091RF (4151017)	Long Napir	1.12	1.20	1.23	1.25	1.25	1.27	1.28
108	1520031RF (4255006)	Long Semado	1.10	1.16	1.19	1.21	1.21	1.23	1.24
109	1560021RF (4339005)	Miri Airport	1.14	1.23	1.28	1.31	1.32	1.35	1.37
110	1560041RF (4440060)	Miri DID	1.11	1.18	1.21	1.24	1.25	1.27	1.28
111	1540101RF (4449012)	Nanga Medamit	1.11	1.18	1.21	1.23	1.24	1.26	1.27
112	1540021RF (4548004)	Ukong	1.10	1.17	1.20	1.22	1.23	1.25	1.26
113	1520041RF (4554001)	Long Sukang	1.10	1.16	1.19	1.21	1.21	1.23	1.24
114	1530011RF (4650023)	Pandaruan	1.09	1.17	1.20	1.23	1.24	1.26	1.28
115	1540111RF (4749001)	Limbang DID	1.10	1.16	1.19	1.20	1.21	1.23	1.24
116	1500011RF (4854009)	Lawas Airfield	1.11	1.16	1.19	1.21	1.22	1.23	1.25

PART 3 – WORKED EXAMPLES

8. GAUGED SITE

8.1. INTENSITY-DURATION FREQUENCY (IDF)

Solution:

Derive the IDF curve for Site 1790061RF (905039) at Bunan Gega.

Step 1: Determine the derived IDF parameters from Table 4.2.

Derived IDF parameters are:

IDF Parameter	Value
Κ	0.1600
λ	74.5208
θ	0.3508
η	0.8503

Step 2: Calculate rainfall intensity from IDF Equation (2.24).

Example calculation for the 24 hour duration rainfall intesity with the return period of 100 years.

Rainfall intensity, I $= \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$

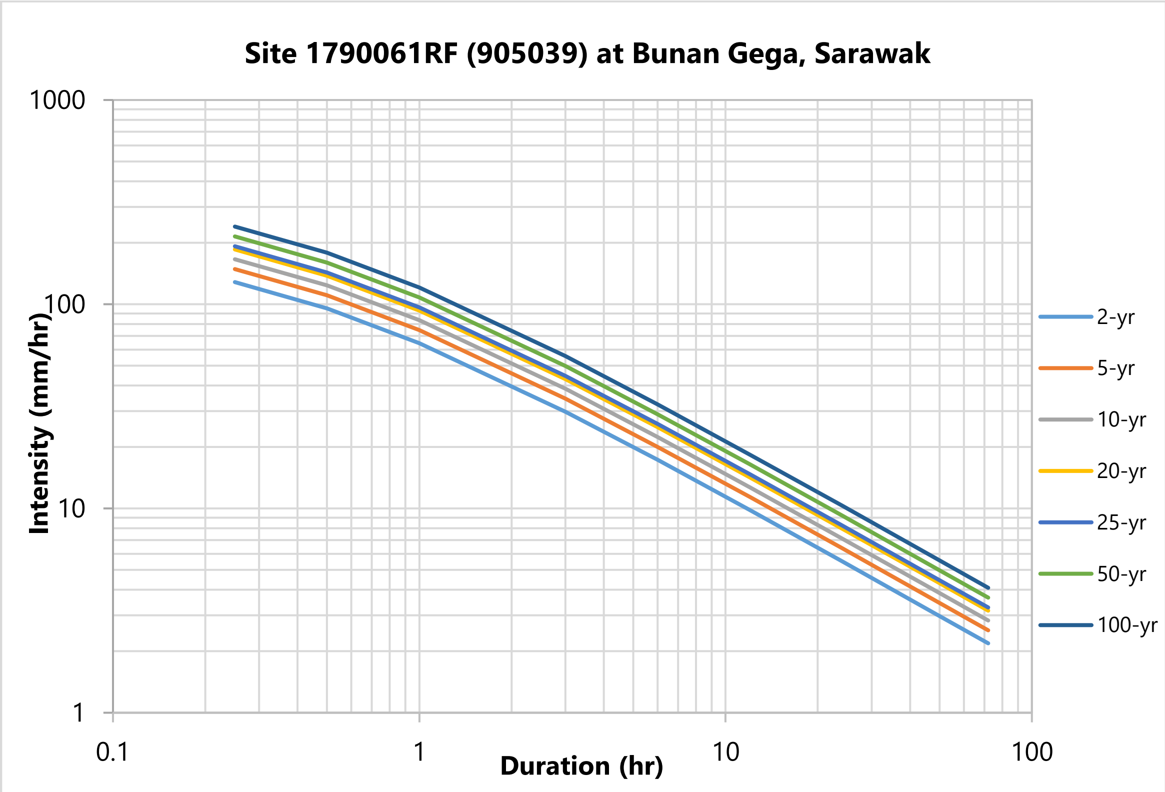
$= \frac{74.5208 \times (100)^{0.1600}}{(24+0.3508)^{0.8503}}$

= 10.31 mm/hr

Calculate rainfall intensity for durations of 15-min, 30-min, 60-min, 3-hr, 6-hr, 12-hr, 24-hr, 48-hr and 72-hr corresponding to the ARI of 2, 5, 10, 20, 25, 50 and 100 years.

Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	128.41	148.68	166.12	185.60	192.35	214.91	240.12
0.5	95.52	110.61	123.58	138.07	143.09	159.87	178.63
1	64.48	74.66	83.41	93.20	96.58	107.91	120.57
3	29.78	34.48	38.53	43.04	44.61	49.84	55.69
6	17.29	20.02	22.37	24.99	25.90	28.94	32.33
12	9.82	11.37	12.71	14.20	14.71	16.44	18.37
24	5.51	6.38	7.13	7.97	8.26	9.23	10.31
48	3.08	3.56	3.98	4.45	4.61	5.15	5.75
72	2.18	2.53	2.83	3.16	3.27	3.66	4.09

Step 5: Draw IDF curves



8.2. DESIGN RAINSTORM

Find the 24 hour duration design rainfall with the return period of 100 years at Site 1790061RF (905039) at Bunan Gega.

Step 1: Find the rainfall intensity from Section 8.1.

The 24 hour duration design rainfall with the return period of 100 years rainfall intensity is **10.31 mm/hr**.

Step 2: Calculate rainfall depth.

Rainfall depth $= I \times d$

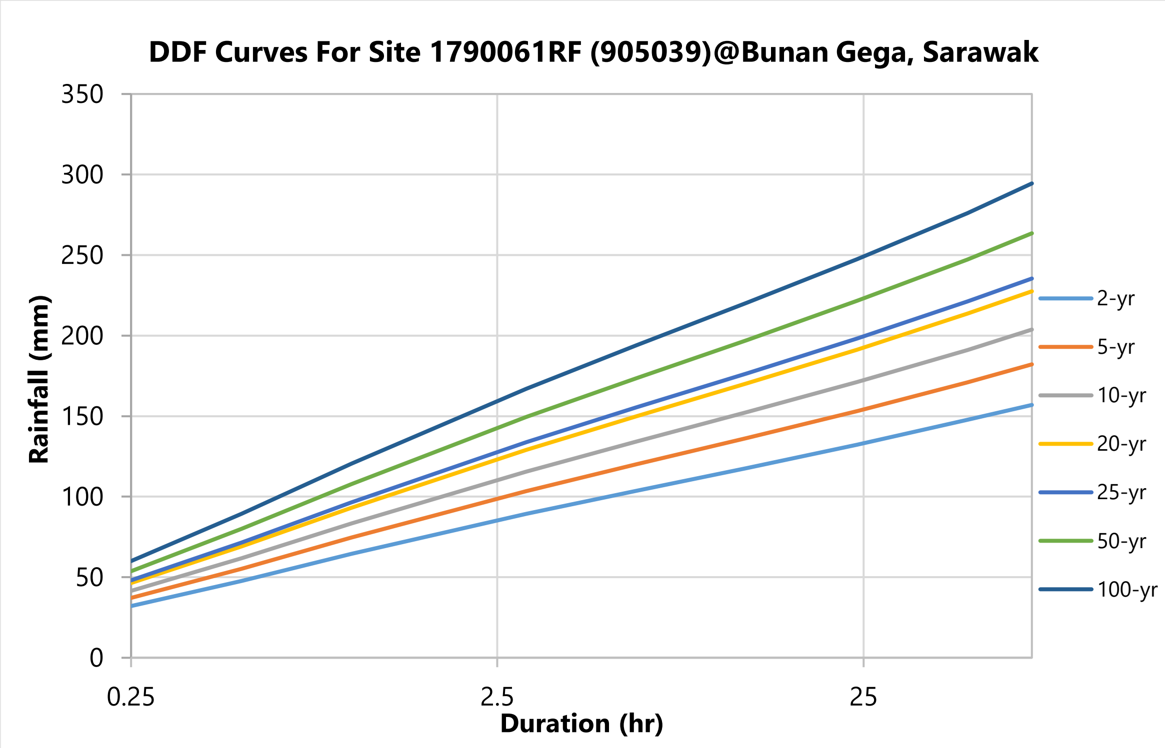
$= 10.31 \times 24$ hr

$= 247.44$ mm

Step 3: Calculate rainfall depth for each duration and return period.

Rain Depth (mm)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	32.10	37.17	41.53	46.40	48.09	53.73	60.03
0.5	47.76	55.31	61.79	69.04	71.55	79.94	89.32
1	64.48	74.66	83.41	93.20	96.58	107.91	120.57
3	89.34	103.44	115.59	129.12	133.83	149.52	167.07
6	103.74	120.12	134.22	149.94	155.40	173.64	193.98
12	117.84	136.44	152.52	170.40	176.52	197.28	220.44
24	132.24	153.12	171.12	191.28	198.24	221.52	247.44
48	147.84	170.88	191.04	213.60	221.28	247.20	276.00
72	156.96	182.16	203.76	227.52	235.44	263.52	294.48

Step 4: Draw Depth-Duration-Frequency curves



8.3. AREAL REDUCTION FACTOR

A barrage is proposed to be constructed at Site 1790061RF (905039) at Bunan Gega with the catchment area of 500 km^2. Find the appropriate areal reduction factor for the design storm of 100 year return period for 24 hour.

Step 1: **Determine the derived IDF parameters from Table 4.2.**

Derived IDF parameters are:

IDF Parameter	Value
Κ	0.1600
λ	74.5208
θ	0.3508
η	0.8503

Step 2: Calculate rainfall intensity from Equation (2.24).

Rainfall intensity, *I* $= \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$

$= \frac{74.5208 \times (100)^{0.1600}}{(24+0.3508)^{0.8503}}$

= 10.31 mm/hr

Step 3: Calculate rainfall depth.

Rainfall depth = *I* x *d*

= 10.31 x 24 hr

= 247.44 mm

Step 4: Find the ARF to be applied to the design storm.

From Table 6.13, the ARF for design rainstorm of 100 year return period for 24-hour duration is 0.669. Therefore, the areal design storm rainfall depth is:

Areal design rainfall depth = 247.44 mm x 0.669

= 165.54 mm

8.4. TEMPORAL STORM PROFILES

Construct the hyetograph of the temporal pattern for 24 hour duration design rainfall with the return period of 100 years at Site 1790061RF (905039) at Bunan Gega.

Step 1: Select a design rainfall depth.

From Section 8.2, the 100-year design rainfall is 247.44 mm.

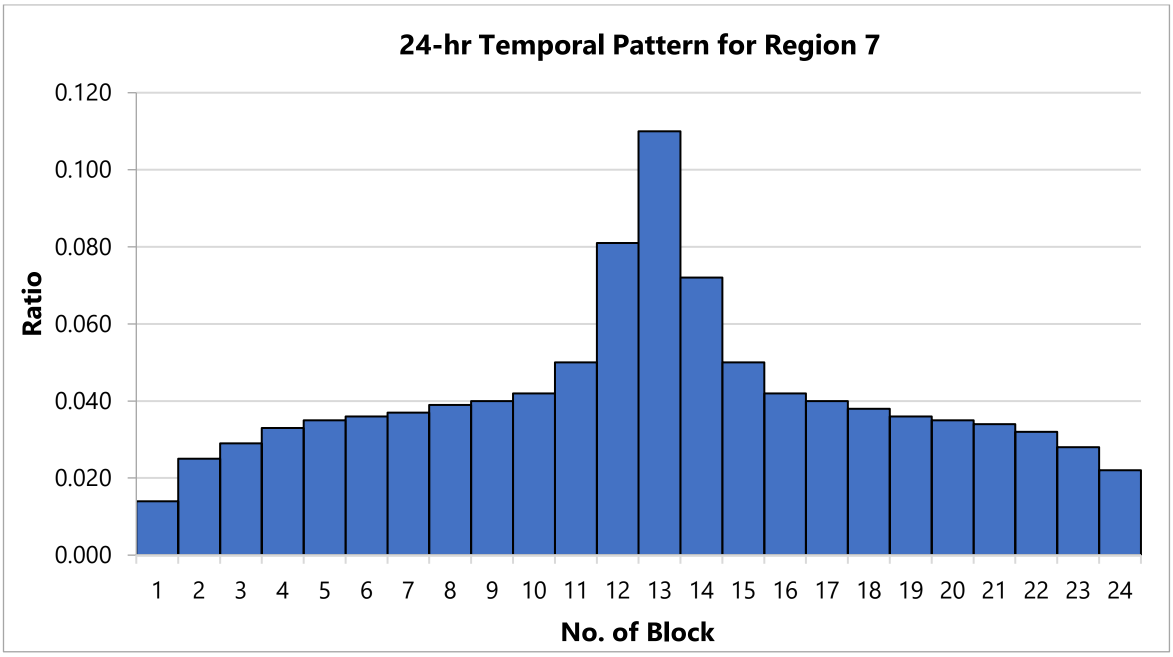
Step 2: Select the region.

From Figure 6.8, Site 1790061RF (905039) at Bunan Gega is located in Region 7.

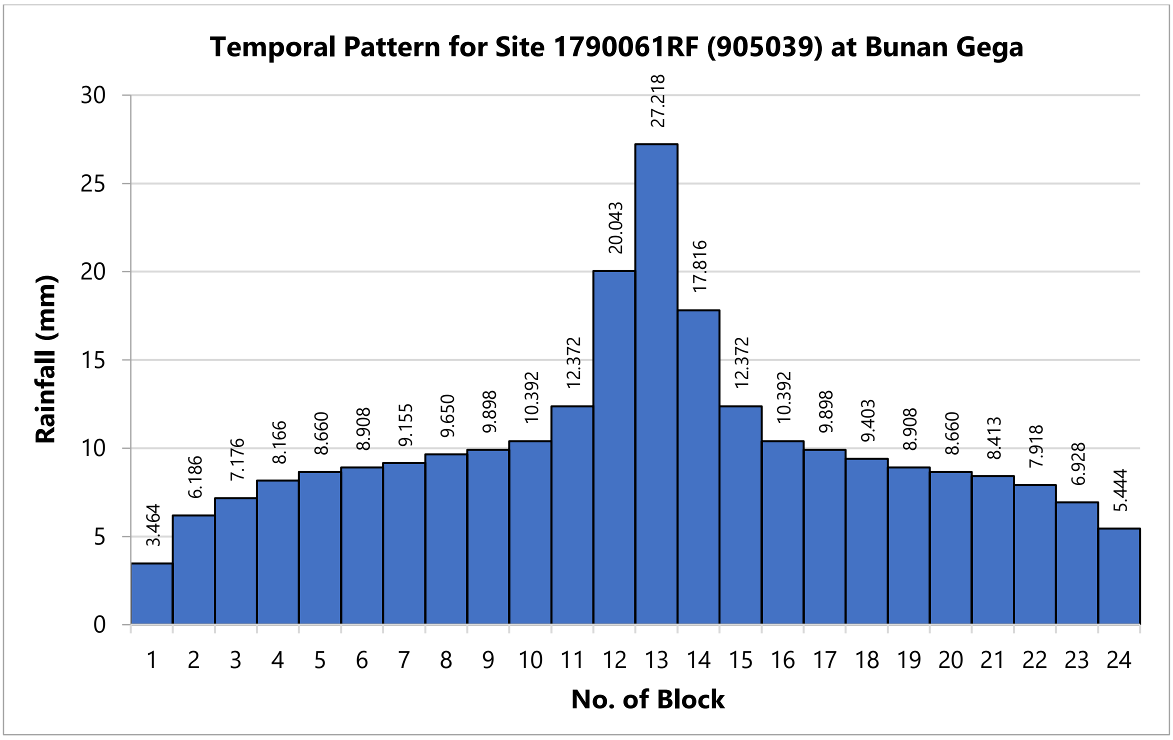
Step 3: Select a temporal pattern from Table 6.8.

The temporal pattern for region 7 are:

No. of Block	Duration								
	0.25	**0.5**	**1**	**3**	**6**	**12**	**24**	**48**	**72**
1	0.322	0.136	0.051	0.022	0.029	0.014	**0.014**	0.026	0.028
2	0.341	0.164	0.060	0.040	0.044	0.044	**0.025**	0.028	0.031
3	0.337	0.184	0.079	0.074	0.055	0.050	**0.029**	0.030	0.032
4		0.188	0.086	0.100	0.081	0.084	**0.033**	0.030	0.033
5		0.173	0.101	0.115	0.116	0.103	**0.035**	0.032	0.036
6		0.155	0.104	0.125	0.140	0.159	**0.036**	0.033	0.037
7			0.104	0.128	0.154	0.193	**0.037**	0.035	0.039
8			0.103	0.120	0.137	0.129	**0.039**	0.038	0.039
9			0.095	0.106	0.091	0.087	**0.040**	0.042	0.043
10			0.086	0.084	0.067	0.066	**0.042**	0.042	0.044
11			0.073	0.057	0.046	0.046	**0.050**	0.045	0.050
12			0.058	0.029	0.040	0.025	**0.081**	0.064	0.053
13							**0.110**	0.165	0.109
14							**0.072**	0.045	0.050
15							**0.050**	0.043	0.046
16							**0.042**	0.042	0.044
17							**0.040**	0.041	0.043
18							**0.038**	0.036	0.039
19							**0.036**	0.033	0.038
20							**0.035**	0.032	0.037
21							**0.034**	0.031	0.034
22							**0.032**	0.030	0.033
23							**0.028**	0.030	0.031
24							**0.022**	0.027	0.031



Step 4: Calculate the rain depth for each block and apply the temporal pattern to the design rainfall depth.



8.5. CLIMATE CHANGE FACTOR

Derive the future IDF curves for Site 1790061RF (905039) at Bunan Gega.

Solution:

Step 1: Determine derived IDF parameters from Table 4.2.

Derived IDF parameters are:

IDF Parameter	Value
Κ	0.1600
λ	74.5208
θ	0.3508
η	0.8503

Step 2: Determine CCF from Table 7.2.

The Climate Change Factor for Site 905039@Bunan Gega are:

Return Period, *T* (yr)	CCF
2	1.10
5	1.14
10	1.16
20	1.18
25	1.18
50	1.20
100	1.21

Step 3: Calculate future rainfall intensity from Equation (2.24).

Rainfall intensity, I $= \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$

Future rainfall intensity, I_{Future} $= I \times CCF$

Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	128.41	148.68	166.12	185.60	192.35	214.91	240.12
0.5	95.52	110.61	123.58	138.07	143.09	159.87	178.63
1	64.48	74.66	83.41	93.20	96.58	107.91	120.57
3	29.78	34.48	38.53	43.04	44.61	49.84	55.69
6	17.29	20.02	22.37	24.99	25.90	28.94	32.33
12	9.82	11.37	12.71	14.20	14.71	16.44	18.37
24	5.51	6.38	7.13	7.97	8.26	9.23	10.31
48	3.08	3.56	3.98	4.45	4.61	5.15	5.75
72	2.18	2.53	2.83	3.16	3.27	3.66	4.09

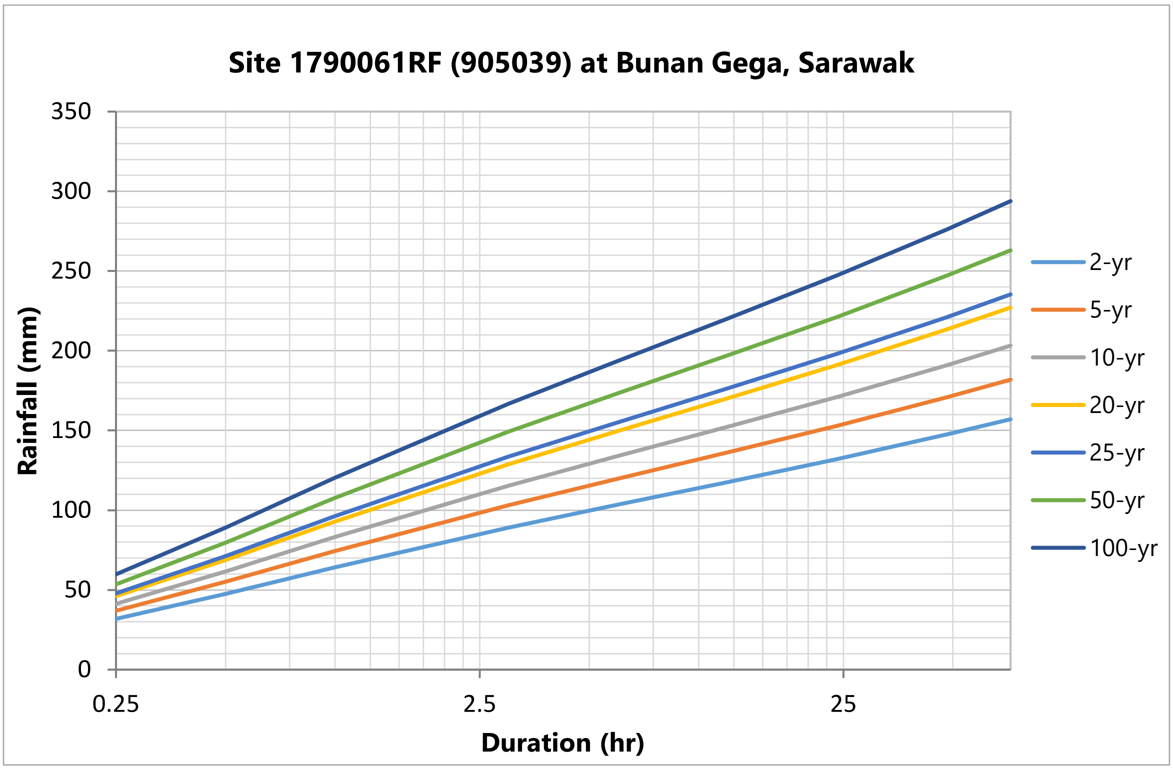
Future Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	141.25	169.50	192.70	219.01	226.97	257.89	290.55
0.5	105.07	126.10	143.35	162.92	168.85	191.84	216.14
1	70.93	85.11	96.76	109.98	113.96	129.49	145.89
3	32.76	39.31	44.69	50.79	52.64	59.81	67.38
6	19.02	22.82	25.95	29.49	30.56	34.73	39.12
12	10.80	12.96	14.74	16.76	17.36	19.73	22.23
24	6.06	7.27	8.27	9.40	9.75	11.08	12.48
48	3.39	4.06	4.62	5.25	5.44	6.18	6.96
72	2.40	2.88	3.28	3.73	3.86	4.39	4.95

Step 4: Draw IDF curves.

Step 5: Calculate rainfall depth for each duration and return period.

Rain Depth (mm)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	35.31	42.38	48.18	54.75	56.74	64.47	72.64
0.5	52.54	63.05	71.68	81.46	84.43	95.92	108.07
1	70.93	85.11	96.76	109.98	113.96	129.49	145.89
3	98.28	117.93	134.07	152.37	157.92	179.43	202.14
6	114.12	136.92	155.70	176.94	183.36	208.38	234.72
12	129.60	155.52	176.88	201.12	208.32	236.76	266.76
24	145.44	174.48	198.48	225.60	234.00	265.92	299.52
48	162.72	194.88	221.76	252.00	261.12	296.64	334.08
72	172.80	207.36	236.16	268.56	277.92	316.08	356.40

Step 6: Draw DDF curves.



9. UNGAUGED SITES

9.1. Example:- BASIN IDF – BARAM RIVER

Derive the future IDF curves for Baram Basin (23,220 km^2) based on 20 km^2 grid.

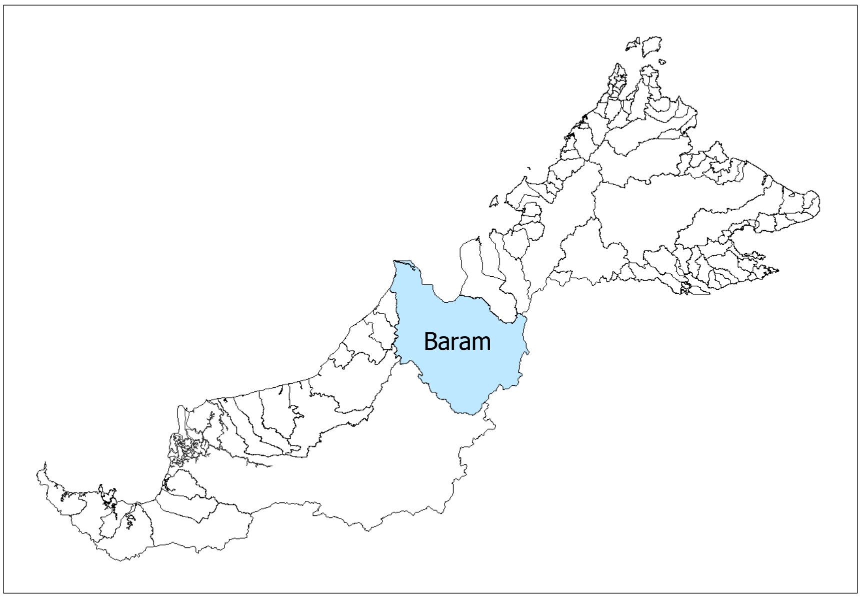


Figure 9.1: Baram Basin

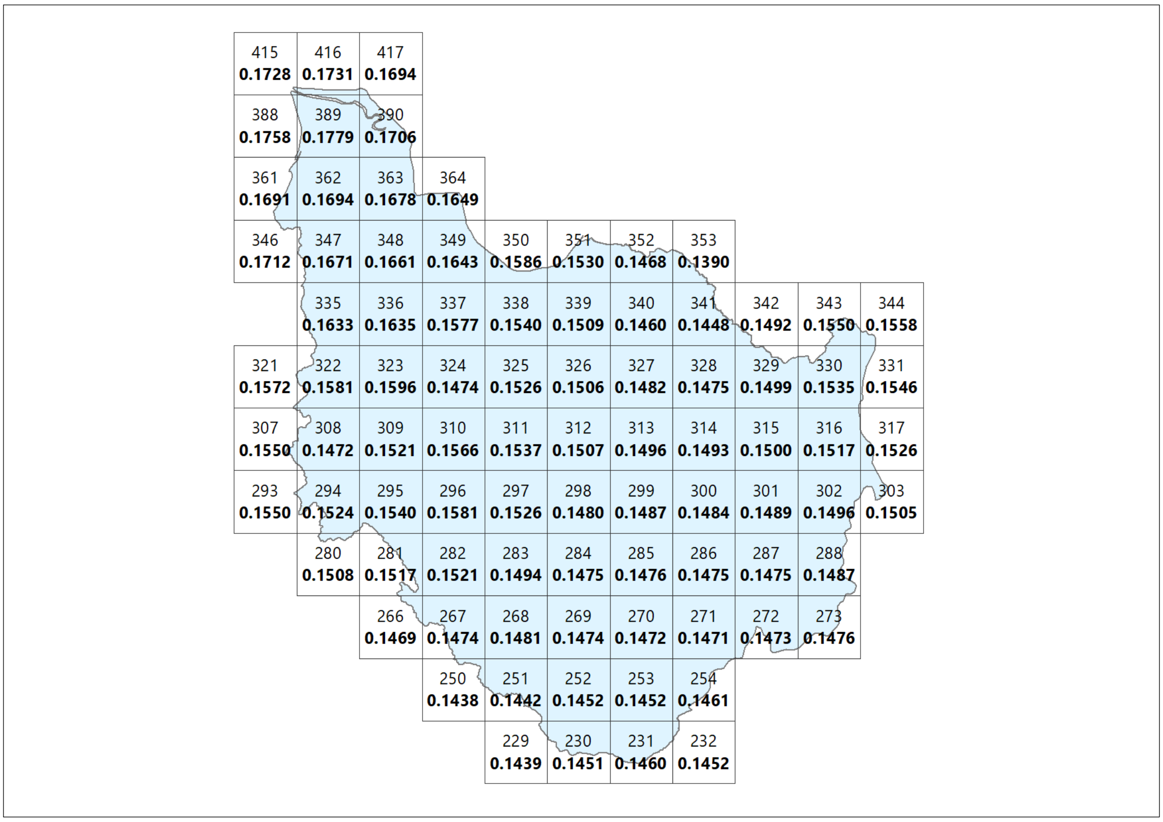


Figure 9.2: 20 km Spatial Resolution of IDF Parameter K

Solution:

Step 1: Determine IDF parameters from 20 km^2 grid and get the average values for each parameter.

The average IDF values are:

IDF Parameter	Average Values
κ	0.1535
λ	67.6933
θ	0.3060
η	0.8110

Step 2: Determine CCF from 20 km^2 grid and get the average values.

The average CCF values are:

Return Period (yr)	Average CCF values
2	1.11
5	1.17
10	1.20
20	1.22
25	1.23
50	1.25
100	1.26

Step 3: Calculate future rainfall intensity from Equation (2.24).

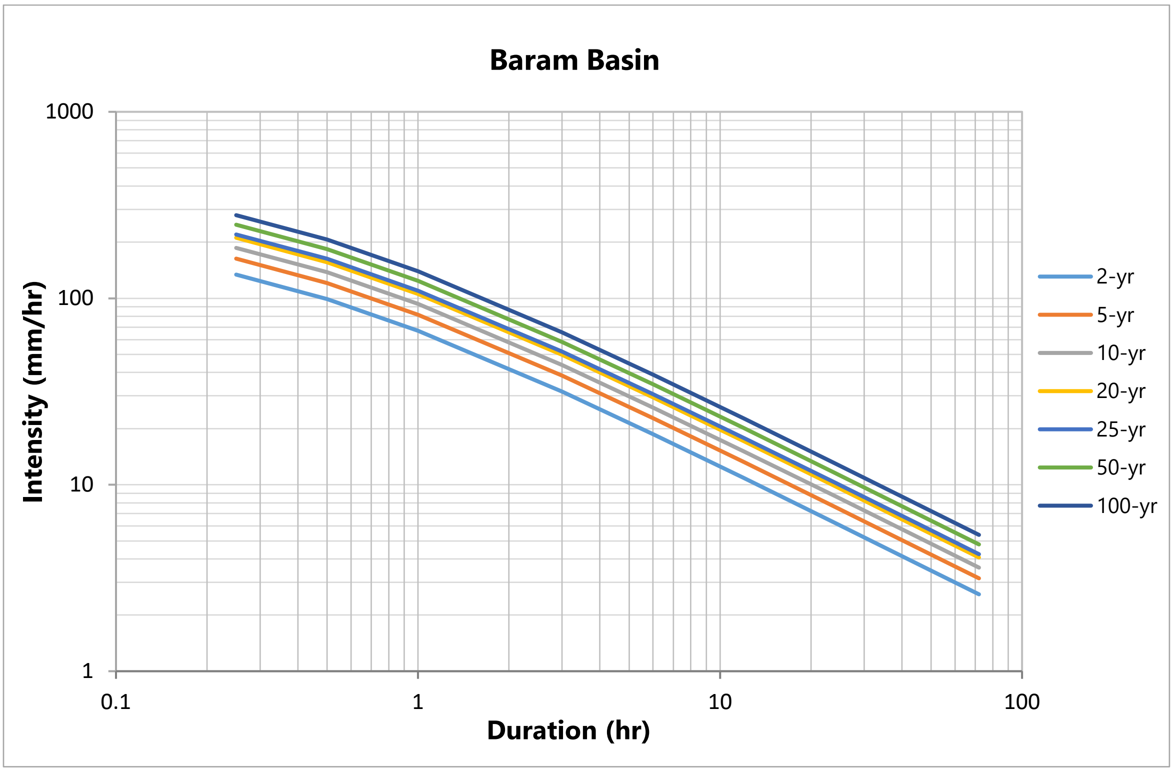
Rainfall intensity, I $= \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$

Future rainfall intensity, I_{Future} $= I \times \text{CCF}$

Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	121.21	139.52	155.18	172.61	178.62	198.68	220.99
0.5	89.69	103.24	114.83	127.72	132.18	147.02	163.53
1	60.64	69.80	77.64	86.35	89.36	99.40	110.56
3	28.55	32.86	36.55	40.66	42.08	46.80	52.06
6	16.91	19.47	21.65	24.08	24.92	27.72	30.83
12	9.83	11.32	12.59	14.00	14.49	16.12	17.93
24	5.66	6.52	7.25	8.06	8.34	9.28	10.32
48	3.24	3.73	4.15	4.62	4.78	5.32	5.91
72	2.34	2.69	2.99	3.33	3.45	3.83	4.26

Future Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	2	5	10	20	25	50	100
0.25	133.96	163.20	186.27	211.18	219.83	248.03	279.04
0.5	99.12	120.77	137.84	156.26	162.68	183.54	206.49
1	67.02	81.65	93.19	105.65	109.98	124.09	139.60
3	31.55	38.44	43.87	49.75	51.79	58.43	65.74
6	18.69	22.78	25.99	29.46	30.67	34.61	38.93
12	10.86	13.24	15.11	17.13	17.83	20.12	22.64
24	6.26	7.63	8.70	9.86	10.26	11.59	13.03
48	3.58	4.36	4.98	5.65	5.88	6.64	7.46
72	2.59	3.15	3.59	4.07	4.25	4.78	5.38

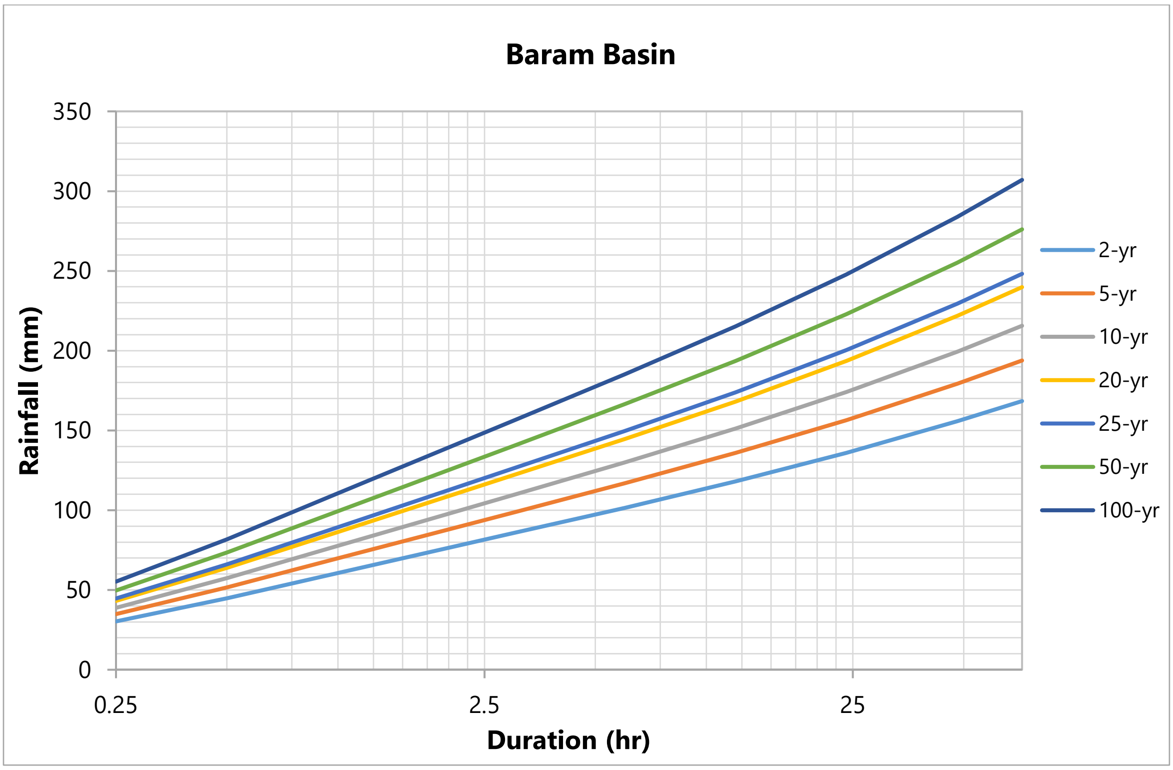
Step 4: Draw IDF curves.



Step 5: Calculate rainfall depth for each duration and return period.

Rain Depth (mm)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	33.49	40.80	46.57	52.80	54.96	62.01	69.76
0.5	49.56	60.39	68.92	78.13	81.34	91.77	103.25
1	67.02	81.65	93.19	105.65	109.98	124.09	139.60
3	94.65	115.32	131.61	149.25	155.37	175.29	197.22
6	112.14	136.68	155.94	176.76	184.02	207.66	233.58
12	130.32	158.88	181.32	205.56	213.96	241.44	271.68
24	150.24	183.12	208.80	236.64	246.24	278.16	312.72
48	171.84	209.28	239.04	271.20	282.24	318.72	358.08
72	186.48	226.80	258.48	293.04	306.00	344.16	387.36

Step 6: Draw DDF curves.



9.2. Example:- BASIN IDF – SARIBAS RIVER

Derive the future IDF curves for Saribas Basin (2,027 km^2) based on 10 km^2 grid.

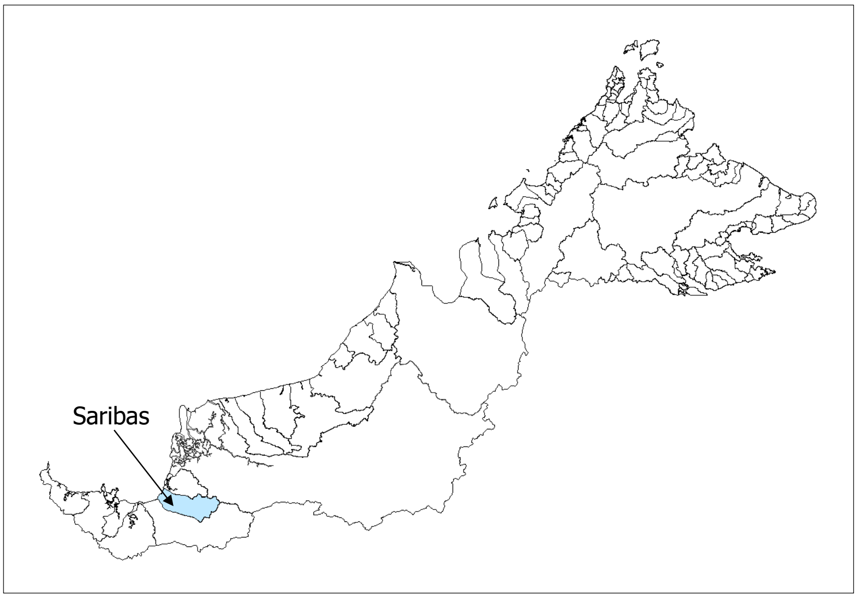


Figure 9.3: Saribas Basin

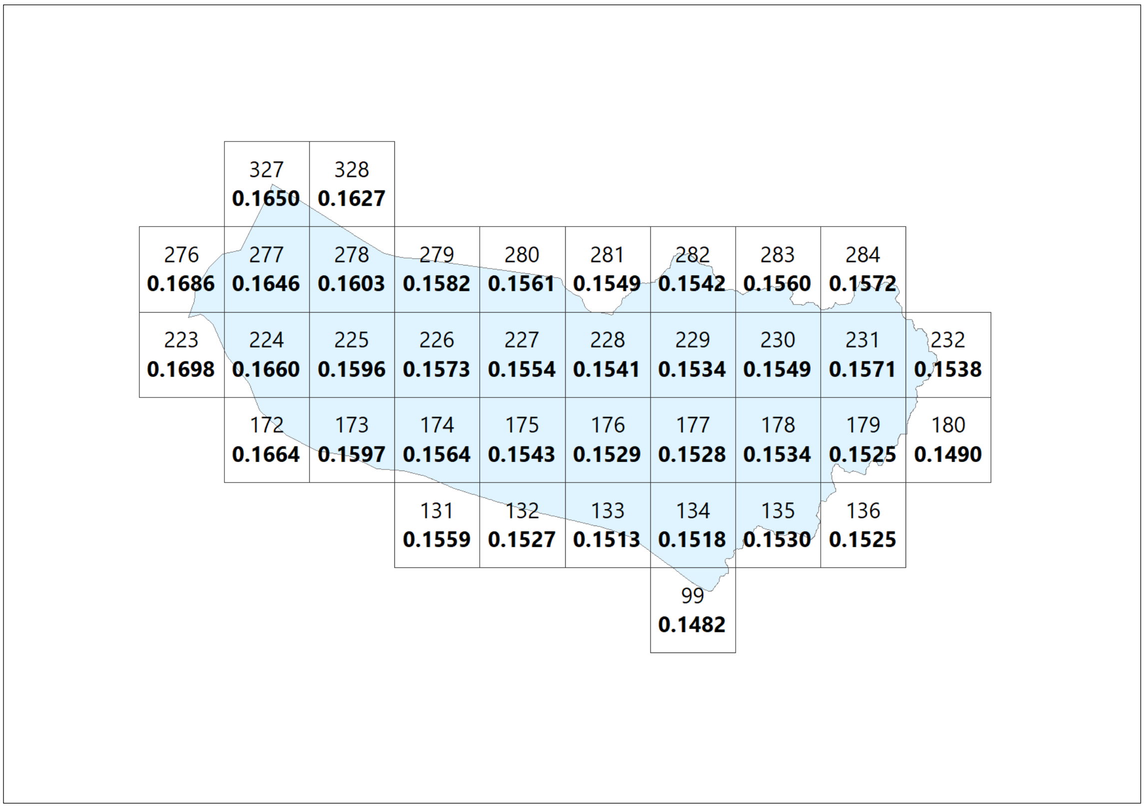


Figure 9.4: 10 km Spatial Resolution of IDF Parameter K

Solution:

Step 1: Determine IDF parameters from 10 km^2 grid and get the average values for each parameter.

The average IDF values are:

IDF Parameter	Average Values
κ	0.1568
λ	77.0979
θ	0.3806
η	0.8284

Step 2: Determine CCF from 10 km^2 grid and get the average values.

The average CCF values are:

Return Period (yr)	Average CCF values
2	1.13
5	1.19
10	1.22
20	1.24
25	1.24
50	1.26
100	1.28

Step 3: Calculate future rainfall intensity from Equation (2.24).

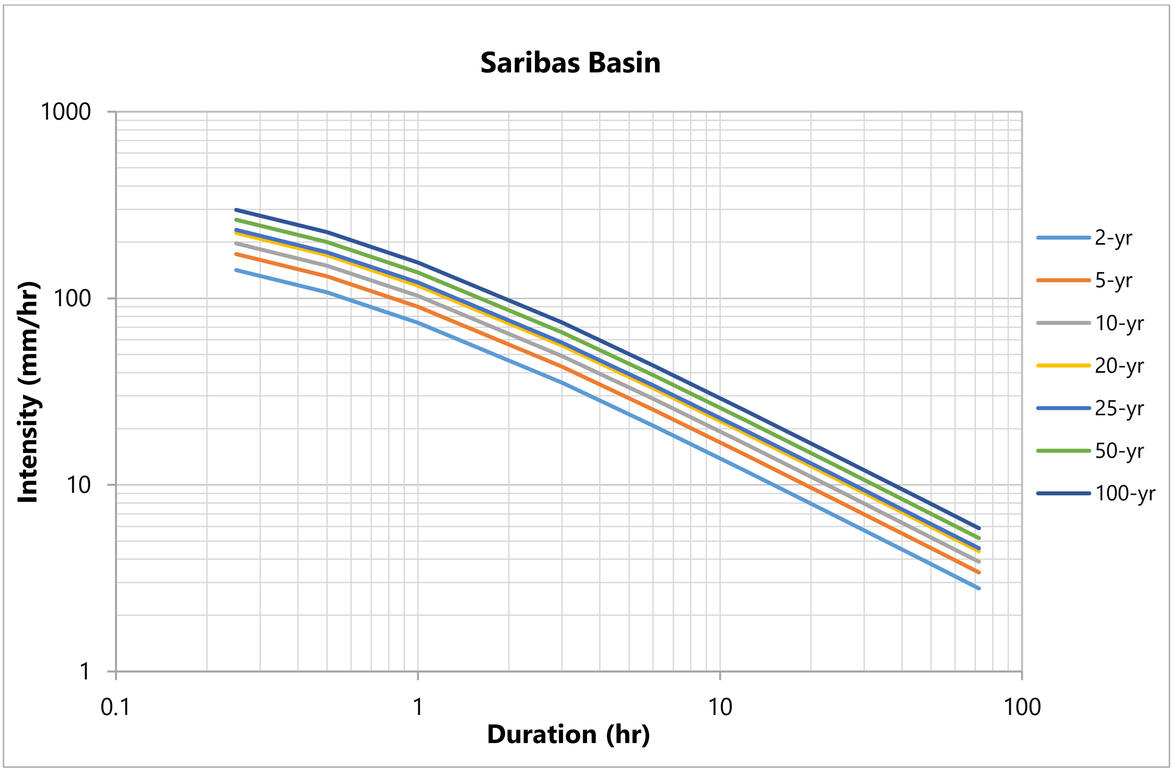
Rainfall intensity, $I = \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$

Future rainfall intensity, $I_{Future} = I \times CCF$

Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	125.93	145.39	162.09	180.70	187.13	208.62	232.57
0.5	95.50	110.25	122.91	137.03	141.91	158.20	176.37
1	65.80	75.97	84.69	94.41	97.77	109.00	121.52
3	31.33	36.18	40.33	44.96	46.56	51.91	57.87
6	18.51	21.37	23.83	26.56	27.51	30.67	34.19
12	10.69	12.34	13.76	15.34	15.89	17.71	19.74
24	6.10	7.04	7.85	8.75	9.06	10.10	11.26
48	3.46	3.99	4.45	4.96	5.14	5.73	6.38
72	2.48	2.86	3.19	3.55	3.68	4.10	4.57

Future Intensity (mm/hr)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	141.69	172.66	197.01	224.21	232.75	263.76	297.88
0.5	107.45	130.93	149.39	170.03	176.51	200.02	225.90
1	74.03	90.22	102.93	117.14	121.60	137.81	155.64
3	35.25	42.97	49.02	55.79	57.91	65.63	74.12
6	20.83	25.38	28.96	32.96	34.22	38.78	43.79
12	12.03	14.65	16.72	19.03	19.76	22.39	25.28
24	6.86	8.36	9.54	10.86	11.27	12.77	14.42
48	3.89	4.74	5.41	6.15	6.39	7.24	8.17
72	2.79	3.40	3.88	4.40	4.58	5.18	5.85

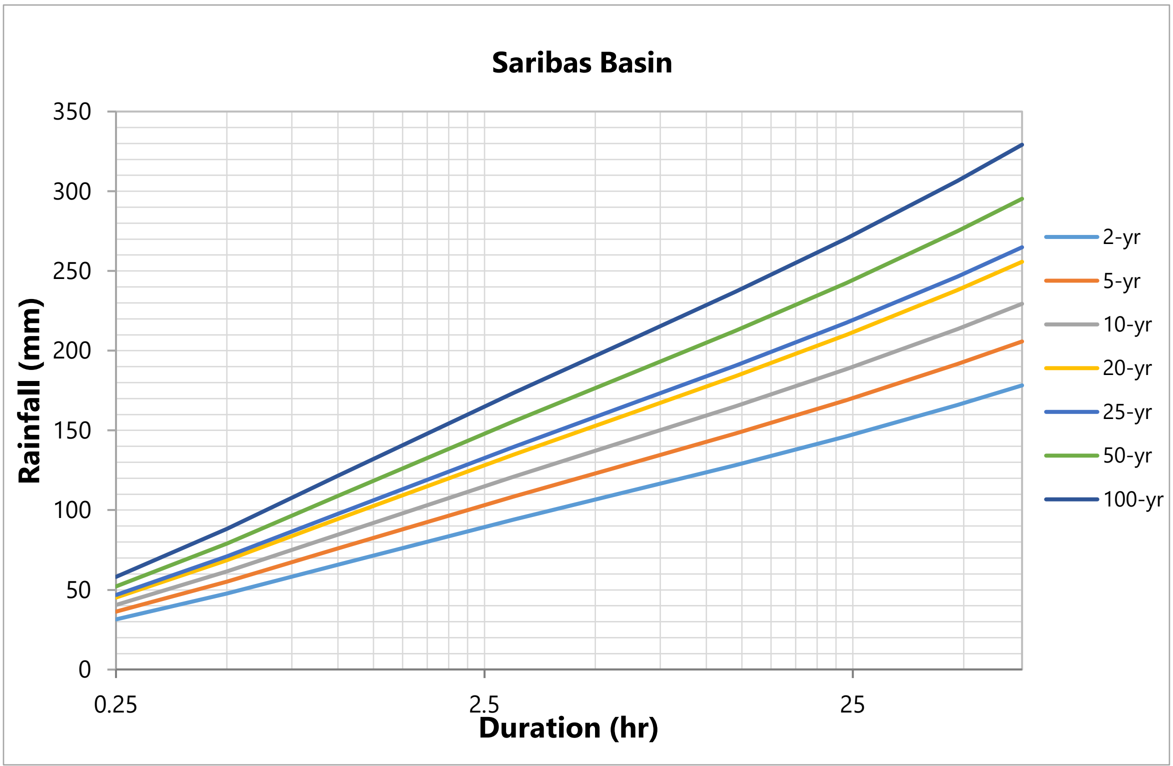
Step 4: Draw IDF curves.



Step 5: Calculate rainfall depth for each duration and return period.

Rain Depth (mm)	Return Period, *T* (yr)						
Duration (hr)	**2**	**5**	**10**	**20**	**25**	**50**	**100**
0.25	35.42	43.17	49.25	56.05	58.19	65.94	74.47
0.5	53.73	65.47	74.70	85.02	88.26	100.01	112.95
1	74.03	90.22	102.93	117.14	121.60	137.81	155.64
3	105.75	128.91	147.06	167.37	173.73	196.89	222.36
6	124.98	152.28	173.76	197.76	205.32	232.68	262.74
12	144.36	175.80	200.64	228.36	237.12	268.68	303.36
24	164.64	200.64	228.96	260.64	270.48	306.48	346.08
48	186.72	227.52	259.68	295.20	306.72	347.52	392.16
72	200.88	244.80	279.36	316.80	329.76	372.96	421.20

Step 6: Draw DDF curves.



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APPENDIX A: SUMMARY OF STATIONS USED FOR AUTOMATIC STATIONS

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a) Sabah

No.	Station ID	Station Name	Records (Year)	Longitude	Latitude
1	96465	Labuan	39	115.2425	5.3075
2	96471	Kota Kinabalu	66	116.0475	5.9325
3	96477	Kudat	36	116.8333	6.9167
4	96481	Tawau	66	118.1189	4.3161
5	96491	Sandakan	66	118.0664	5.8992
6	0850051RF (4278004)	Kuhara	29	117.8881	4.2681
7	0790011RF (4474002)	Kalabakan	29	117.4214	4.4464
8	0890011RF (4486001)	Semporna Airport	28	118.5947	4.4578
9	0750031RF (4563001)	Pensiangan	24	116.3122	4.5392
10	0750011RF (4764002)	Sapulut	32	116.4813	4.6903
11	1490021RF (4955001)	Sindumin	32	115.5411	4.9906
12	1460261RF (4959001)	Kemabong	32	115.9236	4.9169
13	1460271RF (4961001)	Bonor	31	116.1797	4.9689
14	1460171RF (5061001)	Kalampun	31	118.1697	4.5934
15	1040151RF (5074001)	Ulu Kuamut	32	117.4451	5.0807
16	0950011RF (5088002)	Tungku	30	118.8708	5.0215
17	1480041RF (5156001)	Mesapol	25	115.6397	5.1329
18	1460141RF (5158001)	Pangi Dam Site	26	115.8769	5.1323
19	1460031RF (5163002)	Sook	32	116.3042	5.1475
20	1010041RF (5181001)	Limkabong	25	118.1320	5.1261
21	1040061RF (5269001)	Tongod	32	117.9736	5.2703
22	1040021RF (5274001)	Kuamut Met. Stn.	32	117.4908	5.2227
23	1040181RF (5275001)	Balat	32	117.5998	5.3099
24	1450011RF (5353001)	Mempakul	30	115.3494	5.2959
25	1460011RF (5357003)	Beaufort JPS	32	115.7269	5.3532
26	1460061RF (5361002)	Keningau Met. Stn.	32	116.1625	5.3444
27	1460161RF (5364002)	Tulid	30	116.4239	5.3232
28	1040161RF (5372001)	Tangkulap	32	117.3206	5.3060
29	1460071RF (5462001)	Apin Apin	32	116.2686	5.478
30	1460281RF (5465001)	Sinua	24	116.5775	5.4826
31	1040111RF (5482001)	Bilit	31	118.209	5.4978
32	1420011RF (5558001)	Bongawan	32	115.8736	5.5187
33	1040101RF (5582001)	Sukau	31	118.2869	5.5096
34	1460291RF (5663001)	Tambunan Agr. Stn.	32	116.3275	5.6189
35	1160071RF (5671002)	Telupid	32	117.1280	5.6279
36	1160171RF (5768001)	Tampias	32	116.8642	5.7155
37	1390011RF (5862002)	Ulu Moyog	32	116.2515	5.8695
38	1160201RF (5875001)	Beluran	31	117.5563	5.8972

No.	Station ID	Station Name	Records (Year)	Longitude	Latitude
39	1380021RF (5961001)	Kiansam	32	116.1730	5.9730
40	1380041RF (5961002)	Inanam Met. Stn.	32	116.1153	5.9958
41	1160101RF (5966001)	Ranau Agr. Stn.	32	116.6691	5.9528
42	1160141RF (5973001)	Trusan Sapi Met. Stn.	32	117.3758	5.8984
43	1360021RF (6062001)	Kiulu (Tuaran)	31	116.2800	6.0614
44	1340011RF (6064001)	Dalas	32	116.4553	6.0339
45	1160221RF (6073001)	Basai	31	117.3257	6.0574
46	1160181RF (6168001)	Merungin	32	116.8509	5.7283
47	1200041RF (6172001)	Bukit Mondou	32	117.2401	6.1951
48	1340041RF (6264001)	Tamu Darat Agr. Stn.	32	116.4570	6.2635
49	1320011RF (6365001)	Rosok	32	116.5271	6.3922
50	1270021RF (6468001)	Tandek Pump House	30	116.8508	6.4688
51	1270031RF (6476001)	Trusan Sugut	31	117.6975	6.4190
52	1260021RF (6670001)	Kobon	31	117.0417	6.6200
53	1260031RF (6770001)	Pitas	32	117.0778	6.7076
54	1310021RF (6868001)	Kudat JPS	32	116.8601	6.8819

b) Sarawak

No.	Station ID	Station Name	Records (Year)	Longitude	Latitude
1	96413	Kuching	66	110.3525	1.4903
2	96418	Sri Aman	34	111.4500	1.2167
3	96421	Sibu	49	111.9667	2.2500
4	96441	Bintulu	66	113.0247	3.1200
5	96449	Miri	49	113.9833	4.3333
6	1790061RF (905039)	Bunan Gega	50	110.5372	0.9164
7	1790071RF (1003031)	Tebedu	46	110.3603	1.0239
8	1790081RF (1004001)	Krusen	32	110.4978	1.0708
9	1790091RF (1005079)	Bukit Matuh	46	110.6072	1.0664
10	1790101RF (1005080)	Sungai Busit	45	110.5819	1.0906
11	1790111RF (1006028)	Sungai Bedup	37	110.6317	1.0853
12	1790121RF (1006033)	Sungai Merang	51	110.6044	1.0906
13	1790131RF (1006037)	Sungai Teb	51	110.6197	1.0631
14	1790141RF (1007040)	Balai Ringin	38	110.7453	1.0492
15	1770081RF (1015001)	Batu Lintang	37	111.5525	1.0186
16	1770021RF (1018002)	Lubok Antu	43	111.8369	1.0417
17	1810071RF (1102019)	Padawan	41	110.2553	1.1633
18	1790151RF (1105027)	Serian	55	110.5664	1.1603
19	1790161RF (1105035)	Semuja Nonok	40	110.6000	1.1111
20	1790171RF (1105050)	Tebakang	40	110.4989	1.0975

APPENDIX A: SUMMARY OF STATIONS USED FOR AUTOMATIC STATIONS

No.	Station ID	Station Name	Records (Year)	Longitude	Latitude
21	1770091RF (1111008)	Pantu	40	111.1144	1.1500
22	1770101RF (1118002)	Bekatan	32	111.8186	1.1869
23	1800051RF (1203002)	Kampung Gayu	34	110.3431	1.2178
24	1800061RF (1204001)	Plaman Nyabet	34	110.4406	1.2081
25	1800011RF (1204024)	Dragon School	37	110.4164	1.2753
26	1800081RF (1205006)	Tarat	44	110.5242	1.2056
27	1790181RF (1208001)	Kampung Sangkalan Pasir	28	110.8908	1.2617
28	1770011RF (1214001)	Sri Aman	54	111.4569	1.2425
29	1770111RF (1220025)	Nanga Delok	30	112.0186	1.2336
30	1810081RF (1301001)	Kampung Monggak	27	110.1044	1.3278
31	1810091RF (1302078)	Kampung Git	27	110.2631	1.3561
32	1800091RF (1303014)	Semongok	55	110.3261	1.3894
33	1770121RF (1313006)	Stumbin	47	111.3883	1.3011
34	1770131RF (1321001)	Nanga Mujan	29	112.1144	1.3450
35	1810101RF (1400001)	Kampung Opar	27	110.0675	1.4403
36	1810021RF (1401005)	Bau	48	110.1494	1.4183
37	1810111RF (1402001)	Siniawan Water Works	34	110.2103	1.4461
38	1810121RF (1402002)	Siniawan	26	110.215	1.4472
39	1810011RF (1403001)	Kuching Airport	66	110.3492	1.4908
40	1800101RF (1404049)	Paya Paloh	40	110.4917	1.4422
41	1750031RF (1415001)	Nanga Lubau	36	111.5875	1.4961
42	1770141RF (1417001)	Nanga Entalau	24	111.7867	1.4569
43	1840011RF (1502001)	Sebubut	38	110.2175	1.5803
44	1810131RF (1503004)	Kuching Saberkas	30	110.3367	1.5381
45	1800111RF (1505081)	Ketup	46	110.5267	1.5486
46	1800031RF (1506001)	Semera	30	110.6706	1.5558
47	1800041RF (1506034)	Asa Jaya	33	110.6056	1.5450
48	1780021RF (1509009)	Sebuyau	44	110.9325	1.5200
49	1730141RF (1544001)	Long Singut	35	113.9144	2.9186
50	1850011RF (1601001)	Sungai Rayu	27	110.1469	1.6133
51	1750041RF (1616021)	Nanga Tiga	31	111.6964	1.6075
52	1860011RF (1698007)	Lundu	49	109.8542	1.6711
53	1820011RF (1704013)	Telok Assam	30	110.4414	1.7178
54	1740041RF (1713005)	Saratok DID	45	111.3408	1.7583
55	1730151RF (1726041)	Nanga Bangkit	33	112.6333	1.7725
56	1730161RF (1731001)	Nanga Balang	31	113.1661	1.7567
57	1740051RF (1811007)	Kabong	24	111.1142	1.8011
58	1730171RF (1816029)	Pakan	28	111.6761	1.8989
59	1730181RF (1823001)	Nanga Jagau	32	112.3075	1.8828
60	1730191RF (1834001)	Gaat Balleh	31	113.4289	1.8950
61	1730201RF (1836042)	Nanga Entawau	34	113.6758	1.8236
62	1730211RF (1843001)	Long Busang	35	114.3142	1.8711

APPENDIX A: SUMMARY OF STATIONS USED FOR AUTOMATIC STATIONS

No.	Station ID	Station Name	Records (Year)	Longitude	Latitude
63	1870011RF (1897016)	Sematan	45	109.7728	1.81
64	1740061RF (1914001)	Asun SRK	20	111.4931	1.9231
65	1730221RF (1947001)	Long Unai	28	114.7139	1.9583
66	1730231RF (2021001)	Renan Kemiding	27	112.1492	2.0625
67	1730241RF (2021036)	Kanowit Water Works	27	112.1517	2.0997
68	1730251RF (2025012)	Song	36	112.5461	2.0103
69	(2029001)	Kapit JKR	26	112.9444	2.0167
70	1730261RF (2029002)	Kapit New Head Works	29	112.9497	2.0178
71	1730271RF (2031034)	Nanga Mujong	29	113.1733	2.0239
72	1730281RF (2036001)	Tunoh Scheme	28	113.6678	2.0511
73	1730291RF (2115008)	Sarikei DID	43	111.5286	2.1267
74	1730301RF (2134001)	Nanga Tiau	30	113.4436	2.1158
75	1730311RF (2141048)	Long Jawe	35	114.1872	2.1169
76	1730321RF (2212001)	Belawai	28	111.2075	2.2264
77	1730331RF (2218017)	Sibu JKR Water Works	27	111.8408	2.2736
78	1730341RF (2219001)	Sibu New Airport	23	111.9817	2.2589
79	1730351RF (2230143)	Nanga Merit	41	113.0958	2.2714
80	(2239147)	Batu Keling	28	113.9083	2.2542
81	(2318007)	Sibu Airport	34	111.8389	2.3389
82	1710011RF (2321001)	Stapang	28	112.1361	2.3986
83	1700051RF (2325039)	Sungai Arau	28	112.5664	2.3081
84	1730361RF (2333001)	Punan Bah	30	113.3442	2.3839
85	1730371RF (2346001)	Long Lidam	37	114.6744	2.3378
86	1730381RF (2442001)	Long Laku	31	114.2444	2.4675
87	1730391RF (2514004)	JPS Daro	31	111.4231	2.5153
88	1700061RF (2522038)	Bukit Engkerbai	35	112.2878	2.5975
89	1670021RF (2625051)	Nanga Lemai	28	112.5022	2.6881
90	1720011RF (2712001)	Tekajong	33	111.3047	2.7397
91	1730401RF (2718022)	Sungai Kut	27	111.835	2.7183
92	1730021RF (2737103)	Belaga	54	113.7819	2.7075
93	1650011RF (2828025)	Tatau Town	37	112.8472	2.8764
94	1730411RF (2843001)	Long Jek	25	114.3156	2.8092
95	1700021RF (2920005)	Mukah JKR	37	112.0906	2.9050
96	1730421RF (2939045)	Long Sambop	34	113.3442	2.3839
97	1640041RF (3130002)	Bintulu Airport	52	113.0389	3.1722
98	1640051RF (3132023)	Sebauh	37	113.2625	3.1083
99	1640031RF (3137021)	Tubau	36	113.7083	3.1625
100	1550111RF (3152011)	Lio Matu	36	115.2208	3.1694
101	1550121RF (3347003)	Long Akah	33	114.7847	3.3144
102	1550131RF (3444018)	Long Pilah	37	114.4275	3.4836
103	1550141RF (3541033)	Long Jegan	30	114.1119	3.5839
104	1580031RF (3737045)	Sungai Lebai	34	113.7853	3.7322

No.	Station ID	Station Name	Records (Year)	Longitude	Latitude
105	1550151RF (3744009)	Long Lama	35	114.4011	3.7625
106	1550161RF (3842034)	Long Teru	37	114.2417	3.865
107	1550171RF (3950020)	Long Seridan	28	115.0686	3.9767
108	1520021RF (3956001)	Ba Kelalan	29	115.6156	3.9753
109	1570021RF (4038006)	Bekenu	37	113.8417	4.0567
110	1550061RF (4143004)	Marudi	39	114.3114	4.1781
111	1540091RF (4151017)	Long Napir	37	115.1381	4.1794
112	1520031RF (4255006)	Long Semado	31	115.5875	4.2189
113	1560021RF (4339005)	Miri Airport	64	113.9792	4.3119
114	1560041RF (4440060)	Miri DID	35	113.9981	4.4328
115	1540101RF (4449012)	Nanga Medamit	30	114.9092	4.4875
116	1540021RF (4548004)	Ukong	40	114.8544	4.5497
117	1520041RF (4554001)	Long Sukang	28	115.4847	4.5547
118	1530011RF (4650023)	Pandaruan	43	115.0189	4.6883
119	1540111RF (4749001)	Limbang DID	37	114.9986	4.7456
120	1500011RF (4854009)	Lawas Airfield	29	115.4039	4.8469

APPENDIX B: SUMMARY OF STATIONS USED FOR MANUAL STATIONS

APPENDIX B: SUMMARY OF STATIONS USED FOR MANUAL STATIONS

No.	State	Station ID	Station Name	Year	Records (Year)
1	Sabah	4955002	Sindumin	1989-2016	26
2	Sabah	4959002	Kemabong	1969-2000	32
3	Sabah	5159003	Tenom	1983-2016	33
4	Sabah	5274002	Kuamut Met. Stn.	1969-2012	44
5	Sabah	5357005	Beaufort JPS	1984-2016	31
6	Sabah	5361003	Keningau Met. Stn.	1968-2013	46
7	Sabah	5457003	Membakut	1982-2016	33
8	Sabah	5462003	Apin Apin	1967-2016	49
9	Sabah	5558002	Bongawan JPS	1989-2016	26
10	Sabah	5759003	Papar JPS	1981-2016	34
11	Sabah	5961003	Inanam Met. Stn.	1975-2015	41
12	Sabah	5966003	Ranau JPS	1980-2014	34
13	Sabah	5973002	Trusan Sapi Met. Stn.	1977-2016	40
14	Sabah	6162003	Tuaran P.H. No.1	1986-2016	30
15	Sabah	6168002	Merungin	1985-2016	28
16	Sabah	6364001	Kota Belud JPS	1979-2013	35
17	Sabah	6567002	Kota Marudu	1978-2016	37
18	Sabah	6868002	Kudat JPS	1973-2004	33
19	Sarawak	905039	Bunan Gega	1965-2011	47
20	Sarawak	1003031	Tebedu	1964-2002	38
21	Sarawak	1005079	Bukit Matuh	1971-2012	41
22	Sarawak	1005080	Sungai Busit	1971-2012	42
23	Sarawak	1006028	Sungai Bedup	1963-2009	47
24	Sarawak	1006033	Sungai Merang	1964-2012	48
25	Sarawak	1006037	Sungai Teb	1978-2004	42
26	Sarawak	1007040	Balai Ringin	1967-2012	46
27	Sarawak	1008032	Sungai Pinang	1964-2012	49
28	Sarawak	1015001	Batu Lintang	1962-2007	43
29	Sarawak	1018002	Lubok Antu	1951-2012	59
30	Sarawak	1102019	Padawan	1957-1997	35
31	Sarawak	1105027	Serian	1964-1996	31
32	Sarawak	1105035	Semuja Nonok	1978-2004	48
33	Sarawak	1105050	Tebakang	1965-2003	39
34	Sarawak	1111008	Pantu	1963-2012	48
35	Sarawak	1114019	Temudok	1964-2000	37
36	Sarawak	1114028	Melugu	1969-2005	36
37	Sarawak	1201076	Embahn	1970-2011	30
38	Sarawak	1203002	Kampung Gayu	1982-2012	31
39	Sarawak	1204024	Dragon School	1961-2000	40
40	Sarawak	1205006	Tarat	1962-2002	41
41	Sarawak	1206089	Gedong	1981-2011	29

APPENDIX B: SUMMARY OF STATIONS USED FOR MANUAL STATIONS

No.	State	Station ID	Station Name	Year	Records (Year)
42	Sarawak	1212032	Banting	1972-2008	37
43	Sarawak	1214001	Sri Aman	1947-2012	62
44	Sarawak	1217011	Riddan	1963-2002	39
45	Sarawak	1219024	Nanga Tutong 2	1969-2011	32
46	Sarawak	1303014	Semongok	1962-2004	43
47	Sarawak	1305038	Samarahan Estate	1961-2012	50
48	Sarawak	1306055	Lubok Ipoi	1966-2006	39
49	Sarawak	1307018	Simunjan	1955-2003	49
50	Sarawak	1311003	Lingga	1963-2006	44
51	Sarawak	1313006	Stumbin	1956-2012	54
52	Sarawak	1401005	Bau	1951-2001	46
53	Sarawak	1402047	Batu Kitang	1950-2012	60
54	Sarawak	1403001	Kuching Airport	1950-2012	61
55	Sarawak	1404049	Paya Paloh	1964-2012	49
56	Sarawak	1404091	Kota Samarahan	1981-2012	32
57	Sarawak	1415004	Betong	1949-2002	53
58	Sarawak	1502001	Sebubut	1980-2007	28
59	Sarawak	1502026	Matang	1948-2008	60
60	Sarawak	1505081	Ketup	1971-2006	36
61	Sarawak	1506034	Asa Jaya	1964-2003	39
62	Sarawak	1509009	Sebuyau	1962-2002	36
63	Sarawak	1601003	Sungai China	1948-2005	58
64	Sarawak	1603058	Rampangi	1978-2004	39
65	Sarawak	1612030	Pusa	1970-2002	33
66	Sarawak	1615023	Batu Danau	1978-2004	43
67	Sarawak	1616021	Nanga Tiga	1972-2005	34
68	Sarawak	1698007	Lundu	1925-2004	70
69	Sarawak	1704013	Telok Assam	1960-2001	42
70	Sarawak	1713005	Saratok DID	1950-2009	60
71	Sarawak	1726041	Nanga Bangkit	1964-2012	45
72	Sarawak	1811007	Kabong	1978-2004	45
73	Sarawak	1811010	Sessang	1965-2002	38
74	Sarawak	1816029	Pakan	1963-2007	35
75	Sarawak	1823001	Nanga Jagau	1971-2002	32
76	Sarawak	1836042	Nanga Entawau	1978-2004	37
77	Sarawak	1897016	Sematan	1959-2004	42
78	Sarawak	2019024	Julau	1963-2007	45
79	Sarawak	2021036	Kanowit Water Works	1964-2003	39
80	Sarawak	2025012	Song	1950-2012	58
81	Sarawak	2029001	Kapit JKR At Upper Rajang	1948-1985	36
82	Sarawak	2112027	Rejang	1965-2002	38
83	Sarawak	2115008	Sarikei DID	1963-2009	47

APPENDIX B: SUMMARY OF STATIONS USED FOR MANUAL STATIONS

No.	State	Station ID	Station Name	Year	Records (Year)
84	Sarawak	2116030	Bintangor	1965-2010	46
85	Sarawak	2121002	Kanowit Sedaya At Lower Rajang	1948-2000	50
86	Sarawak	2212001	Belawai	1977-2009	33
87	Sarawak	2218017	Sibu JKR WW	1963-2005	43
88	Sarawak	2230143	Nanga Merit	1964-2012	46
89	Sarawak	2318007	Sibu Airport At Lower Rajang	1953-1985	33
90	Sarawak	2320059	Sibintek	1970-2007	35
91	Sarawak	2321066	Sekuau	1977-2006	29
92	Sarawak	2325039	Sungai Arau	1965-2001	32
93	Sarawak	2418013	Rantau Panjang	1963-2001	38
94	Sarawak	2514004	Daro	1978-2004	51
95	Sarawak	2615009	Matu	1956-2005	49
96	Sarawak	2623001	Mukah-Balingian OPS1	1977-2009	32
97	Sarawak	2625051	Nanga Lemai	1974-2004	30
98	Sarawak	2718022	Sungai Kut	1963-2001	39
99	Sarawak	2828025	Tatau	1963-2005	43
100	Sarawak	2920005	Mukah JKR	1948-2009	62
101	Sarawak	2925010	Balingian	1960-2008	49
102	Sarawak	2939045	Long Sambop	1984-2011	27
103	Sarawak	3050015	Long Moh	1963-2001	38
104	Sarawak	3130002	Bintulu Town	1948-2003	52
105	Sarawak	3132023	Sebauh	1963-2006	42
106	Sarawak	3137021	Tubau	1969-2002	33
107	Sarawak	3152011	Lio Matu	1963-1999	37
108	Sarawak	3234022	Labang	1963-2002	31
109	Sarawak	3342032	Long Subing	1968-2002	35
110	Sarawak	3347003	Long Akah	1950-1993	41
111	Sarawak	3444018	Long Pilah	1978-2004	39
112	Sarawak	3541033	Long Jegan	1964-2000	33
113	Sarawak	3737045	Sungai Lebai	1968-2004	37
114	Sarawak	3842034	Long Teru	1972-2010	37
115	Sarawak	3847035	Long Atip	1969-2000	32
116	Sarawak	3939051	Tangit	1972-2003	32
117	Sarawak	3940036	Beluru	1968-2005	34
118	Sarawak	3945017	Long Panai	1962-2001	37
119	Sarawak	3950020	Long Seridan	1971-2008	35
120	Sarawak	4038006	Bekenu	1952-2000	48
121	Sarawak	4038054	Paya Selanyau	1967-2012	39
122	Sarawak	4039019	Bukit Peninjau	1971-2000	29
123	Sarawak	4143004	Marudi	1948-2010	61
124	Sarawak	4151017	Long Napir	1977-2003	27
125	Sarawak	4255006	Long Semado	1963-2003	41

No.	State	Station ID	Station Name	Year	Records (Year)
126	Sarawak	4339005	Miri Airport	1947-2012	65
127	Sarawak	4440001	Lutong	1952-1999	48
128	Sarawak	4440060	Miri DID Barrack	1975-2012	38
129	Sarawak	4449012	Nanga Medamit	1963-2009	47
130	Sarawak	4548004	Ukong	1948-2004	56
131	Sarawak	4649025	Lubai Tengah	1972-2009	34
132	Sarawak	4650007	Tegarai	1967-2007	41
133	Sarawak	4650023	Pandaruan	1972-2009	38
134	Sarawak	4749001	Limbang DID	1980-2013	34
135	Sarawak	4752022	Trusan	1972-2003	32
136	Sarawak	4852002	Sundar	1948-2003	49
137	Sarawak	4854003	Samaha Estate	1962-2003	40
138	Sarawak	4854009	Lawas Airfield	1962-1994	31
139	Sarawak	4955021	Merapok	1972-2007	36

APPENDIX C: ESTIMATED DESIGN RAINSTORM FOR LONG DURATIONS

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No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
1	Sabah	4955002	Sindumin	Upper Confidence Limit	24	141.69	193.74	229.01	263.02	273.83	307.17	340.31
					48	171.84	236.58	280.45	322.75	336.20	377.67	418.88
					72	200.62	273.16	322.31	369.72	384.78	431.25	477.44
				Estimated Design Rainstorm	24	134.2	180.6	211.3	240.8	250.1	278.9	307.5
					48	162.5	220.2	258.4	295.1	306.7	342.5	378.1
					72	190.2	254.8	297.7	338.7	351.8	391.9	431.7
				Lower Confidence Limit	24	126.69	167.45	193.63	218.56	226.45	250.70	274.74
					48	153.19	203.88	236.45	267.45	277.26	307.43	337.33
					72	179.71	236.52	273.01	307.75	318.75	352.55	386.05
2	Sabah	4959002	Kemabong	Upper Confidence Limit	24	75.37	94.41	107.31	119.75	123.70	135.90	148.02
					48	89.10	111.88	127.31	142.19	146.92	161.51	176.01
					72	105.51	133.88	153.11	171.65	177.54	195.72	213.78
				Estimated Design Rainstorm	24	72.6	89.6	100.8	111.6	115.0	125.6	136.0
					48	85.8	106.1	119.6	132.5	136.6	149.2	161.7
					72	101.4	126.7	143.5	159.5	164.6	180.3	195.9
				Lower Confidence Limit	24	69.89	84.79	94.37	103.49	106.37	115.25	124.04
					48	82.54	100.37	111.83	122.74	126.19	136.80	147.32
					72	97.33	119.55	133.82	147.41	151.71	164.93	178.04
3	Sabah	5159003	Tenom	Upper Confidence Limit	24	96.86	126.29	146.22	165.44	171.55	190.40	209.12
					48	109.34	143.99	167.47	190.11	197.31	219.50	241.56
					72	120.71	156.45	180.67	204.02	211.44	234.34	257.09
				Estimated Design Rainstorm	24	92.6	118.9	136.2	152.9	158.2	174.4	190.6
					48	104.3	135.2	155.7	175.3	181.5	200.7	219.7
					72	115.6	147.4	168.5	188.8	195.2	215.0	234.6
				Lower Confidence Limit	24	88.39	111.42	126.22	140.31	144.77	158.48	172.07
					48	99.35	126.49	143.92	160.51	165.76	181.91	197.91
					72	110.41	138.40	156.38	173.49	178.91	195.56	212.07

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
4	Sabah	5274002	Kuamut Met. Stn.	Upper Confidence Limit	24	132.30	168.55	193.11	216.79	224.32	247.53	270.61
					48	160.34	207.49	239.44	270.25	280.04	310.25	340.27
					72	184.77	233.54	266.59	298.47	308.60	339.84	370.89
				Estimated Design Rainstorm	24	127.1	159.4	180.8	201.3	207.8	227.9	247.8
					48	153.5	195.6	223.4	250.1	258.6	284.7	310.6
					72	177.7	221.2	250.0	277.6	286.4	313.4	340.2
				Lower Confidence Limit	24	121.86	150.24	168.47	185.83	191.32	208.21	224.95
					48	146.75	183.67	207.39	229.98	237.12	259.10	280.87
					72	170.71	208.90	233.44	256.80	264.19	286.92	309.45
5	Sabah	5357005	Beaufort JPS	Upper Confidence Limit	24	147.39	194.31	226.11	256.77	266.52	296.57	326.45
					48	179.34	233.50	270.19	305.58	316.83	351.52	386.00
					72	200.43	253.91	290.14	325.09	336.20	370.46	404.51
				Estimated Design Rainstorm	24	140.6	182.5	210.2	236.7	245.2	271.1	296.9
					48	171.5	219.8	251.8	282.5	292.2	322.1	351.9
					72	192.7	240.4	272.0	302.3	311.9	341.4	370.8
				Lower Confidence Limit	24	133.86	170.61	194.21	216.69	223.80	245.67	267.34
					48	163.74	206.14	233.39	259.33	267.53	292.77	317.78
					72	185.01	226.89	253.80	279.41	287.52	312.44	337.14
6	Sabah	5361003	Keningau Met. Stn.	Upper Confidence Limit	24	84.74	105.29	119.22	132.65	136.92	150.09	163.17
					48	104.78	130.35	147.68	164.39	169.70	186.08	202.36
					72	117.10	145.71	165.09	183.78	189.72	208.04	226.25
				Estimated Design Rainstorm	24	81.8	100.1	112.2	123.9	127.6	138.9	150.2
					48	101.1	123.9	139.0	153.5	158.1	172.2	186.3
					72	113.0	138.5	155.4	171.6	176.7	192.5	208.2
				Lower Confidence Limit	24	78.82	94.91	105.25	115.10	118.21	127.79	137.28
					48	97.42	117.44	130.30	142.55	146.42	158.34	170.15
					72	108.86	131.26	145.65	159.35	163.68	177.01	190.22
7	Sabah	5457003	Membakut	Upper Confidence Limit	24	133.44	175.97	204.79	232.58	241.41	268.66	295.73
					48	157.33	207.83	242.04	275.04	285.52	317.87	350.01
					72	176.64	231.62	268.87	304.80	316.22	351.44	386.45

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	127.3	165.2	190.3	214.4	222.1	245.6	268.9
					48	150.1	195.1	224.9	253.5	262.5	290.5	318.2
					72	168.7	217.7	250.2	281.3	291.2	321.6	351.8
				Lower Confidence Limit	24	121.18	154.49	175.88	196.25	202.70	222.52	242.16
					48	142.78	182.32	207.72	231.91	239.56	263.09	286.41
					72	160.79	203.85	231.51	257.84	266.17	291.80	317.19
8	Sabah	5462003	Apin Apin	Upper Confidence Limit	24	86.18	113.47	131.95	149.79	155.45	172.93	190.30
					48	100.50	129.37	148.93	167.80	173.79	192.29	210.67
					72	115.40	147.04	168.48	189.15	195.72	215.99	236.13
				Estimated Design Rainstorm	24	82.2	106.6	122.7	138.1	143.0	158.1	173.1
					48	96.3	122.1	139.1	155.5	160.7	176.6	192.5
					72	110.8	139.0	157.7	175.6	181.3	198.8	216.2
				Lower Confidence Limit	24	78.31	99.68	113.41	126.48	130.61	143.33	155.93
					48	92.18	114.78	129.31	143.14	147.51	160.96	174.30
					72	106.28	131.06	146.97	162.13	166.92	181.66	196.28
9	Sabah	5558002	Bongawan JPS	Upper Confidence Limit	24	119.22	169.33	203.28	236.02	246.42	278.52	310.42
					48	150.34	204.78	241.65	277.23	288.53	323.40	358.05
					72	172.74	234.88	276.97	317.57	330.48	370.28	409.83
				Estimated Design Rainstorm	24	112.0	156.7	186.3	214.6	223.6	251.3	278.9
					48	142.5	191.0	223.2	254.0	263.8	293.9	323.8
					72	163.8	219.2	255.9	291.0	302.2	336.6	370.7
				Lower Confidence Limit	24	104.79	144.02	169.22	193.22	200.81	224.16	247.30
					48	134.65	177.28	204.66	230.73	238.98	264.35	289.48
					72	154.84	203.49	234.75	264.50	273.92	302.87	331.56
10	Sabah	5759003	Papar JPS	Upper Confidence Limit	24	161.42	209.94	242.80	274.50	284.58	315.65	346.54
					48	180.21	228.68	261.51	293.19	303.25	334.30	365.15
					72	199.11	251.21	286.50	320.54	331.36	364.73	397.90
				Estimated Design Rainstorm	24	154.4	197.7	226.3	253.8	262.5	289.3	316.0
					48	173.2	216.4	245.0	272.5	281.2	308.0	334.6
					72	191.6	238.1	268.8	298.3	307.7	336.5	365.1

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	147.44	185.43	209.83	233.07	240.42	263.02	285.43
					48	166.24	204.19	228.58	251.79	259.13	281.72	304.10
					72	184.10	224.89	251.10	276.05	283.94	308.22	332.28
11	Sabah	5961003	Inanam Met. Stn.	Upper Confidence Limit	24	167.07	234.41	280.03	324.02	338.01	381.14	424.01
					48	195.53	269.40	319.44	367.71	383.05	430.37	477.39
					72	215.61	296.82	351.84	404.90	421.77	473.79	525.48
				Estimated Design Rainstorm	24	157.4	217.4	257.1	295.3	307.4	344.6	381.6
					48	184.9	250.7	294.3	336.2	349.4	390.3	430.9
					72	203.9	276.3	324.2	370.2	384.8	429.7	474.3
				Lower Confidence Limit	24	147.67	200.39	234.26	266.51	276.72	308.09	339.19
					48	174.25	232.09	269.24	304.62	315.81	350.23	384.34
					72	192.21	255.80	296.65	335.54	347.85	385.69	423.19
12	Sabah	5966003	Ranau JPS	Upper Confidence Limit	24	105.23	147.03	175.34	202.65	211.33	238.09	264.70
					48	136.54	188.42	223.57	257.48	268.25	301.49	334.52
					72	156.71	213.86	252.58	289.93	301.80	338.41	374.79
				Estimated Design Rainstorm	24	99.2	136.5	161.1	184.8	192.3	215.4	238.4
					48	129.1	175.3	205.9	235.3	244.6	273.3	301.8
					72	148.5	199.4	233.2	265.5	275.8	307.4	338.8
				Lower Confidence Limit	24	93.19	125.91	146.94	166.95	173.28	192.76	212.06
					48	121.59	162.21	188.31	213.16	221.02	245.20	269.16
					72	140.24	184.99	213.74	241.11	249.77	276.41	302.80
13	Sabah	5973002	Trusan Sapi Met. Stn.	Upper Confidence Limit	24	191.49	269.61	322.53	373.58	389.80	439.84	489.58
					48	236.45	326.49	387.48	446.31	465.01	522.68	580.00
					72	271.95	383.43	458.96	531.80	554.95	626.36	697.33
				Estimated Design Rainstorm	24	180.2	249.9	296.0	340.2	354.2	397.5	440.4
					48	223.5	303.7	356.9	407.9	424.0	473.8	523.3
					72	255.9	355.3	421.1	484.2	504.2	565.9	627.1
				Lower Confidence Limit	24	168.98	230.14	269.44	306.86	318.69	355.10	391.17
					48	210.51	281.00	326.29	369.41	383.06	425.01	466.59
					72	239.83	327.12	383.19	436.59	453.48	505.43	556.90

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
14	Sabah	6162003	Tuaran P.H. No.1	Upper Confidence Limit	24	144.31	183.28	209.68	235.15	243.24	268.20	293.01
					48	166.60	213.04	244.51	274.86	284.51	314.26	343.83
					72	183.07	231.55	264.39	296.07	306.14	337.19	368.05
				Estimated Design Rainstorm	24	138.7	173.4	196.4	218.5	225.5	247.1	268.5
					48	159.9	201.3	228.7	255.0	263.4	289.1	314.6
					72	176.1	219.3	247.9	275.4	284.1	310.9	337.5
				Lower Confidence Limit	24	133.08	163.60	183.20	201.86	207.77	225.93	243.92
					48	153.21	189.58	212.94	235.19	242.23	263.87	285.32
					72	169.11	207.06	231.45	254.66	262.01	284.60	306.98
15	Sabah	6168002	Merungin	Upper Confidence Limit	24	96.65	125.38	144.84	163.61	169.58	187.98	206.26
					48	125.90	162.64	187.53	211.54	219.17	242.70	266.09
					72	147.11	189.67	218.50	246.31	255.15	282.42	309.51
				Estimated Design Rainstorm	24	92.5	118.1	135.1	151.3	156.5	172.4	188.2
					48	120.6	153.4	175.0	195.8	202.4	222.8	243.0
					72	141.0	178.9	204.0	228.1	235.8	259.3	282.7
				Lower Confidence Limit	24	88.37	110.86	125.31	139.07	143.43	156.81	170.08
					48	115.32	144.08	162.56	180.16	185.73	202.85	219.81
					72	134.85	168.17	189.58	209.96	216.41	236.25	255.90
16	Sabah	6364001	Kota Belud JPS	Upper Confidence Limit	24	112.24	152.94	180.50	207.09	215.54	241.61	267.51
					48	144.79	201.58	240.04	277.15	288.94	325.31	361.46
					72	164.27	229.05	272.93	315.26	328.71	370.20	411.43
				Estimated Design Rainstorm	24	106.4	142.7	166.7	189.7	197.0	219.5	241.9
					48	136.6	187.2	220.7	252.9	263.1	294.5	325.7
					72	154.9	212.7	250.9	287.6	299.2	335.1	370.6
				Lower Confidence Limit	24	100.52	132.38	152.85	172.34	178.50	197.47	216.26
					48	128.43	172.89	201.45	228.65	237.25	263.71	289.94
					72	145.61	196.32	228.91	259.93	269.75	299.93	329.84
17	Sabah	6567002	Kota Marudu	Upper Confidence Limit	24	160.47	243.96	300.52	355.07	372.41	425.89	479.04
					48	222.58	339.48	418.68	495.07	519.34	594.22	668.64
					72	262.83	401.90	496.12	586.99	615.87	704.95	793.48

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	148.4	222.9	272.2	319.4	334.4	380.6	426.5
					48	205.7	310.0	379.0	445.1	466.1	530.8	595.0
					72	242.8	366.8	448.9	527.6	552.6	629.5	705.9
				Lower Confidence Limit	24	136.41	201.78	243.78	283.77	296.42	335.32	373.88
					48	188.90	280.43	339.24	395.22	412.94	467.41	521.39
					72	222.76	331.65	401.61	468.21	489.28	554.09	618.30
18	Sabah	6868002	Kudat JPS	Upper Confidence Limit	24	148.92	208.33	248.58	287.39	299.73	337.78	375.60
					48	186.58	255.74	302.59	347.78	362.14	406.43	450.46
					72	222.94	313.53	374.89	434.08	452.89	510.92	568.58
				Estimated Design Rainstorm	24	140.4	193.3	228.4	262.0	272.7	305.6	338.2
					48	176.6	238.3	279.1	318.2	330.7	368.9	406.9
					72	209.9	290.6	344.1	395.4	411.7	461.8	511.5
				Lower Confidence Limit	24	131.81	178.32	208.20	236.65	245.66	273.34	300.77
					48	166.65	220.80	255.59	288.71	299.19	331.41	363.35
					72	196.84	267.77	313.33	356.72	370.44	412.65	454.48
19	Sarawak	905039	Bunan Gega	Upper Confidence Limit	24	120.0	147.8	166.6	184.8	190.6	208.4	226.0
					48	151.5	186.8	210.6	233.7	241.0	263.6	286.1
					72	171.3	210.8	237.6	263.4	271.6	297.0	322.1
				Estimated Design Rainstorm	24	116.05	140.81	157.21	172.94	177.92	193.29	208.55
					48	146.41	177.85	198.66	218.63	224.97	244.48	263.85
					72	165.64	200.87	224.19	246.57	253.66	275.53	297.23
				Lower Confidence Limit	24	112.0	133.8	147.8	161.1	165.3	178.2	191.1
					48	141.3	168.9	186.7	203.6	208.9	225.4	241.6
					72	159.9	190.9	210.8	229.7	235.7	254.1	272.3
20	Sarawak	1003031	Tebedu	Upper Confidence Limit	24	113.2	154.8	183.0	210.3	218.9	245.6	272.1
					48	144.9	193.5	226.5	258.2	268.3	299.5	330.5
					72	169.1	227.3	266.7	304.8	316.9	354.1	391.2
				Estimated Design Rainstorm	24	107.17	144.30	168.89	192.47	199.95	222.99	245.86
					48	137.87	181.23	209.93	237.47	246.21	273.12	299.83
					72	160.69	212.59	246.95	279.91	290.37	322.57	354.54

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	101.2	133.8	154.7	174.7	181.0	200.4	219.6
					48	130.9	168.9	193.4	216.7	224.1	246.7	269.2
					72	152.3	197.9	227.2	255.1	263.9	291.0	317.9
21	Sarawak	1005079	Bukit Matuh	Upper Confidence Limit	24	123.6	163.1	189.9	215.7	223.9	249.2	274.4
					48	141.0	185.7	216.0	245.2	254.5	283.2	311.6
					72	163.1	211.9	244.9	276.8	286.9	318.2	349.3
				Estimated Design Rainstorm	24	117.93	153.15	176.47	198.84	205.94	227.80	249.50
					48	134.60	174.45	200.84	226.15	234.18	258.91	283.46
					72	156.05	199.54	228.34	255.97	264.73	291.73	318.52
				Lower Confidence Limit	24	112.2	143.2	163.0	182.0	188.0	206.4	224.6
					48	128.2	163.2	185.6	207.1	213.8	234.7	255.3
					72	149.0	187.2	211.8	235.1	242.5	265.3	287.8
22	Sarawak	1005080	Sungai Busit	Upper Confidence Limit	24	147.8	203.6	241.4	277.9	289.5	325.3	360.9
					48	176.1	249.8	299.7	347.9	363.2	410.4	457.3
					72	199.4	278.3	331.8	383.4	399.8	450.4	500.6
				Estimated Design Rainstorm	24	139.71	189.50	222.47	254.09	264.12	295.02	325.70
					48	165.49	231.19	274.70	316.42	329.66	370.44	410.91
					72	188.00	258.39	304.99	349.69	363.87	407.56	450.92
				Lower Confidence Limit	24	131.7	175.4	203.5	230.2	238.7	264.7	290.5
					48	154.9	212.6	249.7	285.0	296.1	330.5	364.5
					72	176.6	238.4	278.2	316.0	327.9	364.7	401.2
23	Sarawak	1006028	Sungai Bedup	Upper Confidence Limit	24	143.2	194.6	229.4	262.9	273.6	306.4	339.1
					48	169.2	224.3	261.6	297.6	309.0	344.3	379.4
					72	191.1	252.7	294.5	334.8	347.6	387.1	426.3
				Estimated Design Rainstorm	24	135.85	181.61	211.91	240.98	250.20	278.60	306.79
					48	161.25	210.37	242.88	274.08	283.97	314.45	344.71
					72	182.17	237.14	273.54	308.45	319.52	353.64	387.50
				Lower Confidence Limit	24	128.5	168.6	194.5	219.1	226.8	250.8	274.5
					48	153.3	196.5	224.2	250.5	258.9	284.6	310.0
					72	173.3	221.6	252.6	282.1	291.5	320.2	348.7

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
24	Sarawak	1006033	Sungai Merang	Upper Confidence Limit	24	139.7	191.7	226.9	260.9	271.7	305.0	338.1
					48	166.1	223.9	263.0	300.8	312.8	349.8	386.5
					72	187.6	251.2	294.3	335.9	349.1	389.8	430.3
				Estimated Design Rainstorm	24	132.25	178.59	209.27	238.71	248.04	276.80	305.35
					48	157.82	209.31	243.40	276.11	286.48	318.44	350.16
					72	178.48	235.18	272.71	308.72	320.14	355.33	390.26
				Lower Confidence Limit	24	124.8	165.5	191.6	216.5	224.4	248.6	272.6
					48	149.5	194.7	223.8	251.4	260.2	287.1	313.8
					72	169.3	219.1	251.1	281.6	291.2	320.8	350.2
25	Sarawak	1006037	Sungai Teb	Upper Confidence Limit	24	174.1	251.1	303.3	353.6	369.6	418.9	467.9
					48	182.0	251.4	298.4	343.8	358.2	402.6	446.8
					72	192.7	255.9	298.8	340.1	353.2	393.7	434.0
				Estimated Design Rainstorm	24	163.02	231.67	277.12	320.72	334.55	377.15	419.44
					48	172.00	233.87	274.84	314.13	326.60	365.00	403.11
					72	183.56	239.94	277.26	313.07	324.42	359.41	394.14
				Lower Confidence Limit	24	151.9	212.2	251.0	287.8	299.5	335.4	370.9
					48	162.0	216.3	251.3	284.5	295.0	327.4	359.4
					72	174.5	224.0	255.8	286.1	295.6	325.1	354.3
26	Sarawak	1007040	Balai Ringin	Upper Confidence Limit	24	132.9	172.6	199.4	225.4	233.6	259.0	284.3
					48	162.0	209.0	240.9	271.7	281.4	311.6	341.5
					72	182.0	231.9	265.8	298.4	308.7	340.7	372.5
				Estimated Design Rainstorm	24	127.16	162.53	185.95	208.42	215.54	237.49	259.28
					48	155.20	197.15	224.92	251.56	260.01	286.04	311.89
					72	174.84	219.34	248.80	277.06	286.03	313.64	341.06
				Lower Confidence Limit	24	121.4	152.5	172.5	191.5	197.5	216.0	234.3
					48	148.4	185.3	208.9	231.5	238.6	260.5	282.3
					72	167.7	206.7	231.8	255.7	263.3	286.6	309.6
27	Sarawak	1008032	Sungai Pinang	Upper Confidence Limit	24	135.4	174.3	200.5	225.9	234.0	258.8	283.5
					48	168.4	211.2	240.3	268.3	277.2	304.6	331.9
					72	197.9	245.0	276.9	307.7	317.4	347.6	377.6

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	129.85	164.45	187.36	209.33	216.30	237.77	259.08
					48	162.20	200.41	225.70	249.96	257.66	281.36	304.90
					72	191.16	233.12	260.91	287.56	296.02	322.06	347.92
				Lower Confidence Limit	24	124.3	154.6	174.2	192.8	198.6	216.7	234.6
					48	156.0	189.6	211.1	231.7	238.2	258.1	277.9
					72	184.4	221.2	244.9	267.5	274.6	296.5	318.3
28	Sarawak	1015001	Batu Lintang	Upper Confidence Limit	24	146.8	201.4	238.4	274.1	285.5	320.4	355.2
					48	179.5	248.2	294.8	339.7	354.0	398.0	441.7
					72	206.2	286.8	341.4	394.1	410.9	462.5	513.9
				Estimated Design Rainstorm	24	138.91	187.61	219.85	250.78	260.59	290.81	320.81
					48	169.64	230.89	271.45	310.35	322.69	360.70	398.43
					72	194.57	266.45	314.05	359.70	374.18	418.79	463.07
				Lower Confidence Limit	24	131.0	173.8	201.3	227.5	235.7	261.2	286.4
					48	159.7	213.5	248.1	281.0	291.4	323.4	355.2
					72	183.0	246.1	286.6	325.3	337.5	375.1	412.3
29	Sarawak	1018002	Lubok Antu	Upper Confidence Limit	24	123.7	161.8	187.6	212.5	220.4	244.8	269.1
					48	147.4	193.5	224.7	254.8	264.4	293.9	323.3
					72	175.0	232.2	271.1	308.5	320.4	357.1	393.6
				Estimated Design Rainstorm	24	118.18	152.15	174.65	196.22	203.07	224.15	245.08
					48	140.78	181.87	209.07	235.16	243.44	268.93	294.24
					72	166.70	217.77	251.59	284.02	294.31	326.01	357.47
				Lower Confidence Limit	24	112.7	142.5	161.7	179.9	185.7	203.5	221.1
					48	134.1	170.2	193.4	215.5	222.5	243.9	265.2
					72	158.4	203.3	232.1	259.6	268.2	294.9	321.4
30	Sarawak	1102019	Padawan	Upper Confidence Limit	24	132.7	180.1	212.3	243.3	253.1	283.5	313.7
					48	180.6	242.4	284.3	324.7	337.5	377.1	416.5
					72	206.6	281.4	332.1	380.9	396.4	444.3	491.9
				Estimated Design Rainstorm	24	125.82	168.12	196.13	223.00	231.52	257.77	283.83
					48	171.71	226.82	263.31	298.30	309.40	343.60	377.55
					72	195.87	262.52	306.65	348.98	362.41	403.78	444.84

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	119.0	156.1	180.0	202.7	209.9	232.0	253.9
					48	162.8	211.2	242.3	271.9	281.3	310.1	338.6
					72	185.1	243.6	281.2	317.1	328.4	363.2	397.7
31	Sarawak	1105027	Serian	Upper Confidence Limit	24	142.4	184.6	213.2	240.8	249.5	276.5	303.4
					48	182.5	241.4	281.4	319.9	332.2	369.9	407.5
					72	213.2	288.0	338.7	387.6	403.1	451.0	498.7
				Estimated Design Rainstorm	24	136.33	173.94	198.85	222.74	230.31	253.66	276.83
					48	173.95	226.53	261.34	294.73	305.33	337.96	370.34
					72	202.45	269.13	313.29	355.64	369.07	410.46	451.54
				Lower Confidence Limit	24	130.3	163.3	184.5	204.7	211.1	230.8	250.3
					48	165.5	211.6	241.3	269.5	278.5	306.0	333.2
					72	191.7	250.2	287.9	323.7	335.0	369.9	404.4
32	Sarawak	1105035	Semuja Nonok	Upper Confidence Limit	24	150.4	200.6	234.6	267.3	277.8	309.9	341.9
					48	179.6	241.2	282.9	323.1	335.9	375.4	414.6
					72	204.4	270.1	314.7	357.7	371.3	413.5	455.3
				Estimated Design Rainstorm	24	143.14	187.88	217.50	245.91	254.92	282.69	310.25
					48	170.68	225.59	261.95	296.82	307.88	341.96	375.79
					72	194.89	253.53	292.35	329.59	341.40	377.79	413.91
				Lower Confidence Limit	24	135.9	175.2	200.4	224.5	232.1	255.5	278.6
					48	161.8	210.0	241.0	270.5	279.9	308.6	337.0
					72	185.4	236.9	270.0	301.5	311.5	342.1	372.5
33	Sarawak	1105050	Tebakang	Upper Confidence Limit	24	138.4	189.4	223.9	257.2	267.8	300.4	332.8
					48	167.2	226.8	267.2	306.1	318.5	356.6	394.6
					72	194.8	263.7	310.4	355.4	369.7	413.8	457.7
				Estimated Design Rainstorm	24	131.10	176.52	206.59	235.43	244.58	272.77	300.75
					48	158.65	211.76	246.93	280.66	291.37	324.33	357.05
					72	184.83	246.26	286.94	325.95	338.33	376.45	414.29
				Lower Confidence Limit	24	123.8	163.7	189.3	213.7	221.4	245.1	268.7
					48	150.1	196.7	226.7	255.2	264.2	292.0	319.5
					72	174.9	228.9	263.5	296.5	307.0	339.1	370.9

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
34	Sarawak	1111008	Pantu	Upper Confidence Limit	24	139.5	188.2	221.2	253.0	263.1	294.3	325.3
					48	165.1	218.3	254.3	289.1	300.1	334.2	368.0
					72	188.4	245.7	284.5	321.9	333.8	370.5	407.0
				Estimated Design Rainstorm	24	132.49	175.89	204.63	232.19	240.93	267.86	294.60
					48	157.48	204.88	236.26	266.36	275.90	305.32	334.51
					72	180.19	231.25	265.05	297.48	307.76	339.45	370.90
				Lower Confidence Limit	24	125.5	163.6	188.1	211.4	218.8	241.5	263.9
					48	149.8	191.4	218.2	243.7	251.7	276.5	301.0
					72	171.9	216.8	245.6	273.0	281.7	308.4	334.8
35	Sarawak	1114019	Temudok	Upper Confidence Limit	24	110.4	145.6	169.4	192.4	199.7	222.2	244.6
					48	133.8	177.6	207.2	235.7	244.8	272.8	300.7
					72	158.2	208.4	242.3	275.1	285.5	317.6	349.5
				Estimated Design Rainstorm	24	105.37	136.72	157.47	177.38	183.70	203.15	222.46
					48	127.53	166.51	192.32	217.07	224.92	249.11	273.13
					72	151.02	195.70	225.28	253.65	262.66	290.38	317.90
				Lower Confidence Limit	24	100.3	127.8	145.5	162.4	167.7	184.1	200.3
					48	121.2	155.5	177.5	198.4	205.0	225.4	245.6
					72	143.8	183.0	208.3	232.3	239.8	263.2	286.3
36	Sarawak	1114028	Melugu	Upper Confidence Limit	24	141.1	179.8	206.1	231.4	239.4	264.3	288.9
					48	164.4	205.3	233.0	259.8	268.3	294.5	320.5
					72	188.8	236.1	268.2	299.1	308.9	339.2	369.3
				Estimated Design Rainstorm	24	135.49	170.04	192.91	214.85	221.81	243.25	264.53
					48	158.49	194.97	219.13	242.30	249.64	272.29	294.76
					72	182.00	224.18	252.10	278.89	287.39	313.56	339.54
				Lower Confidence Limit	24	129.9	160.2	179.7	198.3	204.2	222.2	240.1
					48	152.6	184.6	205.2	224.8	231.0	250.1	269.0
					72	175.2	212.2	236.0	258.7	265.9	287.9	309.7
37	Sarawak	1201076	Embahn	Upper Confidence Limit	24	142.0	209.4	255.0	299.0	313.0	356.1	399.0
					48	189.0	284.7	349.5	412.0	431.9	493.2	554.1
					72	222.7	327.6	398.7	467.2	489.0	556.2	623.0

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	132.29	192.34	232.10	270.24	282.34	319.60	356.60
					48	175.23	260.53	317.01	371.18	388.37	441.30	493.85
					72	207.62	301.14	363.06	422.45	441.29	499.33	556.94
				Lower Confidence Limit	24	122.6	175.3	209.2	241.5	251.7	283.1	314.2
					48	161.4	236.4	284.5	330.3	344.8	389.4	433.6
					72	192.5	274.6	327.4	377.7	393.5	442.4	490.9
38	Sarawak	1203002	Kampung Gayu	Upper Confidence Limit	24	138.8	182.8	212.6	241.3	250.5	278.6	306.6
					48	178.4	242.1	285.3	326.9	340.2	381.0	421.5
					72	208.9	282.5	332.3	380.3	395.6	442.7	489.5
				Estimated Design Rainstorm	24	132.47	171.69	197.65	222.55	230.45	254.79	278.95
					48	169.26	226.06	263.66	299.73	311.18	346.42	381.41
					72	198.34	263.88	307.28	348.91	362.11	402.79	443.17
				Lower Confidence Limit	24	126.1	160.6	182.7	203.8	210.4	230.9	251.2
					48	160.1	210.0	242.0	272.5	282.2	311.9	341.3
					72	187.7	245.3	282.3	317.5	328.7	362.9	396.9
39	Sarawak	1204024	Dragon School	Upper Confidence Limit	24	147.4	202.4	239.7	275.7	287.1	322.3	357.4
					48	198.2	282.3	339.2	394.1	411.6	465.4	518.9
					72	233.2	336.7	406.7	474.3	495.8	562.1	627.9
				Estimated Design Rainstorm	24	139.46	188.52	221.00	252.15	262.04	292.48	322.70
					48	186.12	261.05	310.65	358.24	373.33	419.83	465.98
					72	218.32	310.54	371.59	430.16	448.74	505.97	562.78
				Lower Confidence Limit	24	131.5	174.6	202.3	228.7	237.0	262.6	288.0
					48	174.0	239.8	282.1	322.3	335.1	374.2	413.1
					72	203.4	284.4	336.4	386.0	401.7	449.9	497.6
40	Sarawak	1205006	Tarat	Upper Confidence Limit	24	149.7	196.3	227.8	258.3	267.9	297.8	327.4
					48	200.0	270.8	318.8	365.0	379.7	425.0	470.1
					72	229.6	310.1	364.7	417.4	434.1	485.7	537.0
				Estimated Design Rainstorm	24	143.01	184.52	212.01	238.37	246.74	272.50	298.07
					48	189.84	252.93	294.70	334.77	347.48	386.64	425.50
					72	217.94	289.78	337.34	382.96	397.43	442.01	486.26

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	136.3	172.8	196.2	218.5	225.5	247.2	268.7
					48	179.6	235.1	270.7	304.5	315.3	348.3	380.9
					72	206.3	269.4	310.0	348.5	360.8	398.3	435.5
41	Sarawak	1206089	Gedong	Upper Confidence Limit	24	136.1	189.2	225.1	259.9	270.9	304.9	338.7
					48	175.9	236.3	277.2	316.6	329.1	367.8	406.2
					72	197.4	262.6	306.8	349.4	363.0	404.7	446.2
				Estimated Design Rainstorm	24	128.41	175.75	207.10	237.17	246.71	276.09	305.26
					48	167.24	221.04	256.65	290.82	301.66	335.04	368.18
					72	188.02	246.16	284.65	321.57	333.28	369.36	405.17
				Lower Confidence Limit	24	120.8	162.3	189.1	214.5	222.5	247.3	271.8
					48	158.5	205.8	236.2	265.1	274.2	302.3	330.2
					72	178.6	229.7	262.5	293.7	303.6	334.0	364.1
42	Sarawak	1212032	Banting	Upper Confidence Limit	24	131.7	163.8	185.6	206.5	213.2	233.8	254.2
					48	162.4	201.4	227.9	253.4	261.5	286.6	311.4
					72	188.3	230.3	258.7	286.1	294.8	321.6	348.3
				Estimated Design Rainstorm	24	127.12	155.73	174.67	192.84	198.61	216.36	233.99
					48	156.74	191.57	214.63	236.75	243.76	265.37	286.83
					72	182.30	219.68	244.43	268.17	275.70	298.90	321.93
				Lower Confidence Limit	24	122.5	147.6	163.8	179.1	184.0	199.0	213.8
					48	151.1	181.7	201.4	220.1	226.0	244.2	262.2
					72	176.3	209.1	230.2	250.3	256.6	276.2	295.5
43	Sarawak	1214001	Sri Aman	Upper Confidence Limit	24	129.9	160.8	181.8	202.1	208.5	228.3	248.0
					48	151.3	189.2	214.9	239.7	247.6	271.9	296.1
					72	170.9	212.8	241.2	268.6	277.3	304.1	330.8
				Estimated Design Rainstorm	24	125.42	153.02	171.30	188.84	194.40	211.53	228.54
					48	145.79	179.62	202.02	223.50	230.32	251.31	272.15
					72	164.85	202.22	226.96	250.69	258.22	281.41	304.43
				Lower Confidence Limit	24	121.0	145.2	160.8	175.6	180.3	194.7	209.0
					48	140.3	170.0	189.1	207.3	213.0	230.7	248.3
					72	158.8	191.6	212.7	232.8	239.1	258.7	278.0

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
44	Sarawak	1217011	Riddan	Upper Confidence Limit	24	119.5	167.0	199.2	230.2	240.1	270.5	300.7
					48	147.1	195.2	227.8	259.3	269.3	300.1	330.8
					72	164.6	213.8	247.1	279.2	289.4	320.9	352.2
				Estimated Design Rainstorm	24	112.68	155.01	183.04	209.93	218.46	244.73	270.81
					48	140.16	183.07	211.48	238.74	247.38	274.01	300.45
					72	157.51	201.35	230.38	258.23	267.06	294.27	321.28
				Lower Confidence Limit	24	105.8	143.0	166.9	189.7	196.8	219.0	240.9
					48	133.2	170.9	195.1	218.2	225.5	247.9	270.1
					72	150.4	188.9	213.7	237.2	244.7	267.6	290.3
45	Sarawak	1219024	Nanga Tutong 2	Upper Confidence Limit	24	101.4	122.9	137.4	151.4	155.9	169.6	183.3
					48	128.8	152.1	167.9	183.1	187.9	202.8	217.7
					72	150.1	181.2	202.4	222.7	229.2	249.1	269.0
				Estimated Design Rainstorm	24	98.35	117.47	130.13	142.27	146.12	157.98	169.76
					48	125.44	146.20	159.94	173.13	177.31	190.20	202.99
					72	145.60	173.38	191.77	209.41	215.01	232.24	249.35
				Lower Confidence Limit	24	95.3	112.1	122.8	133.1	136.4	146.4	156.3
					48	122.1	140.3	152.0	163.2	166.7	177.6	188.3
					72	141.1	165.5	181.2	196.1	200.8	215.3	229.7
46	Sarawak	1303014	Semongok	Upper Confidence Limit	24	180.7	250.2	297.2	342.6	357.0	401.5	445.7
					48	237.3	336.0	402.9	467.4	487.9	551.2	614.0
					72	280.8	409.0	495.9	579.7	606.3	688.4	770.1
				Estimated Design Rainstorm	24	170.74	232.65	273.64	312.95	325.43	363.85	401.98
					48	223.04	311.06	369.34	425.24	442.97	497.60	551.82
					72	262.33	376.64	452.33	524.92	547.95	618.89	689.31
				Lower Confidence Limit	24	160.7	215.1	250.0	283.3	293.8	326.2	358.2
					48	208.8	286.1	335.8	383.1	398.0	444.0	489.6
					72	243.9	344.3	408.8	470.2	489.6	549.3	608.6
47	Sarawak	1305038	Samarahan Estate	Upper Confidence Limit	24	172.2	239.6	285.2	329.3	343.2	386.4	429.3
					48	223.0	311.1	370.8	428.4	446.7	503.1	559.2
					72	260.7	369.7	443.6	514.8	537.4	607.3	676.7

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	162.51	222.57	262.34	300.48	312.58	349.85	386.85
					48	210.33	288.88	340.89	390.78	406.60	455.36	503.75
					72	244.98	342.17	406.52	468.24	487.82	548.13	608.00
				Lower Confidence Limit	24	152.8	205.6	239.4	271.7	281.9	313.3	344.4
					48	197.6	266.6	310.9	353.2	366.5	407.6	448.3
					72	229.3	314.6	369.5	421.7	438.2	489.0	539.3
48	Sarawak	1306055	Lubok Ipoi	Upper Confidence Limit	24	149.5	199.9	234.0	266.9	277.4	309.7	341.7
					48	189.4	262.3	311.7	359.3	374.4	421.1	467.5
					72	218.0	301.7	358.5	413.2	430.6	484.2	537.5
				Estimated Design Rainstorm	24	142.28	187.18	216.91	245.43	254.48	282.34	310.00
					48	178.90	243.88	286.90	328.17	341.26	381.58	421.61
					72	205.89	280.56	329.99	377.41	392.45	438.79	484.79
				Lower Confidence Limit	24	135.0	174.5	199.8	223.9	231.6	255.0	278.3
					48	168.4	225.5	262.1	297.0	308.1	342.0	375.7
					72	193.8	259.4	301.5	341.6	354.3	393.4	432.0
49	Sarawak	1307018	Simunjan	Upper Confidence Limit	24	173.5	245.3	294.0	341.0	355.9	401.9	447.6
					48	224.9	320.4	385.2	447.6	467.4	528.6	589.5
					72	260.2	374.6	452.0	526.8	550.5	623.8	696.6
				Estimated Design Rainstorm	24	163.14	227.18	269.59	310.27	323.17	362.92	402.38
					48	211.15	296.32	352.71	406.80	423.96	476.82	529.28
					72	243.73	345.68	413.18	477.93	498.47	561.74	624.54
				Lower Confidence Limit	24	152.8	209.0	245.2	279.6	290.5	324.0	357.1
					48	197.4	272.2	320.2	366.0	380.5	425.0	469.1
					72	227.3	316.8	374.3	429.1	446.4	499.7	552.5
50	Sarawak	1311003	Lingga	Upper Confidence Limit	24	135.7	174.9	201.4	227.0	235.2	260.3	285.2
					48	162.9	212.8	246.7	279.3	289.7	321.7	353.5
					72	190.4	245.0	282.0	317.7	329.1	364.1	398.8
				Estimated Design Rainstorm	24	130.04	164.97	188.10	210.28	217.32	239.00	260.52
					48	155.67	200.21	229.70	257.99	266.96	294.60	322.04
					72	182.53	231.23	263.47	294.40	304.21	334.43	364.43

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	124.4	155.1	174.8	193.6	199.5	217.7	235.8
					48	148.5	187.6	212.7	236.6	244.2	267.5	290.6
					72	174.7	217.4	244.9	271.1	279.3	304.8	330.0
51	Sarawak	1313006	Stumbin	Upper Confidence Limit	24	124.3	153.1	172.6	191.4	197.4	215.8	234.1
					48	148.6	181.1	203.2	224.5	231.3	252.1	272.9
					72	169.1	211.0	239.5	266.9	275.6	302.5	329.2
				Estimated Design Rainstorm	24	120.19	145.84	162.82	179.10	184.27	200.18	215.98
					48	143.87	172.91	192.14	210.59	216.44	234.46	252.35
					72	163.03	200.44	225.21	248.98	256.51	279.73	302.78
				Lower Confidence Limit	24	116.0	138.6	153.0	166.8	171.2	184.6	197.9
					48	139.2	164.7	181.1	196.7	201.6	216.8	231.8
					72	157.0	189.8	211.0	231.1	237.4	257.0	276.3
52	Sarawak	1401005	Bau	Upper Confidence Limit	24	177.0	260.4	316.9	371.3	388.7	442.1	495.1
					48	234.7	335.8	404.3	470.4	491.3	556.1	620.4
					72	284.2	414.2	502.3	587.2	614.2	697.5	780.2
				Estimated Design Rainstorm	24	165.01	239.33	288.54	335.74	350.71	396.84	442.62
					48	220.17	310.28	369.95	427.18	445.34	501.27	556.78
					72	265.51	381.40	458.12	531.72	555.06	626.98	698.37
				Lower Confidence Limit	24	153.0	218.3	260.2	300.1	312.8	351.6	390.1
					48	205.6	284.8	335.6	384.0	399.3	446.4	493.1
					72	246.8	348.6	414.0	476.2	495.9	556.5	616.5
53	Sarawak	1402047	Batu Kitang	Upper Confidence Limit	24	200.2	282.3	338.0	391.7	408.8	461.4	513.8
					48	263.9	376.5	452.9	526.5	549.9	622.1	693.8
					72	310.2	439.7	527.3	611.9	638.8	721.7	804.1
				Estimated Design Rainstorm	24	188.32	261.59	310.10	356.63	371.39	416.87	462.00
					48	247.62	348.09	414.60	478.40	498.64	560.99	622.87
					72	291.58	406.96	483.36	556.64	579.88	651.49	722.57
				Lower Confidence Limit	24	176.5	240.8	282.2	321.5	334.0	372.3	410.2
					48	231.4	319.6	376.3	430.3	447.4	499.9	551.9
					72	272.9	374.3	439.4	501.4	521.0	581.3	641.1

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
54	Sarawak	1403001	Kuching Airport	Upper Confidence Limit	24	200.3	282.9	338.8	392.8	409.9	462.8	515.4
					48	265.4	378.9	455.7	529.8	553.4	626.0	698.2
					72	311.8	441.1	528.8	613.3	640.1	723.0	805.3
				Estimated Design Rainstorm	24	188.40	262.03	310.77	357.53	372.36	418.05	463.41
					48	249.11	350.22	417.16	481.38	501.75	564.49	626.78
					72	293.15	408.46	484.81	558.04	581.27	652.84	723.87
				Lower Confidence Limit	24	176.5	241.2	282.7	322.3	334.8	373.3	411.4
					48	232.8	321.6	378.6	432.9	450.1	503.0	555.3
					72	274.5	375.8	440.9	502.8	522.4	582.7	642.4
55	Sarawak	1404049	Paya Paloh	Upper Confidence Limit	24	204.7	281.4	333.4	383.6	399.5	448.7	497.5
					48	260.3	359.6	426.9	491.8	512.5	576.1	639.3
					72	297.0	413.4	492.4	568.5	592.6	667.2	741.4
				Estimated Design Rainstorm	24	193.62	262.05	307.35	350.80	364.59	407.05	449.21
					48	246.00	334.55	393.18	449.42	467.26	522.21	576.76
					72	280.20	384.03	452.78	518.72	539.64	604.07	668.04
				Lower Confidence Limit	24	182.6	242.7	281.3	318.0	329.7	365.4	400.9
					48	231.7	309.5	359.4	407.0	422.0	468.3	514.2
					72	263.4	354.6	413.2	469.0	486.6	540.9	594.7
56	Sarawak	1404091	Kota Samarahan	Upper Confidence Limit	24	205.6	290.6	348.1	403.6	421.2	475.6	529.7
					48	271.5	382.2	457.2	529.5	552.5	623.3	693.8
					72	312.8	432.6	513.8	592.1	617.0	693.7	770.0
				Estimated Design Rainstorm	24	193.40	269.11	319.24	367.32	382.58	429.56	476.20
					48	255.55	354.22	419.54	482.21	502.08	563.32	624.10
					72	295.55	402.36	473.08	540.92	562.44	628.72	694.52
				Lower Confidence Limit	24	181.2	247.7	290.4	331.1	343.9	383.5	422.7
					48	239.6	326.3	381.9	434.9	451.7	503.3	554.4
					72	278.3	372.1	432.4	489.8	507.9	563.7	619.1
57	Sarawak	1415004	Betong	Upper Confidence Limit	24	112.6	145.8	168.2	189.9	196.8	218.1	239.2
					48	137.6	175.8	201.7	226.6	234.5	259.0	283.3
					72	164.5	204.4	231.4	257.5	265.8	291.3	316.7

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	107.78	137.37	156.96	175.75	181.71	200.08	218.30
					48	132.09	166.14	188.68	210.30	217.16	238.29	259.27
					72	158.78	194.34	217.88	240.46	247.63	269.70	291.60
				Lower Confidence Limit	24	103.0	129.0	145.7	161.6	166.6	182.1	197.4
					48	126.6	156.5	175.7	194.0	199.8	217.6	235.2
					72	153.0	184.3	204.3	223.4	229.5	248.1	266.5
58	Sarawak	1502001	Sebubut	Upper Confidence Limit	24	233.2	301.0	346.9	391.1	405.2	448.6	491.7
					48	288.3	379.5	441.2	500.7	519.7	578.0	636.0
					72	339.9	456.4	535.3	611.4	635.6	710.2	784.4
				Estimated Design Rainstorm	24	223.46	283.86	323.85	362.21	374.38	411.87	449.07
					48	275.20	356.44	410.23	461.82	478.19	528.60	578.65
					72	323.09	426.93	495.69	561.64	582.57	647.01	710.99
				Lower Confidence Limit	24	213.7	266.8	300.8	333.3	343.5	375.1	406.4
					48	262.1	333.4	379.3	422.9	436.7	479.2	521.3
					72	306.3	397.5	456.1	511.9	529.5	583.8	637.6
59	Sarawak	1502026	Matang	Upper Confidence Limit	24	222.0	300.5	353.7	405.0	421.3	471.6	521.5
					48	289.4	392.2	461.8	528.9	550.3	616.1	681.5
					72	344.1	471.2	557.3	640.3	666.7	748.1	829.0
				Estimated Design Rainstorm	24	210.73	280.70	327.04	371.48	385.58	429.00	472.11
					48	274.61	366.21	426.86	485.04	503.49	560.34	616.77
					72	325.78	439.07	514.08	586.03	608.85	679.16	748.95
				Lower Confidence Limit	24	199.4	260.9	300.4	338.0	349.9	386.4	422.7
					48	259.8	340.3	391.9	441.2	456.7	504.6	552.1
					72	307.5	407.0	470.9	531.8	551.0	610.2	668.9
60	Sarawak	1505081	Ketup	Upper Confidence Limit	24	218.5	313.8	378.5	440.8	460.6	521.7	582.4
					48	280.7	398.3	477.9	554.7	579.1	654.4	729.2
					72	327.9	466.2	559.9	650.3	679.0	767.6	855.6
				Estimated Design Rainstorm	24	204.72	289.75	346.05	400.06	417.19	469.96	522.34
					48	263.78	368.56	437.94	504.50	525.61	590.64	655.19
					72	307.93	431.24	512.88	591.20	616.04	692.57	768.53

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	191.0	265.7	313.6	359.3	373.8	418.2	462.3
					48	246.8	338.9	398.0	454.3	472.1	526.9	581.2
					72	288.0	396.3	465.9	532.1	553.1	617.5	681.4
61	Sarawak	1506034	Asa Jaya	Upper Confidence Limit	24	223.5	303.1	357.1	409.1	425.6	476.6	527.3
					48	275.9	379.1	449.0	516.4	537.8	603.9	669.6
					72	326.2	445.9	527.0	605.1	630.0	706.7	782.8
				Estimated Design Rainstorm	24	212.08	283.04	330.02	375.09	389.38	433.42	477.14
					48	261.03	353.01	413.91	472.33	490.86	547.95	604.61
					72	308.98	415.66	486.29	554.05	575.54	641.74	707.46
				Lower Confidence Limit	24	200.6	262.9	303.0	341.1	353.2	390.2	427.0
					48	246.2	327.0	378.9	428.3	443.9	492.0	539.6
					72	291.7	385.4	445.6	502.9	521.1	576.8	632.1
62	Sarawak	1509009	Sebuyau	Upper Confidence Limit	24	170.9	216.5	247.4	277.2	286.6	315.8	344.9
					48	207.1	268.2	309.6	349.5	362.2	401.4	440.3
					72	238.3	307.6	354.6	399.9	414.3	458.7	502.9
				Estimated Design Rainstorm	24	164.32	204.97	231.88	257.70	265.89	291.11	316.15
					48	198.25	252.74	288.82	323.42	334.40	368.21	401.78
					72	228.27	290.10	331.04	370.30	382.76	421.13	459.22
				Lower Confidence Limit	24	157.7	193.5	216.4	238.2	245.1	266.4	287.4
					48	189.4	237.3	268.0	297.3	306.6	335.1	363.3
					72	218.3	272.6	307.5	340.7	351.2	383.5	415.5
63	Sarawak	1601003	Sungai China	Upper Confidence Limit	24	248.2	326.9	380.3	431.7	448.0	498.5	548.6
					48	341.6	460.8	541.7	619.6	644.4	720.8	796.7
					72	396.7	536.5	631.2	722.6	751.7	841.2	930.3
				Estimated Design Rainstorm	24	236.89	307.05	353.51	398.08	412.21	455.76	498.99
					48	324.39	430.72	501.12	568.65	590.08	656.07	721.57
					72	376.51	501.18	583.73	662.90	688.02	765.39	842.19
				Lower Confidence Limit	24	225.5	287.2	326.8	364.5	376.4	413.1	449.4
					48	307.2	400.6	460.6	517.7	535.8	591.4	646.5
					72	356.4	465.9	536.2	603.2	624.4	689.5	754.1

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
64	Sarawak	1603058	Rampangi	Upper Confidence Limit	24	178.8	247.9	294.6	339.8	354.1	398.3	442.3
					48	249.9	345.0	409.4	471.5	491.3	552.2	612.7
					72	302.1	408.2	480.1	549.5	571.5	639.5	707.1
				Estimated Design Rainstorm	24	168.90	230.44	271.19	310.27	322.67	360.86	398.77
					48	236.23	320.98	377.09	430.92	447.99	500.59	552.80
					72	286.76	381.39	444.04	504.14	523.21	581.93	640.23
				Lower Confidence Limit	24	159.0	213.0	247.7	280.8	291.2	323.4	355.3
					48	222.5	297.0	344.8	390.3	404.7	449.0	492.9
					72	271.5	354.6	408.0	458.8	474.9	524.4	573.4
65	Sarawak	1612030	Pusa	Upper Confidence Limit	24	146.4	184.6	210.5	235.5	243.4	267.9	292.2
					48	174.9	216.7	245.0	272.3	281.0	307.8	334.4
					72	202.0	250.2	282.9	314.5	324.5	355.4	386.1
				Estimated Design Rainstorm	24	140.94	174.99	197.53	219.16	226.02	247.15	268.13
					48	168.89	206.15	230.81	254.47	261.97	285.09	308.04
					72	195.04	238.06	266.54	293.87	302.53	329.23	355.74
				Lower Confidence Limit	24	135.4	165.3	184.6	202.8	208.6	226.4	244.1
					48	162.9	195.6	216.6	236.6	243.0	262.4	281.7
					72	188.1	225.9	250.1	273.3	280.6	303.1	325.3
66	Sarawak	1615023	Batu Danau	Upper Confidence Limit	24	133.2	165.9	188.1	209.4	216.2	237.2	258.0
					48	161.8	198.8	223.8	247.9	255.6	279.2	302.7
					72	181.4	222.9	251.0	278.1	286.8	313.3	339.8
				Estimated Design Rainstorm	24	128.46	157.63	176.94	195.47	201.34	219.44	237.41
					48	156.52	189.43	211.22	232.12	238.75	259.18	279.45
					72	175.44	212.44	236.93	260.43	267.88	290.84	313.63
				Lower Confidence Limit	24	123.8	149.4	165.8	181.5	186.5	201.7	216.8
					48	151.2	180.1	198.7	216.4	222.0	239.2	256.2
					72	169.5	202.0	222.8	242.7	249.0	268.3	287.5
67	Sarawak	1616021	Nanga Tiga	Upper Confidence Limit	24	125.7	164.1	190.1	215.1	223.1	247.7	272.1
					48	150.8	190.6	217.6	243.6	251.8	277.3	302.7
					72	171.0	214.7	244.2	272.8	281.8	309.8	337.6

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	120.20	154.40	177.04	198.76	205.65	226.88	247.94
					48	145.04	180.53	204.03	226.57	233.72	255.75	277.62
					72	164.74	203.65	229.41	254.12	261.96	286.11	310.08
				Lower Confidence Limit	24	114.7	144.7	164.0	182.4	188.2	206.1	223.8
					48	139.3	170.5	190.5	209.6	215.6	234.2	252.5
					72	158.5	192.6	214.6	235.5	242.1	262.4	282.6
68	Sarawak	1698007	Lundu	Upper Confidence Limit	24	196.5	288.9	351.4	411.8	431.0	490.1	548.9
					48	265.9	391.1	475.9	557.7	583.7	663.9	743.6
					72	311.8	445.8	536.6	624.1	651.9	737.7	823.0
				Estimated Design Rainstorm	24	183.19	265.53	320.05	372.34	388.93	440.03	490.75
					48	247.84	359.45	433.34	504.22	526.71	595.97	664.72
					72	292.55	411.97	491.04	566.88	590.94	665.05	738.61
				Lower Confidence Limit	24	169.9	242.2	288.7	332.9	346.9	389.9	432.6
					48	229.8	327.8	390.8	450.8	469.7	528.1	585.9
					72	273.2	378.1	445.5	509.7	530.0	592.4	654.2
69	Sarawak	1704013	Telok Assam	Upper Confidence Limit	24	167.9	257.2	317.7	376.1	394.6	451.8	508.7
					48	228.7	341.9	418.5	492.5	516.0	588.5	660.5
					72	265.9	391.8	477.1	559.3	585.5	666.1	746.2
				Estimated Design Rainstorm	24	155.07	234.68	287.39	337.95	353.99	403.40	452.44
					48	212.44	313.31	380.10	444.16	464.48	527.08	589.22
					72	247.75	359.98	434.29	505.56	528.17	597.82	666.95
				Lower Confidence Limit	24	142.2	212.1	257.0	299.8	313.3	355.0	396.2
					48	196.1	284.7	341.6	395.8	413.0	465.7	518.0
					72	229.6	328.2	391.5	451.8	470.9	529.5	587.7
70	Sarawak	1713005	Saratok DID	Upper Confidence Limit	24	133.1	167.8	191.3	214.0	221.2	243.4	265.5
					48	158.5	199.3	226.9	253.5	262.0	288.1	314.0
					72	182.3	231.7	265.2	297.5	307.8	339.4	370.9
				Estimated Design Rainstorm	24	128.10	159.04	179.52	199.17	205.40	224.60	243.66
					48	152.64	188.97	213.03	236.10	243.42	265.97	288.35
					72	175.18	219.23	248.40	276.38	285.26	312.60	339.74

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	123.1	150.3	167.7	184.3	189.6	205.8	221.8
					48	146.8	178.7	199.2	218.7	224.9	243.9	262.7
					72	168.1	206.8	231.6	255.3	262.8	285.8	308.6
71	Sarawak	1726041	Nanga Bangkit	Upper Confidence Limit	24	144.3	189.4	219.9	249.3	258.6	287.5	316.1
					48	174.4	219.7	250.4	280.0	289.4	318.4	347.3
					72	202.4	249.2	281.0	311.6	321.3	351.4	381.2
				Estimated Design Rainstorm	24	137.85	177.99	204.56	230.05	238.14	263.05	287.77
					48	167.85	208.24	234.99	260.64	268.78	293.84	318.73
					72	195.64	237.41	265.07	291.60	300.02	325.94	351.67
				Lower Confidence Limit	24	131.4	166.6	189.3	210.8	217.6	238.6	259.4
					48	161.3	196.8	219.6	241.3	248.2	269.3	290.2
					72	188.9	225.6	249.1	271.6	278.7	300.5	322.2
72	Sarawak	1811007	Kabong	Upper Confidence Limit	24	157.3	197.0	223.9	249.8	258.0	283.5	308.7
					48	202.4	261.7	301.8	340.6	352.9	390.8	428.6
					72	233.2	303.6	351.4	397.4	412.0	457.2	502.0
				Estimated Design Rainstorm	24	151.59	186.96	210.38	232.85	239.97	261.93	283.72
					48	193.90	246.73	281.71	315.26	325.90	358.69	391.23
					72	223.03	285.84	327.43	367.32	379.98	418.96	457.65
				Lower Confidence Limit	24	145.9	176.9	196.9	215.9	221.9	240.4	258.7
					48	185.4	231.8	261.6	290.0	298.9	326.5	353.9
					72	212.9	268.0	303.5	337.2	347.9	380.7	413.3
73	Sarawak	1811010	Sessang	Upper Confidence Limit	24	147.3	196.1	229.2	261.1	271.2	302.5	333.6
					48	183.7	240.0	278.2	315.0	326.7	362.8	398.7
					72	212.8	280.5	326.3	370.6	384.6	427.9	471.0
				Estimated Design Rainstorm	24	140.26	183.78	212.60	240.24	249.01	276.03	302.84
					48	175.56	225.79	259.04	290.94	301.06	332.23	363.17
					72	203.09	263.41	303.35	341.66	353.81	391.24	428.40
				Lower Confidence Limit	24	133.2	171.5	196.0	219.4	226.8	249.5	272.1
					48	167.4	211.6	239.9	266.9	275.4	301.7	327.7
					72	193.3	246.3	280.4	312.8	323.0	354.5	385.8

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
74	Sarawak	1816029	Pakan	Upper Confidence Limit	24	138.0	185.3	217.3	248.2	258.1	288.3	318.5
					48	162.7	210.0	242.1	273.1	282.9	313.3	343.4
					72	185.9	237.2	271.9	305.4	316.0	348.9	381.5
				Estimated Design Rainstorm	24	131.18	173.34	201.26	228.04	236.53	262.70	288.67
					48	155.83	198.07	226.03	252.85	261.36	287.56	313.58
					72	178.50	224.21	254.47	283.49	292.70	321.07	349.22
				Lower Confidence Limit	24	124.4	161.4	185.2	207.8	215.0	237.0	258.9
					48	149.0	186.1	209.9	232.6	239.8	261.9	283.7
					72	171.1	211.3	237.0	261.6	269.4	293.3	316.9
75	Sarawak	1823001	Nanga Jagau	Upper Confidence Limit	24	121.8	167.2	198.0	227.6	237.1	266.2	295.1
					48	152.0	210.6	250.3	288.6	300.8	338.3	375.6
					72	181.8	256.8	307.6	356.7	372.2	420.3	468.0
				Estimated Design Rainstorm	24	115.22	155.71	182.53	208.25	216.40	241.54	266.48
					48	143.61	195.83	230.41	263.58	274.10	306.52	338.69
					72	171.01	237.88	282.16	324.63	338.10	379.60	420.80
				Lower Confidence Limit	24	108.7	144.2	167.1	188.8	195.7	216.9	237.9
					48	135.2	181.0	210.5	238.6	247.4	274.7	301.8
					72	160.2	218.9	256.7	292.6	304.0	338.9	373.6
76	Sarawak	1836042	Nanga Entawau	Upper Confidence Limit	24	140.5	177.2	202.0	226.0	233.6	257.2	280.5
					48	179.2	228.1	261.3	293.2	303.4	334.7	365.9
					72	209.3	262.0	297.6	332.0	343.0	376.7	410.2
				Estimated Design Rainstorm	24	135.20	167.92	189.58	210.35	216.94	237.25	257.40
					48	172.15	215.77	244.64	272.34	281.13	308.19	335.06
					72	201.71	248.66	279.74	309.56	319.02	348.15	377.07
				Lower Confidence Limit	24	129.9	158.6	177.1	194.7	200.2	217.3	234.3
					48	165.1	203.4	228.0	251.4	258.9	281.7	304.3
					72	194.1	235.4	261.8	287.1	295.1	319.6	343.9
77	Sarawak	1897016	Sematan	Upper Confidence Limit	24	210.1	286.8	338.8	388.9	404.8	453.9	502.8
					48	282.8	391.6	465.3	536.4	559.0	628.7	698.0
					72	333.8	470.8	563.7	653.2	681.6	769.4	856.6

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	199.07	267.44	312.71	356.13	369.90	412.34	454.45
					48	267.09	364.11	428.34	489.96	509.50	569.71	629.48
					72	314.09	436.23	517.10	594.67	619.28	695.08	770.32
				Lower Confidence Limit	24	188.0	248.1	286.6	323.4	335.0	370.7	406.2
					48	251.4	336.6	391.4	443.5	460.0	510.7	560.9
					72	294.3	401.6	470.5	536.2	556.9	620.8	684.0
78	Sarawak	2019024	Julau	Upper Confidence Limit	24	146.9	195.5	228.5	260.2	270.3	301.5	332.4
					48	176.1	228.7	264.3	298.7	309.6	343.3	376.8
					72	197.7	260.6	303.2	344.3	357.3	397.6	437.6
				Estimated Design Rainstorm	24	139.92	183.26	211.95	239.47	248.20	275.10	301.80
					48	168.51	215.40	246.44	276.22	285.66	314.76	343.65
					72	188.66	244.70	281.81	317.41	328.70	363.48	398.00
				Lower Confidence Limit	24	132.9	171.0	195.4	218.7	226.1	248.7	271.2
					48	160.9	202.1	228.6	253.8	261.7	286.2	310.5
					72	179.6	228.8	260.4	290.6	300.1	329.4	358.4
79	Sarawak	2021036	Kanowit Water Works	Upper Confidence Limit	24	118.3	150.1	171.8	192.6	199.2	219.7	240.0
					48	139.6	177.2	202.6	227.2	235.0	259.1	283.0
					72	157.9	191.8	214.8	237.0	244.0	265.8	287.4
				Estimated Design Rainstorm	24	113.66	142.09	160.92	178.98	184.71	202.35	219.87
					48	134.15	167.67	189.85	211.14	217.89	238.69	259.33
					72	152.98	183.24	203.27	222.48	228.58	247.35	265.99
				Lower Confidence Limit	24	109.1	134.0	150.1	165.4	170.2	185.1	199.8
					48	128.7	158.2	177.1	195.1	200.8	218.3	235.7
					72	148.1	174.7	191.7	208.0	213.1	228.9	244.6
80	Sarawak	2025012	Song	Upper Confidence Limit	24	97.7	131.6	154.5	176.7	183.7	205.4	227.0
					48	123.6	167.2	196.7	225.1	234.2	262.1	289.8
					72	141.9	188.1	219.4	249.6	259.2	288.7	318.2
				Estimated Design Rainstorm	24	92.78	123.00	143.00	162.19	168.27	187.02	205.64
					48	117.33	156.16	181.86	206.52	214.35	238.45	262.36
					72	135.26	176.44	203.70	229.85	238.14	263.70	289.06

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	87.9	114.4	131.5	147.7	152.8	168.6	184.3
					48	111.1	145.2	167.1	187.9	194.5	214.8	234.9
					72	128.6	164.8	188.0	210.1	217.1	238.6	260.0
81	Sarawak	2029001	Kapit JKR At Upper Rajang	Upper Confidence Limit	24	116.6	144.0	162.6	180.5	186.2	203.8	221.2
					48	149.6	192.8	222.0	250.2	259.1	286.8	314.2
					72	179.8	229.3	262.8	295.2	305.5	337.2	368.7
				Estimated Design Rainstorm	24	112.65	137.10	153.28	168.80	173.73	188.90	203.95
					48	143.40	181.86	207.33	231.75	239.50	263.37	287.06
					72	172.67	216.80	246.01	274.04	282.93	310.31	337.49
				Lower Confidence Limit	24	108.7	130.2	144.0	157.1	161.2	174.0	186.7
					48	137.2	171.0	192.7	213.3	219.9	240.0	259.9
					72	165.5	204.3	229.2	252.9	260.4	283.5	306.3
82	Sarawak	2112027	Rejang	Upper Confidence Limit	24	139.2	198.9	239.4	278.4	290.8	329.1	367.2
					48	171.2	242.4	290.6	337.1	351.9	397.5	442.8
					72	194.1	272.2	325.1	376.1	392.3	442.3	492.0
				Estimated Design Rainstorm	24	130.56	183.82	219.09	252.92	263.65	296.71	329.52
					48	160.99	224.44	266.45	306.75	319.53	358.90	397.99
					72	182.88	252.47	298.55	342.75	356.76	399.95	442.82
				Lower Confidence Limit	24	121.9	168.7	198.8	227.4	236.5	264.3	291.9
					48	150.7	206.5	242.3	276.4	287.1	320.3	353.2
					72	171.6	232.8	272.0	309.4	321.2	357.6	393.7
83	Sarawak	2115008	Sarikei DID	Upper Confidence Limit	24	126.9	157.2	177.8	197.6	203.9	223.3	242.6
					48	152.7	190.2	215.6	240.0	247.8	271.8	295.6
					72	178.1	220.2	248.7	276.2	284.9	311.9	338.7
				Estimated Design Rainstorm	24	122.56	149.58	167.47	184.63	190.08	206.85	223.49
					48	147.33	180.72	202.83	224.04	230.77	251.49	272.06
					72	172.09	209.59	234.42	258.24	265.79	289.07	312.17
				Lower Confidence Limit	24	118.2	141.9	157.2	171.7	176.3	190.4	204.4
					48	141.9	171.3	190.1	208.0	213.7	231.2	248.5
					72	166.0	199.0	220.1	240.3	246.6	266.2	285.7

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
84	Sarawak	2116030	Bintangor	Upper Confidence Limit	24	132.5	168.1	192.2	215.4	222.8	245.6	268.2
					48	169.9	215.8	246.9	276.9	286.4	315.8	345.0
					72	186.0	237.4	272.3	305.9	316.6	349.5	382.3
				Estimated Design Rainstorm	24	127.40	159.10	180.08	200.22	206.60	226.28	245.80
					48	163.32	204.22	231.30	257.28	265.52	290.90	316.10
					72	178.55	224.41	254.78	283.91	293.15	321.61	349.87
				Lower Confidence Limit	24	122.3	150.1	168.0	185.0	190.4	207.0	223.4
					48	156.7	192.6	215.7	237.7	244.6	266.0	287.2
					72	171.1	211.4	237.3	261.9	269.7	293.7	317.5
85	Sarawak	2121002	Kanowit Sedaya At Lower Rajang	Upper Confidence Limit	24	117.6	154.8	180.0	204.3	212.0	235.9	259.5
					48	140.2	185.0	215.3	244.6	253.9	282.6	311.1
					72	158.0	205.0	236.8	267.5	277.3	307.3	337.3
				Estimated Design Rainstorm	24	112.28	145.43	167.38	188.44	195.11	215.69	236.11
					48	133.79	173.70	200.12	225.47	233.51	258.28	282.86
					72	151.24	193.12	220.85	247.44	255.88	281.87	307.67
				Lower Confidence Limit	24	106.9	136.0	154.7	172.6	178.2	195.5	212.7
					48	127.3	162.4	184.9	206.3	213.1	234.0	254.7
					72	144.5	181.3	204.9	227.4	234.5	256.4	278.1
86	Sarawak	2212001	Belawai	Upper Confidence Limit	24	165.3	218.2	254.1	288.6	299.6	333.5	367.2
					48	203.0	271.7	318.3	363.2	377.5	421.6	465.3
					72	225.0	301.8	353.8	403.9	419.9	469.1	517.9
				Estimated Design Rainstorm	24	157.64	204.83	236.07	266.04	275.55	304.83	333.90
					48	193.09	254.38	294.96	333.89	346.24	384.27	422.03
					72	213.97	282.40	327.71	371.17	384.95	427.42	469.58
				Lower Confidence Limit	24	150.0	191.5	218.1	243.4	251.5	276.1	300.6
					48	183.2	237.0	271.6	304.5	314.9	347.0	378.7
					72	202.9	263.0	301.6	338.4	350.0	385.8	421.2
87	Sarawak	2218017	Sibu JKR WW	Upper Confidence Limit	24	149.1	196.4	228.5	259.4	269.2	299.5	329.7
					48	173.1	223.2	257.2	290.0	300.4	332.5	364.5
					72	193.5	246.9	283.0	317.9	328.9	363.1	397.1

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	142.26	184.46	212.39	239.19	247.69	273.88	299.87
					48	165.84	210.56	240.16	268.56	277.57	305.32	332.87
					72	185.81	233.38	264.87	295.08	304.66	334.18	363.49
				Lower Confidence Limit	24	135.4	172.5	196.3	219.0	226.1	248.2	270.1
					48	158.6	197.9	223.1	247.1	254.7	278.1	301.3
					72	178.1	219.9	246.7	272.3	280.4	305.2	329.9
88	Sarawak	2230143	Nanga Merit	Upper Confidence Limit	24	122.6	155.2	177.4	198.7	205.5	226.4	247.1
					48	154.0	189.4	213.4	236.6	244.0	266.7	289.2
					72	182.7	221.1	247.2	272.4	280.4	305.0	329.5
				Estimated Design Rainstorm	24	117.90	147.00	166.26	184.74	190.60	208.66	226.59
					48	148.88	180.48	201.40	221.46	227.83	247.44	266.90
					72	177.11	211.42	234.14	255.94	262.85	284.15	305.29
				Lower Confidence Limit	24	113.2	138.8	155.2	170.8	175.7	191.0	206.0
					48	143.8	171.5	189.4	206.3	211.7	228.2	244.6
					72	171.6	201.7	221.1	239.5	245.3	263.3	281.0
89	Sarawak	2318007	Sibu Airport At Lower Rajang	Upper Confidence Limit	24	119.2	147.6	166.8	185.4	191.3	209.5	227.6
					48	147.2	179.4	201.1	222.2	228.8	249.4	269.9
					72	168.9	201.8	224.2	245.7	252.6	273.7	294.7
				Estimated Design Rainstorm	24	115.07	140.39	157.16	173.24	178.35	194.06	209.67
					48	142.56	171.23	190.22	208.43	214.21	232.00	249.66
					72	164.11	193.51	212.98	231.65	237.58	255.83	273.94
				Lower Confidence Limit	24	111.0	133.2	147.5	161.1	165.4	178.7	191.8
					48	137.9	163.1	179.3	194.7	199.6	214.6	229.4
					72	159.4	185.2	201.8	217.6	222.6	237.9	253.2
90	Sarawak	2320059	Sibintek	Upper Confidence Limit	24	123.2	165.9	194.8	222.7	231.6	259.0	286.1
					48	156.9	210.3	246.6	281.5	292.6	326.8	360.9
					72	184.5	243.6	283.7	322.4	334.6	372.5	410.2
				Estimated Design Rainstorm	24	117.07	155.13	180.34	204.51	212.18	235.80	259.25
					48	149.18	196.84	228.40	258.66	268.26	297.84	327.20
					72	175.98	228.71	263.62	297.11	307.73	340.45	372.93

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	110.9	144.3	165.8	186.3	192.7	212.6	232.4
					48	141.5	183.3	210.2	235.8	243.9	268.8	293.5
					72	167.5	213.8	243.5	271.8	280.8	308.4	335.7
91	Sarawak	2321066	Sekuau	Upper Confidence Limit	24	128.3	173.6	204.3	233.9	243.3	272.4	301.2
					48	151.9	204.6	240.3	274.7	285.7	319.4	353.0
					72	181.2	247.6	292.5	335.8	349.6	392.1	434.3
				Estimated Design Rainstorm	24	121.78	162.18	188.92	214.58	222.72	247.79	272.67
					48	144.32	191.29	222.39	252.22	261.68	290.84	319.77
					72	171.68	230.80	269.95	307.50	319.41	356.10	392.52
				Lower Confidence Limit	24	115.2	150.7	173.5	195.2	202.1	223.2	244.1
					48	136.7	178.0	204.5	229.7	237.7	262.3	286.6
					72	162.1	214.1	247.4	279.2	289.2	320.1	350.8
92	Sarawak	2325039	Sungai Arau	Upper Confidence Limit	24	123.1	161.9	188.1	213.5	221.5	246.4	271.1
					48	151.5	192.3	220.0	246.7	255.2	281.4	307.4
					72	178.3	227.1	260.2	292.1	302.3	333.6	364.7
				Estimated Design Rainstorm	24	117.47	152.06	174.96	196.92	203.89	225.35	246.65
					48	145.57	182.00	206.12	229.25	236.59	259.20	281.64
					72	171.22	214.77	243.61	271.27	280.04	307.07	333.90
				Lower Confidence Limit	24	111.9	142.3	161.8	180.4	186.2	204.3	222.2
					48	139.7	171.7	192.2	211.8	218.0	237.0	255.9
					72	164.2	202.4	227.0	250.4	257.8	280.6	303.1
93	Sarawak	2418013	Rantau Panjang	Upper Confidence Limit	24	135.7	175.3	202.1	227.9	236.1	261.4	286.6
					48	166.2	223.4	262.1	299.5	311.3	348.0	384.3
					72	192.5	255.9	298.9	340.3	353.5	394.1	434.5
				Estimated Design Rainstorm	24	130.02	165.28	188.62	211.01	218.11	239.99	261.71
					48	158.00	208.96	242.70	275.06	285.33	316.95	348.34
					72	183.33	239.89	277.33	313.24	324.64	359.73	394.57
				Lower Confidence Limit	24	124.3	155.3	175.2	194.1	200.1	218.5	236.8
					48	149.8	194.5	223.3	250.7	259.3	285.9	312.3
					72	174.2	223.9	255.8	286.2	295.8	325.3	354.6

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
94	Sarawak	2514004	Daro	Upper Confidence Limit	24	156.6	221.2	265.0	307.2	320.6	362.0	403.1
					48	191.3	264.7	314.4	362.4	377.6	424.6	471.3
					72	213.4	291.3	344.1	395.0	411.2	461.1	510.7
				Estimated Design Rainstorm	24	147.32	204.91	243.04	279.61	291.22	326.96	362.43
					48	180.76	246.18	289.49	331.03	344.21	384.81	425.11
					72	202.13	271.60	317.60	361.73	375.72	418.84	461.64
				Lower Confidence Limit	24	138.0	188.6	221.1	252.0	261.8	291.9	321.7
					48	170.2	227.6	264.6	299.7	310.8	345.0	378.9
					72	190.9	251.9	291.1	328.4	340.3	376.6	412.6
95	Sarawak	2615009	Matu	Upper Confidence Limit	24	150.0	199.2	232.6	264.7	274.9	306.5	337.8
					48	202.4	266.1	309.2	350.7	363.9	404.7	445.2
					72	233.7	309.7	361.1	410.8	426.6	475.2	523.6
				Estimated Design Rainstorm	24	142.92	186.79	215.84	243.70	252.54	279.77	306.79
					48	193.28	250.00	287.55	323.57	334.99	370.19	405.13
					72	222.75	290.48	335.32	378.34	391.98	434.02	475.74
				Lower Confidence Limit	24	135.8	174.4	199.1	222.7	230.1	253.1	275.8
					48	184.1	233.9	265.9	296.4	306.0	335.7	365.1
					72	211.8	271.3	309.5	345.9	357.4	392.8	427.9
96	Sarawak	2623001	Mukah-Balingian OPS1	Upper Confidence Limit	24	139.2	178.6	205.3	231.0	239.2	264.4	289.5
					48	165.0	203.4	229.3	254.4	262.3	286.9	311.3
					72	193.4	235.6	264.2	291.8	300.5	327.5	354.4
				Estimated Design Rainstorm	24	133.55	168.66	191.91	214.21	221.28	243.07	264.70
					48	159.52	193.68	216.30	238.00	244.88	266.08	287.13
					72	187.33	224.94	249.84	273.73	281.31	304.65	327.83
				Lower Confidence Limit	24	127.9	158.7	178.5	197.4	203.4	221.7	239.9
					48	154.0	184.0	203.3	221.6	227.4	245.3	263.0
					72	181.2	214.3	235.5	255.7	262.1	281.8	301.3
97	Sarawak	2625051	Nanga Lemai	Upper Confidence Limit	24	137.0	172.7	196.8	220.1	227.5	250.3	273.0
					48	169.3	213.1	242.7	271.3	280.4	308.5	336.3
					72	190.7	235.6	266.0	295.3	304.6	333.4	361.9

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	131.88	163.66	184.69	204.87	211.27	230.99	250.57
					48	163.04	202.05	227.88	252.65	260.51	284.72	308.75
					72	184.22	224.23	250.72	276.13	284.19	309.02	333.67
				Lower Confidence Limit	24	126.7	154.7	172.6	189.7	195.1	211.7	228.1
					48	156.7	191.0	213.0	234.0	240.6	261.0	281.2
					72	177.8	212.9	235.5	257.0	263.8	284.7	305.4
98	Sarawak	2718022	Sungai Kut	Upper Confidence Limit	24	160.8	219.3	258.9	297.1	309.2	346.7	383.9
					48	194.0	264.4	312.0	357.9	372.5	417.6	462.3
					72	226.3	310.3	367.1	422.0	439.4	493.2	546.6
				Estimated Design Rainstorm	24	152.35	204.49	239.01	272.12	282.62	314.98	347.10
					48	183.91	246.59	288.09	327.90	340.53	379.43	418.05
					72	214.22	289.06	338.61	386.14	401.22	447.66	493.77
				Lower Confidence Limit	24	143.9	189.7	219.1	247.1	256.0	283.3	310.3
					48	173.8	228.8	264.2	297.9	308.5	341.3	373.8
					72	202.1	267.9	310.1	350.3	363.0	402.1	440.9
99	Sarawak	2828025	Tatau	Upper Confidence Limit	24	145.0	187.5	216.3	244.1	253.0	280.2	307.3
					48	185.4	237.3	272.5	306.5	317.2	350.5	383.6
					72	213.0	276.8	320.0	361.7	375.0	415.8	456.4
				Estimated Design Rainstorm	24	138.82	176.76	201.87	225.96	233.61	257.15	280.51
					48	177.93	224.22	254.88	284.28	293.61	322.34	350.86
					72	203.85	260.71	298.36	334.47	345.93	381.22	416.25
				Lower Confidence Limit	24	132.7	166.0	187.4	207.8	214.2	234.1	253.7
					48	170.4	211.1	237.2	262.1	270.0	294.2	318.2
					72	194.7	244.6	276.7	307.2	316.9	346.6	376.1
100	Sarawak	2920005	Mukah JKR	Upper Confidence Limit	24	190.3	263.6	313.3	361.2	376.4	423.4	470.0
					48	246.5	341.5	405.8	467.8	487.6	548.4	608.8
					72	288.1	395.9	468.9	539.4	561.8	630.8	699.4
				Estimated Design Rainstorm	24	179.74	245.10	288.37	329.88	343.04	383.60	423.87
					48	232.82	317.47	373.52	427.28	444.34	496.88	549.02
					72	272.59	368.69	432.32	493.35	512.71	572.35	631.54

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	169.2	226.6	263.5	298.6	309.7	343.8	377.7
					48	219.1	293.5	341.3	386.7	401.1	445.4	489.2
					72	257.1	341.5	395.7	447.3	463.6	513.9	563.7
101	Sarawak	2925010	Balingian	Upper Confidence Limit	24	182.6	261.2	314.5	365.8	382.2	432.5	482.5
					48	234.5	331.3	396.8	460.0	480.0	542.0	603.5
					72	270.4	371.6	440.2	506.4	527.4	592.2	656.7
				Estimated Design Rainstorm	24	171.31	241.37	287.77	332.27	346.38	389.87	433.03
					48	220.61	306.82	363.91	418.66	436.03	489.53	542.64
					72	255.79	346.05	405.80	463.12	481.30	537.31	592.91
				Lower Confidence Limit	24	160.0	221.5	261.1	298.7	310.6	347.2	383.5
					48	206.7	282.4	331.0	377.4	392.0	437.1	481.7
					72	241.2	320.5	371.4	419.9	435.2	482.4	529.1
102	Sarawak	2939045	Long Sambop	Upper Confidence Limit	24	136.6	167.8	188.9	209.2	215.7	235.7	255.5
					48	172.3	208.7	233.4	257.2	264.8	288.1	311.3
					72	202.3	240.8	266.9	292.1	300.1	324.8	349.4
				Estimated Design Rainstorm	24	132.08	159.88	178.28	195.93	201.53	218.78	235.90
					48	167.02	199.51	221.03	241.66	248.21	268.37	288.39
					72	196.70	231.07	253.83	275.66	282.58	303.91	325.09
				Lower Confidence Limit	24	127.6	152.0	167.7	182.6	187.3	201.9	216.3
					48	161.8	190.3	208.6	226.1	231.6	248.6	265.4
					72	191.1	221.3	240.7	259.2	265.0	283.0	300.8
103	Sarawak	3050015	Long Moh	Upper Confidence Limit	24	132.3	163.3	184.4	204.6	211.1	231.0	250.7
					48	163.5	196.8	219.2	241.0	247.8	269.1	290.3
					72	196.7	239.0	267.7	295.4	304.2	331.4	358.3
				Estimated Design Rainstorm	24	127.84	155.50	173.82	191.39	196.97	214.14	231.18
					48	158.75	188.36	207.96	226.77	232.73	251.11	269.35
					72	190.57	228.34	253.35	277.34	284.95	308.39	331.66
				Lower Confidence Limit	24	123.4	147.7	163.3	178.1	182.8	197.3	211.6
					48	154.0	180.0	196.7	212.6	217.6	233.1	248.4
					72	184.5	217.6	239.0	259.2	265.7	285.4	305.0

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
104	Sarawak	3130002	Bintulu Town	Upper Confidence Limit	24	159.7	207.5	239.9	271.1	281.1	311.7	342.1
					48	192.1	252.1	292.7	331.9	344.4	382.9	421.1
					72	214.0	280.3	325.3	368.6	382.4	424.8	467.1
				Estimated Design Rainstorm	24	152.84	195.45	223.67	250.73	259.32	285.76	312.01
					48	183.42	236.92	272.34	306.32	317.10	350.30	383.26
					72	204.45	263.57	302.72	340.26	352.17	388.87	425.29
				Lower Confidence Limit	24	146.0	183.4	207.4	230.3	237.6	259.8	281.9
					48	174.8	221.8	251.9	280.7	289.8	317.8	345.5
					72	194.9	246.8	280.2	311.9	322.0	352.9	383.5
105	Sarawak	3132023	Sebauh	Upper Confidence Limit	24	127.1	159.0	180.7	201.6	208.2	228.6	249.0
					48	155.7	199.0	228.3	256.5	265.5	293.2	320.8
					72	174.9	227.5	263.2	297.5	308.5	342.2	375.7
				Estimated Design Rainstorm	24	122.50	150.97	169.83	187.91	193.65	211.32	228.86
					48	149.45	188.02	213.56	238.06	245.83	269.77	293.53
					72	167.30	214.21	245.27	275.07	284.52	313.64	342.54
				Lower Confidence Limit	24	117.9	142.9	159.0	174.3	179.1	194.0	208.7
					48	143.2	177.1	198.9	219.6	226.1	246.3	266.3
					72	159.7	200.9	227.4	252.6	260.6	285.1	309.4
106	Sarawak	3137021	Tubau	Upper Confidence Limit	24	168.5	226.2	265.2	302.9	314.9	351.8	388.6
					48	208.9	280.5	329.0	375.7	390.6	436.4	482.0
					72	235.8	311.7	363.1	412.7	428.4	477.0	525.3
				Estimated Design Rainstorm	24	160.20	211.61	245.65	278.30	288.66	320.57	352.24
					48	198.63	262.42	304.66	345.17	358.02	397.61	436.91
					72	224.91	292.55	337.34	380.29	393.92	435.89	477.56
				Lower Confidence Limit	24	151.9	197.0	226.1	253.7	262.4	289.3	315.9
					48	188.3	244.3	280.3	314.6	325.5	358.8	391.8
					72	214.0	273.4	311.6	347.9	359.4	394.7	429.8
107	Sarawak	3152011	Lio Matu	Upper Confidence Limit	24	122.1	158.4	183.1	206.8	214.4	237.7	260.8
					48	160.1	204.6	234.7	263.8	273.0	301.5	329.9
					72	192.9	246.2	282.2	317.0	328.1	362.1	396.0

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	116.81	149.23	170.70	191.29	197.82	217.94	237.91
					48	153.68	193.35	219.61	244.80	252.80	277.41	301.85
					72	185.28	232.73	264.14	294.27	303.83	333.28	362.51
				Lower Confidence Limit	24	111.6	140.0	158.3	175.8	181.3	198.2	215.0
					48	147.3	182.1	204.5	225.8	232.5	253.3	273.8
					72	177.6	219.3	246.1	271.5	279.6	304.4	329.0
108	Sarawak	3234022	Labang	Upper Confidence Limit	24	145.1	190.7	221.6	251.3	260.8	290.0	319.0
					48	180.1	248.6	295.0	339.8	354.0	397.9	441.5
					72	211.0	296.8	354.9	410.9	428.7	483.6	538.2
				Estimated Design Rainstorm	24	138.50	179.14	206.06	231.87	240.06	265.29	290.33
					48	170.22	231.29	271.72	310.50	322.80	360.70	398.32
					72	198.65	275.11	325.72	374.28	389.68	437.12	484.22
				Lower Confidence Limit	24	131.9	167.6	190.6	212.4	219.3	240.6	261.6
					48	160.4	214.0	248.4	281.2	291.6	323.5	355.2
					72	186.3	253.4	296.6	337.7	350.6	390.6	430.2
109	Sarawak	3342032	Long Subing	Upper Confidence Limit	24	145.7	214.7	261.4	306.4	320.8	364.9	408.8
					48	189.0	285.0	350.0	412.7	432.7	494.1	555.2
					72	225.9	342.6	421.6	497.9	522.1	596.8	671.1
				Estimated Design Rainstorm	24	135.81	197.27	237.97	277.00	289.38	327.53	365.39
					48	175.22	260.77	317.41	371.75	388.98	442.07	494.77
					72	209.06	313.08	381.96	448.02	468.98	533.54	597.62
				Lower Confidence Limit	24	125.9	179.9	214.5	247.6	258.0	290.1	322.0
					48	161.4	236.5	284.8	330.8	345.3	390.0	434.3
					72	192.2	283.6	342.3	398.2	415.9	470.2	524.1
110	Sarawak	3347003	Long Akah	Upper Confidence Limit	24	146.2	185.1	211.5	237.0	245.1	270.1	294.9
					48	192.6	244.9	280.4	314.6	325.5	359.0	392.3
					72	235.5	297.7	339.9	380.6	393.5	433.4	473.0
				Estimated Design Rainstorm	24	140.57	175.31	198.31	220.37	227.37	248.93	270.33
					48	185.05	231.71	262.61	292.25	301.65	330.61	359.36
					72	226.53	282.02	318.77	354.01	365.19	399.63	433.82

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	135.0	165.5	185.1	203.7	209.6	227.8	245.8
					48	177.5	218.5	244.8	269.9	277.8	302.2	326.4
					72	217.6	266.3	297.6	327.4	336.9	365.9	394.6
111	Sarawak	3444018	Long Pilah	Upper Confidence Limit	24	150.0	191.9	220.3	247.6	256.3	283.2	309.8
					48	183.6	230.6	262.4	293.1	302.9	333.0	362.9
					72	214.9	263.3	296.1	327.7	337.7	368.7	399.5
				Estimated Design Rainstorm	24	143.95	181.29	206.02	229.73	237.26	260.43	283.44
					48	176.84	218.72	246.45	273.05	281.49	307.48	333.27
					72	207.92	251.06	279.62	307.02	315.71	342.48	369.06
				Lower Confidence Limit	24	137.9	170.7	191.8	211.8	218.2	237.7	257.1
					48	170.1	206.9	230.5	253.0	260.1	282.0	303.7
					72	201.0	238.8	263.2	286.4	293.7	316.2	338.6
112	Sarawak	3541033	Long Jegan	Upper Confidence Limit	24	137.0	185.7	218.7	250.5	260.6	291.8	322.8
					48	173.2	232.9	273.3	312.3	324.6	362.8	400.8
					72	210.2	276.9	322.1	365.6	379.5	422.2	464.7
				Estimated Design Rainstorm	24	130.04	173.43	202.16	229.72	238.47	265.40	292.13
					48	164.65	217.82	253.02	286.79	297.50	330.50	363.25
					72	200.57	260.03	299.39	337.15	349.13	386.03	422.66
				Lower Confidence Limit	24	123.0	161.1	185.6	208.9	216.3	239.0	261.5
					48	156.1	202.8	232.8	261.3	270.4	298.1	325.7
					72	191.0	243.2	276.7	308.7	318.8	349.9	380.7
113	Sarawak	3737045	Sungai Lebai	Upper Confidence Limit	24	99.6	135.3	159.4	182.7	190.1	212.9	235.6
					48	123.5	162.5	188.9	214.4	222.5	247.5	272.3
					72	145.2	186.0	213.6	240.3	248.8	274.9	300.9
				Estimated Design Rainstorm	24	94.47	126.25	147.29	167.47	173.87	193.59	213.17
					48	117.87	152.64	175.66	197.75	204.75	226.34	247.76
					72	139.28	175.66	199.75	222.85	230.18	252.76	275.17
				Lower Confidence Limit	24	89.3	117.2	135.2	152.2	157.6	174.3	190.7
					48	112.2	142.8	162.4	181.1	187.0	205.2	223.2
					72	133.4	165.4	185.9	205.4	211.6	230.6	249.5

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
114	Sarawak	3842034	Long Teru	Upper Confidence Limit	24	129.8	171.0	199.0	225.9	234.5	260.9	287.1
					48	152.7	195.2	224.0	251.8	260.6	287.8	314.9
					72	174.1	216.3	244.8	272.4	281.1	308.1	334.9
				Estimated Design Rainstorm	24	123.87	160.62	184.95	208.29	215.69	238.50	261.14
					48	146.62	184.50	209.58	233.64	241.27	264.78	288.12
					72	168.03	205.61	230.49	254.36	261.93	285.25	308.40
				Lower Confidence Limit	24	117.9	150.2	170.9	190.7	196.9	216.1	235.2
					48	140.5	173.8	195.1	215.5	221.9	241.7	261.4
					72	162.0	195.0	216.2	236.4	242.7	262.4	281.8
115	Sarawak	3847035	Long Atip	Upper Confidence Limit	24	158.0	211.4	247.5	282.4	293.5	327.7	361.7
					48	181.4	235.3	271.9	307.1	318.3	352.9	387.2
					72	214.6	288.1	337.8	385.8	401.1	448.1	494.9
				Estimated Design Rainstorm	24	150.28	197.88	229.39	259.62	269.21	298.75	328.08
					48	173.59	221.68	253.52	284.07	293.75	323.60	353.23
					72	204.05	269.53	312.88	354.47	367.66	408.30	448.63
				Lower Confidence Limit	24	142.6	184.4	211.3	236.8	244.9	269.8	294.4
					48	165.8	208.1	235.2	261.0	269.2	294.3	319.3
					72	193.5	251.0	287.9	323.1	334.2	368.5	402.4
116	Sarawak	3939051	Tangit	Upper Confidence Limit	24	116.8	148.6	170.2	191.0	197.6	218.0	238.3
					48	143.4	184.4	212.2	239.0	247.5	273.7	299.8
					72	163.9	216.7	252.4	286.9	297.8	331.6	365.2
				Estimated Design Rainstorm	24	112.17	140.56	159.36	177.40	183.12	200.74	218.23
					48	137.50	174.05	198.25	221.46	228.82	251.51	274.02
					72	156.30	203.34	234.48	264.35	273.82	303.01	331.99
				Lower Confidence Limit	24	107.6	132.5	148.5	163.8	168.6	183.5	198.2
					48	131.6	163.7	184.3	204.0	210.2	229.3	248.2
					72	148.7	190.0	216.6	241.8	249.8	274.4	298.8
117	Sarawak	3940036	Beluru	Upper Confidence Limit	24	121.5	161.2	188.1	214.1	222.3	247.7	273.0
					48	137.0	174.8	200.5	225.3	233.1	257.4	281.5
					72	149.8	193.4	222.9	251.4	260.4	288.3	316.1

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	115.78	151.18	174.62	197.10	204.23	226.20	248.00
					48	131.50	165.28	187.64	209.09	215.90	236.86	257.67
					72	143.57	182.41	208.13	232.79	240.62	264.72	288.64
				Lower Confidence Limit	24	110.1	141.2	161.1	180.1	186.2	204.7	223.0
					48	126.0	155.7	174.8	192.9	198.7	216.3	233.8
					72	137.3	171.4	193.3	214.2	220.8	241.1	261.2
118	Sarawak	3945017	Long Panai	Upper Confidence Limit	24	151.5	201.8	235.9	268.8	279.3	311.5	343.6
					48	191.9	250.8	290.8	329.3	341.5	379.3	416.8
					72	226.3	296.2	343.5	389.2	403.7	448.4	492.9
				Estimated Design Rainstorm	24	144.22	189.11	218.82	247.33	256.37	284.23	311.88
					48	183.40	235.95	270.74	304.12	314.71	347.32	379.69
					72	216.22	278.52	319.77	359.33	371.88	410.54	448.92
				Lower Confidence Limit	24	137.0	176.4	201.7	225.8	233.5	256.9	280.2
					48	174.9	221.1	250.7	278.9	287.9	315.3	342.6
					72	206.2	260.9	296.0	329.5	340.1	372.6	404.9
119	Sarawak	3950020	Long Seridan	Upper Confidence Limit	24	128.3	164.5	189.1	212.8	220.3	243.5	266.5
					48	163.7	208.4	238.7	268.0	277.3	305.9	334.4
					72	187.9	234.5	266.1	296.6	306.2	336.1	365.8
				Estimated Design Rainstorm	24	123.09	155.39	176.77	197.28	203.79	223.83	243.73
					48	157.24	197.13	223.54	248.88	256.91	281.67	306.24
					72	181.22	222.76	250.27	276.66	285.03	310.82	336.41
				Lower Confidence Limit	24	117.9	146.2	164.5	181.8	187.3	204.2	220.9
					48	150.8	185.8	208.3	229.8	236.5	257.4	278.1
					72	174.5	211.0	234.4	256.8	263.8	285.5	307.1
120	Sarawak	4038006	Bekenu	Upper Confidence Limit	24	141.5	189.0	221.1	252.1	261.9	292.3	322.4
					48	172.1	232.6	273.6	313.1	325.6	364.4	402.9
					72	198.9	273.2	323.6	372.1	387.6	435.2	482.5
				Estimated Design Rainstorm	24	134.71	176.98	204.96	231.80	240.32	266.55	292.59
					48	163.38	217.30	253.00	287.24	298.11	331.57	364.78
					72	188.23	254.48	298.34	340.41	353.75	394.86	435.67

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	127.9	165.0	188.8	211.6	218.7	240.8	262.7
					48	154.7	202.0	232.4	261.4	270.6	298.8	326.7
					72	177.5	235.7	273.1	308.7	319.9	354.6	388.9
121	Sarawak	4038054	Paya Selanyau	Upper Confidence Limit	24	160.8	209.7	242.9	274.9	285.1	316.4	347.6
					48	192.4	248.8	287.0	323.8	335.5	371.7	407.6
					72	214.2	275.8	317.6	357.8	370.6	410.1	449.3
				Estimated Design Rainstorm	24	153.72	197.37	226.26	253.99	262.78	289.87	316.75
					48	184.28	234.55	267.83	299.75	309.88	341.07	372.04
					72	205.32	260.25	296.62	331.51	342.57	376.66	410.50
				Lower Confidence Limit	24	146.7	185.0	209.6	233.1	240.5	263.3	285.9
					48	176.2	220.3	248.7	275.7	284.2	310.5	336.5
					72	196.4	244.7	275.7	305.2	314.5	343.2	371.7
122	Sarawak	4039019	Bukit Peninjau	Upper Confidence Limit	24	130.5	176.6	207.8	237.9	247.5	277.0	306.4
					48	157.7	208.9	243.5	276.9	287.5	320.3	352.8
					72	185.6	255.2	302.3	347.7	362.2	406.7	451.0
				Estimated Design Rainstorm	24	123.89	164.97	192.17	218.26	226.54	252.04	277.34
					48	150.38	195.96	226.14	255.09	264.27	292.56	320.64
					72	175.58	237.60	278.65	318.04	330.53	369.01	407.21
				Lower Confidence Limit	24	117.3	153.3	176.5	198.6	205.6	227.0	248.3
					48	143.0	183.1	208.8	233.3	241.0	264.8	288.4
					72	165.6	220.0	255.0	288.3	298.9	331.3	363.4
123	Sarawak	4143004	Marudi	Upper Confidence Limit	24	120.4	156.0	180.1	203.4	210.8	233.6	256.3
					48	147.6	193.1	224.0	253.8	263.2	292.4	321.4
					72	165.0	214.7	248.3	280.8	291.1	322.9	354.5
				Estimated Design Rainstorm	24	115.23	147.00	168.03	188.20	194.60	214.31	233.88
					48	141.01	181.62	208.52	234.31	242.50	267.71	292.73
					72	157.89	202.15	231.46	259.57	268.49	295.96	323.23
				Lower Confidence Limit	24	110.1	138.0	155.9	173.0	178.4	195.0	211.4
					48	134.4	170.1	193.0	214.9	221.8	243.0	264.0
					72	150.7	189.6	214.6	238.4	245.9	269.0	292.0

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
124	Sarawak	4151017	Long Napir	Upper Confidence Limit	24	103.7	126.3	141.6	156.3	161.0	175.5	189.9
					48	131.6	158.4	176.5	194.0	199.5	216.7	233.7
					72	153.3	188.7	212.7	235.9	243.2	265.9	288.5
				Estimated Design Rainstorm	24	100.43	120.57	133.90	146.69	150.75	163.24	175.65
					48	127.79	151.63	167.41	182.55	187.36	202.15	216.84
					72	148.21	179.79	200.69	220.75	227.11	246.70	266.15
				Lower Confidence Limit	24	97.2	114.9	126.2	137.0	140.5	151.0	161.4
					48	123.9	144.9	158.3	171.1	175.2	187.6	200.0
					72	143.1	170.8	188.7	205.6	211.0	227.5	243.8
125	Sarawak	4255006	Long Semado	Upper Confidence Limit	24	81.1	101.1	114.6	127.7	131.8	144.6	157.3
					48	100.7	121.1	135.0	148.3	152.6	165.6	178.7
					72	118.5	140.0	154.6	168.6	173.1	186.8	200.5
				Estimated Design Rainstorm	24	78.22	96.03	107.82	119.13	122.72	133.77	144.74
					48	97.71	115.94	128.00	139.58	143.25	154.56	165.79
					72	115.46	134.61	147.29	159.45	163.31	175.19	186.99
				Lower Confidence Limit	24	75.3	91.0	101.0	110.6	113.6	122.9	132.2
					48	94.8	110.8	121.1	130.8	133.9	143.5	152.9
					72	112.4	129.2	140.0	150.3	153.5	163.5	173.5
126	Sarawak	4339005	Miri Airport	Upper Confidence Limit	24	152.0	198.3	229.6	259.9	269.5	299.1	328.6
					48	182.7	238.9	276.9	313.6	325.3	361.3	397.0
					72	205.3	271.7	316.7	360.1	373.9	416.4	458.7
				Estimated Design Rainstorm	24	145.31	186.58	213.90	240.10	248.42	274.03	299.45
					48	174.63	224.70	257.85	289.64	299.73	330.80	361.64
					72	195.74	254.94	294.14	331.74	343.67	380.42	416.89
				Lower Confidence Limit	24	138.6	174.9	198.2	220.3	227.4	248.9	270.3
					48	166.5	210.5	238.8	265.7	274.2	300.3	326.3
					72	186.2	238.2	271.6	303.4	313.4	344.4	375.1
127	Sarawak	4440001	Lutong	Upper Confidence Limit	24	177.0	234.9	274.2	312.0	324.0	361.1	397.9
					48	207.5	268.6	310.0	349.9	362.6	401.8	440.7
					72	230.3	294.8	338.5	380.6	393.9	435.2	476.3

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	168.70	220.31	254.49	287.26	297.66	329.69	361.48
					48	198.67	253.15	289.23	323.83	334.80	368.61	402.17
					72	221.05	278.51	316.55	353.04	364.62	400.27	435.67
				Lower Confidence Limit	24	160.4	205.7	234.8	262.5	271.3	298.3	325.0
					48	189.9	237.7	268.5	297.7	307.0	335.5	363.7
					72	211.8	262.2	294.7	325.5	335.3	365.3	395.1
128	Sarawak	4440060	Miri DID Barrack	Upper Confidence Limit	24	146.8	187.6	215.2	241.8	250.3	276.4	302.3
					48	176.0	233.7	272.8	310.5	322.5	359.5	396.2
					72	195.2	259.2	302.6	344.5	357.8	398.8	439.6
				Estimated Design Rainstorm	24	140.92	177.26	201.32	224.40	231.73	254.28	276.67
					48	167.67	219.12	253.18	285.86	296.23	328.16	359.85
					72	185.92	243.04	280.86	317.13	328.64	364.08	399.27
				Lower Confidence Limit	24	135.0	167.0	187.5	207.0	213.2	232.2	251.0
					48	159.4	204.5	233.6	261.2	270.0	296.9	323.5
					72	176.7	226.9	259.1	289.8	299.5	329.3	358.9
129	Sarawak	4449012	Nanga Medamit	Upper Confidence Limit	24	136.9	166.8	187.1	206.6	212.8	232.0	251.0
					48	171.7	204.6	226.9	248.3	255.2	276.2	297.2
					72	199.7	242.5	271.5	299.4	308.3	335.7	363.0
				Estimated Design Rainstorm	24	132.58	159.24	176.90	193.83	199.20	215.75	232.17
					48	166.96	196.28	215.69	234.31	240.21	258.41	276.46
					72	193.50	231.66	256.92	281.15	288.84	312.52	336.02
				Lower Confidence Limit	24	128.3	151.7	166.7	181.1	185.6	199.5	213.3
					48	162.2	188.0	204.5	220.3	225.2	240.6	255.8
					72	187.3	220.8	242.4	262.9	269.4	289.3	309.1
130	Sarawak	4548004	Ukong	Upper Confidence Limit	24	136.6	172.6	197.0	220.6	228.1	251.1	274.1
					48	169.8	214.7	245.2	274.5	283.9	312.7	341.3
					72	199.5	256.2	294.5	331.6	343.3	379.6	415.7
				Estimated Design Rainstorm	24	131.40	163.53	184.80	205.20	211.67	231.60	251.39
					48	163.28	203.36	229.89	255.34	263.42	288.29	312.97
					72	191.34	241.84	275.28	307.36	317.53	348.88	379.99

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Lower Confidence Limit	24	126.2	154.4	172.6	189.8	195.3	212.1	228.7
					48	156.8	192.0	214.6	236.1	243.0	263.9	284.7
					72	183.2	227.5	256.0	283.2	291.7	318.1	344.3
131	Sarawak	4649025	Lubai Tengah	Upper Confidence Limit	24	146.6	193.2	224.8	255.3	265.0	294.9	324.6
					48	182.6	238.7	276.7	313.4	325.1	361.0	396.7
					72	211.3	267.8	306.0	342.9	354.6	390.8	426.7
				Estimated Design Rainstorm	24	139.83	181.42	208.95	235.37	243.75	269.55	295.17
					48	174.53	224.56	257.68	289.45	299.53	330.57	361.39
					72	203.17	253.51	286.83	318.80	328.94	360.17	391.18
				Lower Confidence Limit	24	133.1	169.6	193.1	215.4	222.5	244.3	265.8
					48	166.4	210.4	238.6	265.5	274.0	300.1	326.0
					72	195.0	239.2	267.6	294.7	303.2	329.5	355.6
132	Sarawak	4650007	Tegarai	Upper Confidence Limit	24	163.1	213.0	246.7	279.3	289.7	321.6	353.3
					48	213.3	275.2	317.2	357.6	370.5	410.1	449.6
					72	239.3	305.6	350.6	393.9	407.7	450.2	492.4
				Estimated Design Rainstorm	24	155.93	200.37	229.80	258.02	266.97	294.55	321.93
					48	204.36	259.57	296.11	331.17	342.30	376.55	410.56
					72	229.75	288.88	328.03	365.59	377.50	414.20	450.62
				Lower Confidence Limit	24	148.8	187.8	212.9	236.7	244.3	267.5	290.5
					48	195.4	243.9	275.1	304.7	314.1	343.0	371.6
					72	220.2	272.1	305.5	337.3	347.3	378.2	408.8
133	Sarawak	4650023	Pandaruan	Upper Confidence Limit	24	142.1	177.5	201.5	224.6	231.9	254.6	277.2
					48	178.7	217.6	243.9	269.2	277.3	302.2	326.9
					72	204.9	253.2	285.9	317.4	327.4	358.3	389.1
				Estimated Design Rainstorm	24	136.95	168.52	189.42	209.47	215.83	235.42	254.87
					48	173.14	207.75	230.67	252.65	259.62	281.10	302.42
					72	197.93	240.96	269.45	296.78	305.45	332.15	358.66
				Lower Confidence Limit	24	131.9	159.6	177.4	194.3	199.7	216.2	232.6
					48	167.6	197.9	217.5	236.1	242.0	260.0	278.0
					72	191.0	228.8	253.0	276.2	283.5	306.0	328.3

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
134	Sarawak	4749001	Limbang DID	Upper Confidence Limit	24	132.4	165.7	188.3	210.0	216.9	238.3	259.5
					48	160.6	196.7	221.2	244.8	252.3	275.5	298.5
					72	181.9	225.6	255.3	283.8	292.9	320.9	348.8
				Estimated Design Rainstorm	24	127.63	157.31	176.96	195.81	201.79	220.20	238.48
					48	155.35	187.59	208.93	229.40	235.89	255.90	275.75
					72	175.56	214.56	240.39	265.16	273.01	297.22	321.25
				Lower Confidence Limit	24	122.8	148.9	165.6	181.6	186.6	202.1	217.5
					48	150.1	178.5	196.6	214.0	219.4	236.3	253.0
					72	169.3	203.5	225.5	246.5	253.1	273.5	293.7
135	Sarawak	4752022	Trusan	Upper Confidence Limit	24	170.6	240.3	287.5	333.1	347.6	392.2	436.6
					48	221.7	313.6	375.8	435.9	454.9	513.8	572.3
					72	257.1	358.3	426.9	493.0	514.0	578.8	643.3
				Estimated Design Rainstorm	24	160.52	222.68	263.83	303.31	315.84	354.41	392.70
					48	208.46	290.37	344.60	396.62	413.12	463.95	514.41
					72	242.56	332.78	392.50	449.79	467.97	523.95	579.52
				Lower Confidence Limit	24	150.5	205.1	240.1	273.5	284.1	316.6	348.8
					48	195.2	267.2	313.4	357.4	371.3	414.1	456.5
					72	228.0	307.2	358.1	406.6	421.9	469.1	515.8
136	Sarawak	4852002	Sundar	Upper Confidence Limit	24	143.5	196.8	233.0	267.8	278.9	313.1	347.0
					48	177.2	239.1	281.0	321.5	334.3	374.0	413.4
					72	201.5	268.1	313.2	356.7	370.5	413.2	455.5
				Estimated Design Rainstorm	24	135.80	183.35	214.84	245.04	254.62	284.13	313.43
					48	168.30	223.48	260.01	295.06	306.17	340.42	374.41
					72	191.87	251.23	290.54	328.24	340.20	377.04	413.61
				Lower Confidence Limit	24	128.1	169.9	196.7	222.3	230.3	255.2	279.8
					48	159.4	207.8	239.0	268.6	278.0	306.8	335.4
					72	182.3	234.4	267.9	299.8	309.9	340.9	371.7
137	Sarawak	4854003	Samaha Estate	Upper Confidence Limit	24	133.8	177.2	206.5	234.9	243.9	271.6	299.2
					48	180.8	241.9	283.2	323.1	335.8	374.9	413.8
					72	210.2	278.0	324.0	368.3	382.4	425.9	469.1

No.	State	Station ID	Station Name	Analysis	Duration (hr)	Rainfall (mm)						
						2	5	10	20	25	50	100
				Estimated Design Rainstorm	24	127.56	166.21	191.80	216.35	224.14	248.12	271.93
					48	172.01	226.44	262.47	297.04	308.01	341.79	375.32
					72	200.40	260.89	300.94	339.35	351.54	389.08	426.34
				Lower Confidence Limit	24	121.3	155.3	177.1	197.8	204.4	224.6	244.6
					48	163.2	211.0	241.7	271.0	280.2	308.7	336.9
					72	190.6	243.8	277.9	310.4	320.7	352.3	383.6
138	Sarawak	4854009	Lawas Airfield	Upper Confidence Limit	24	158.1	204.8	236.3	266.8	276.5	306.4	336.0
					48	191.5	240.2	273.1	305.0	315.1	346.3	377.3
					72	214.4	266.5	301.9	336.0	346.8	380.2	413.5
				Estimated Design Rainstorm	24	151.42	192.99	220.50	246.90	255.27	281.07	306.67
					48	184.45	227.86	256.60	284.17	292.92	319.85	346.60
					72	206.85	253.36	284.16	313.70	323.07	351.94	380.59
				Lower Confidence Limit	24	144.7	181.2	204.7	227.0	234.1	255.8	277.3
					48	177.4	215.6	240.1	263.4	270.8	293.4	315.9
					72	199.3	240.2	266.4	291.4	299.3	323.6	347.7
139	Sarawak	4955021	Merapok	Upper Confidence Limit	24	164.3	201.6	226.8	251.2	258.9	282.8	306.5
					48	205.7	262.1	300.4	337.2	349.0	385.1	421.0
					72	228.1	287.6	327.8	366.7	379.0	417.1	454.9
				Estimated Design Rainstorm	24	158.94	192.17	214.17	235.27	241.96	262.58	283.05
					48	197.55	247.86	281.17	313.13	323.26	354.49	385.48
					72	219.56	272.54	307.62	341.27	351.95	384.83	417.47
				Lower Confidence Limit	24	153.6	182.8	201.5	219.4	225.0	242.4	259.6
					48	189.4	233.6	262.0	289.0	297.6	323.9	349.9
					72	211.0	257.5	287.4	315.9	324.9	352.6	380.0

APPENDIX D: TEMPORAL STORM PROFILES BLOCK DIAGRAM

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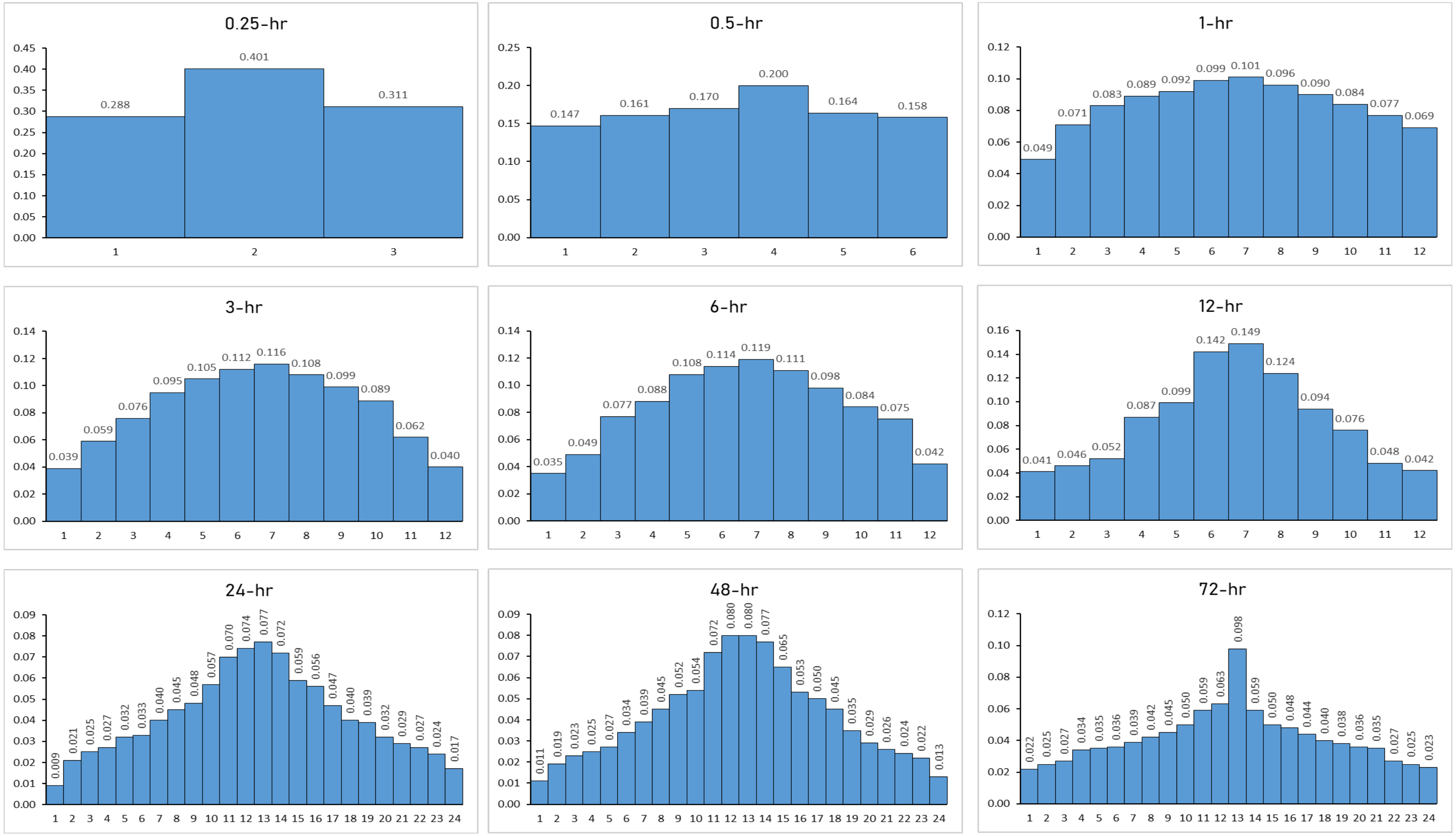

Figure D1: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 1

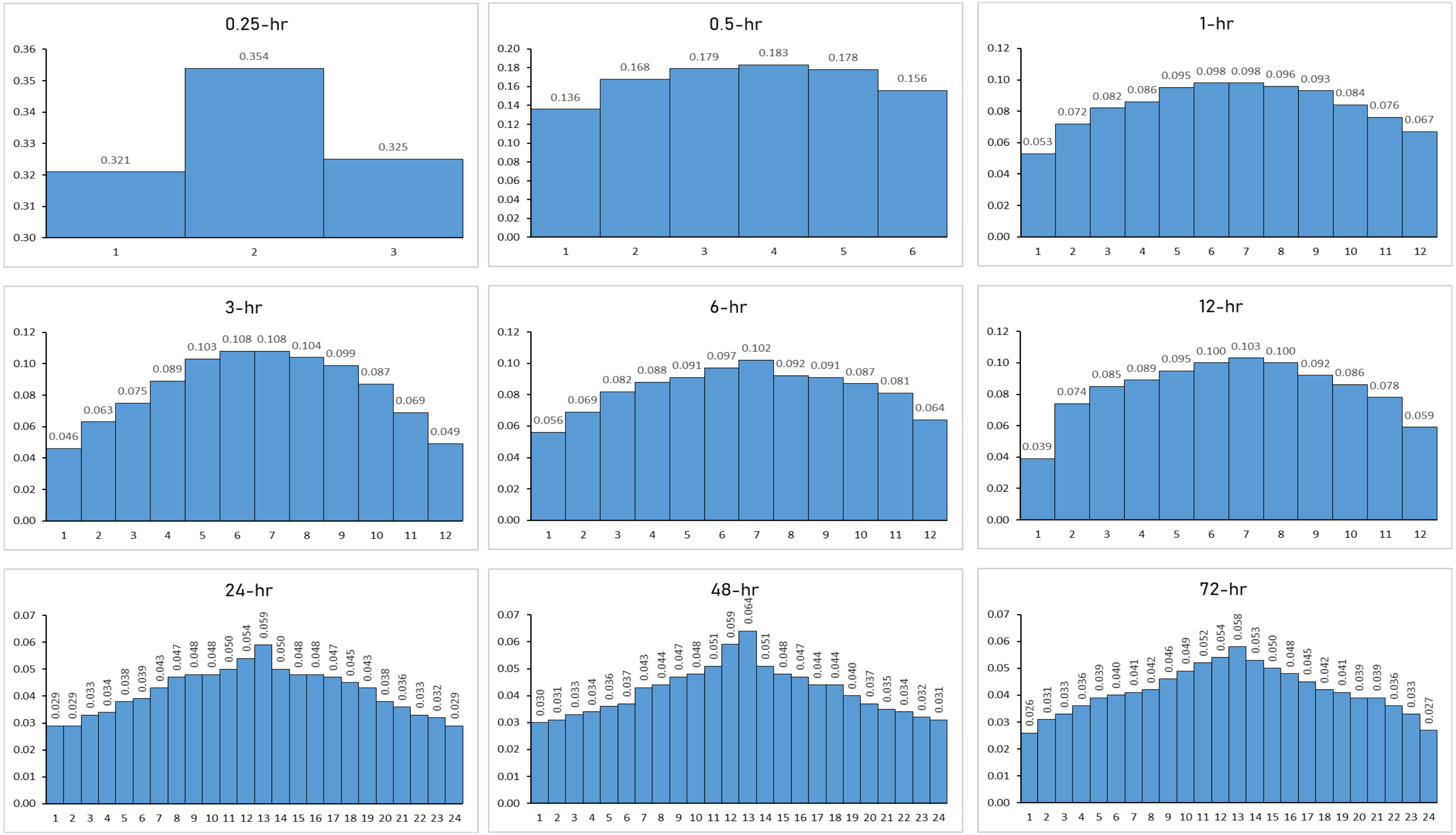

Figure D2: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 2.

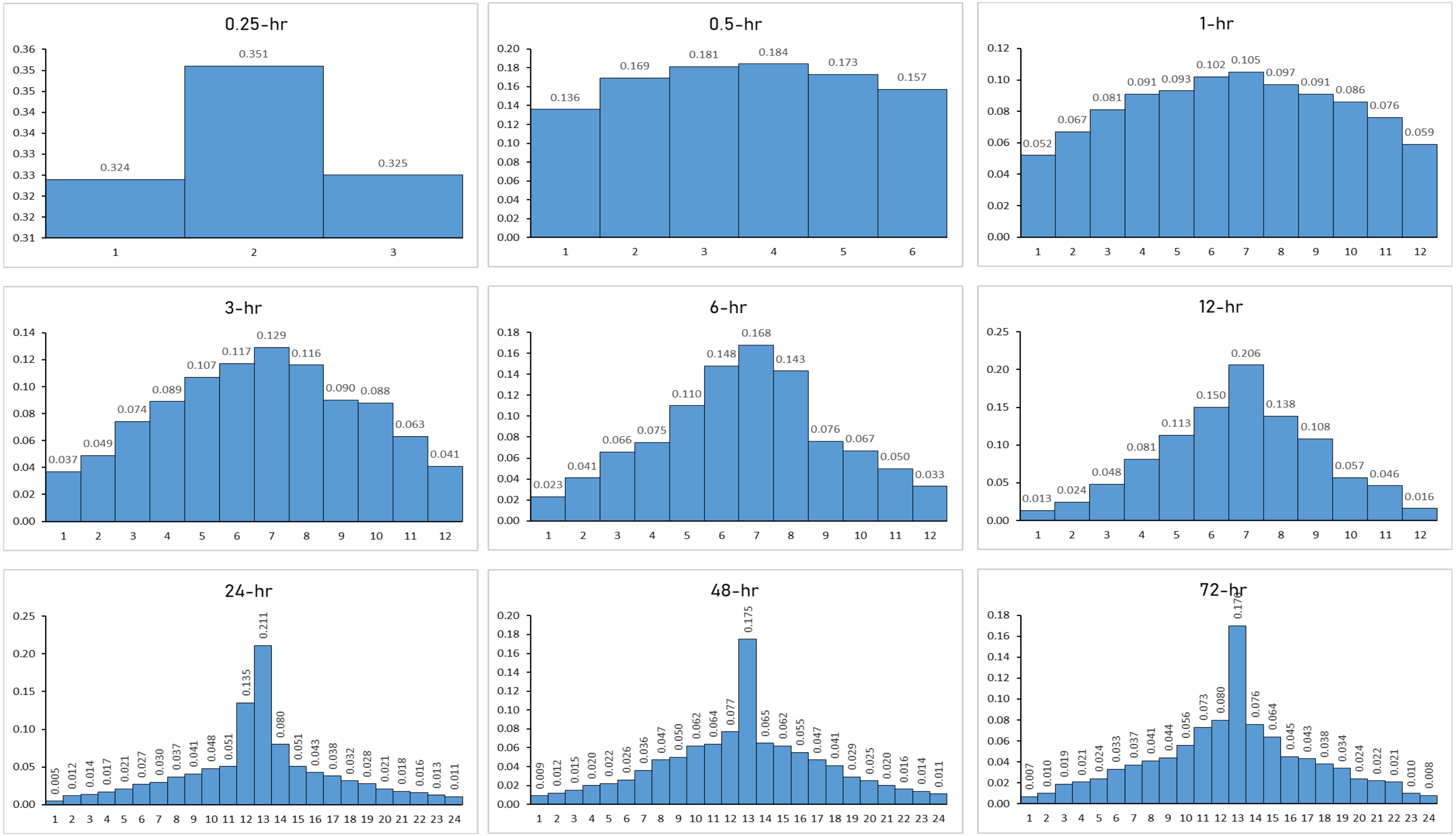

Figure D3: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 3.

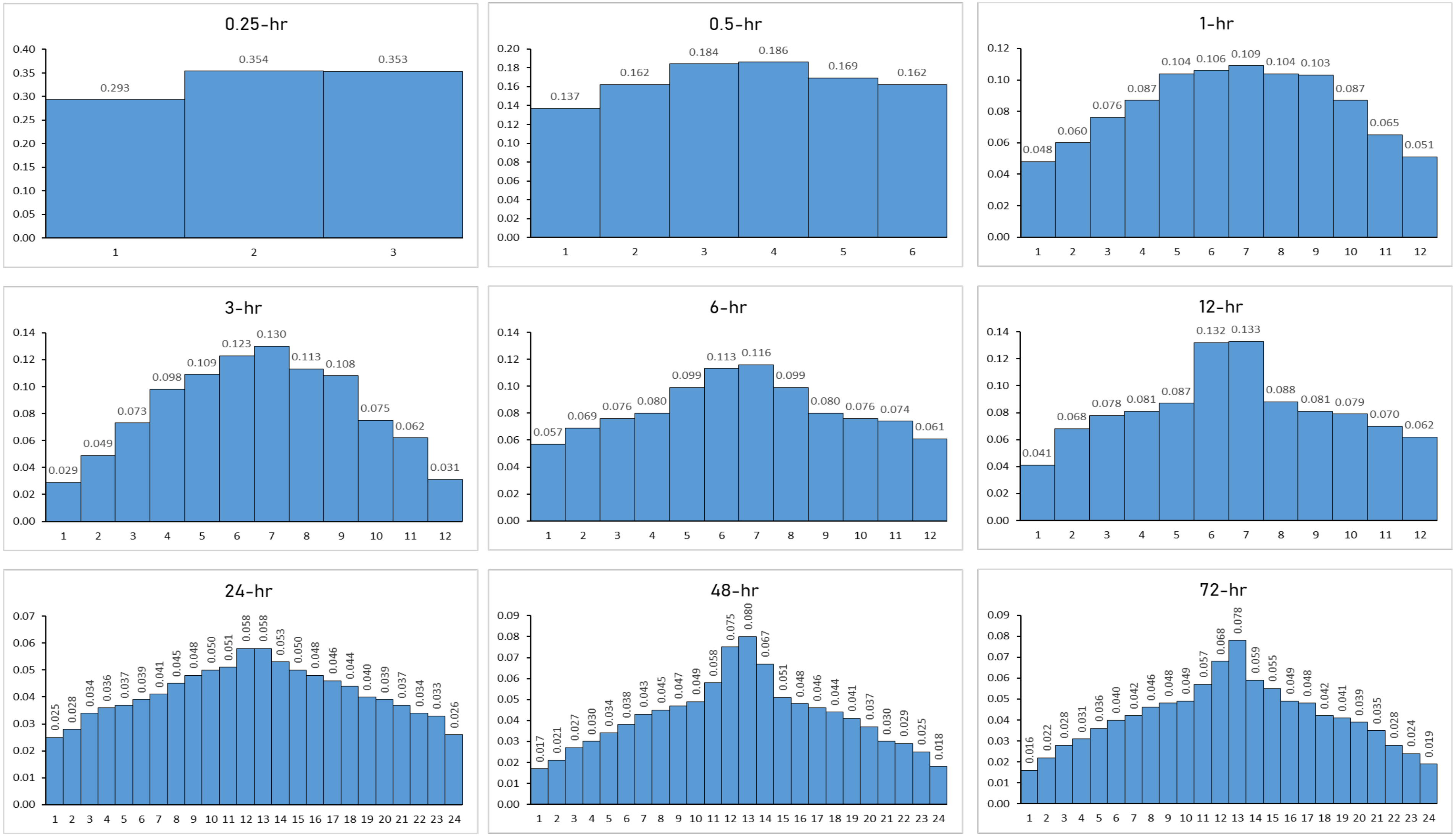

Figure D4: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 4.

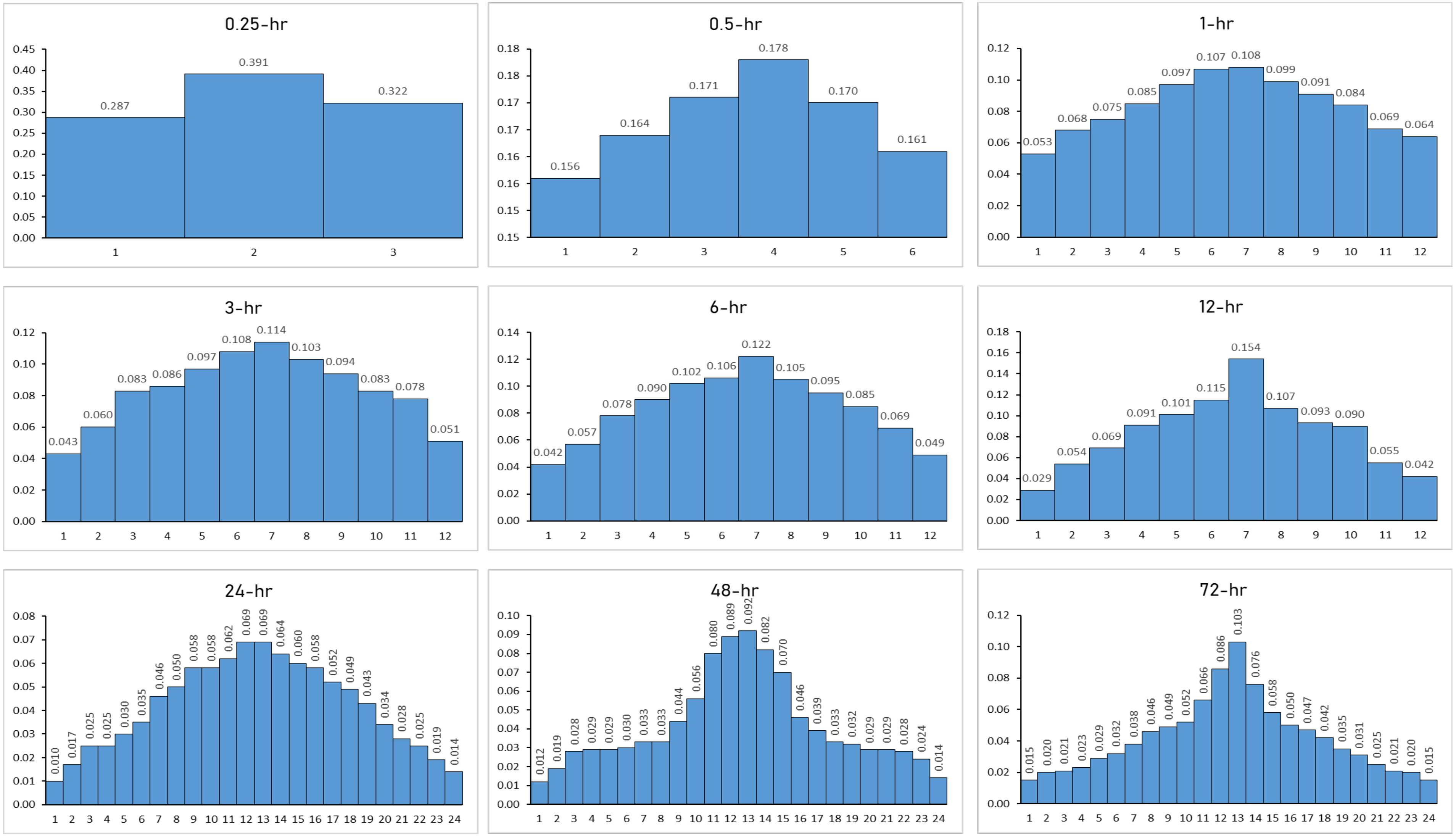

Figure D5: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 5.

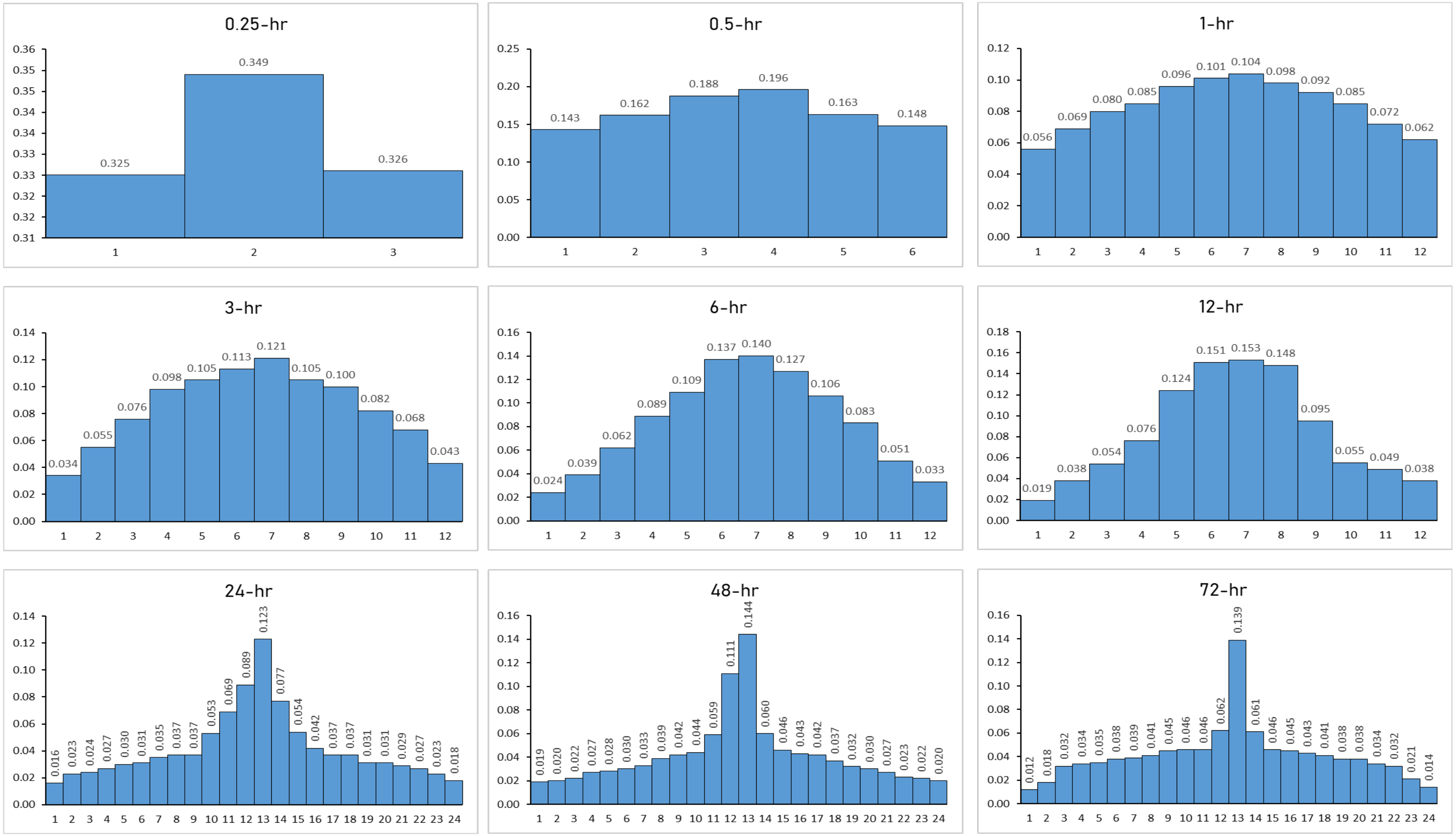

Figure D6: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 6.

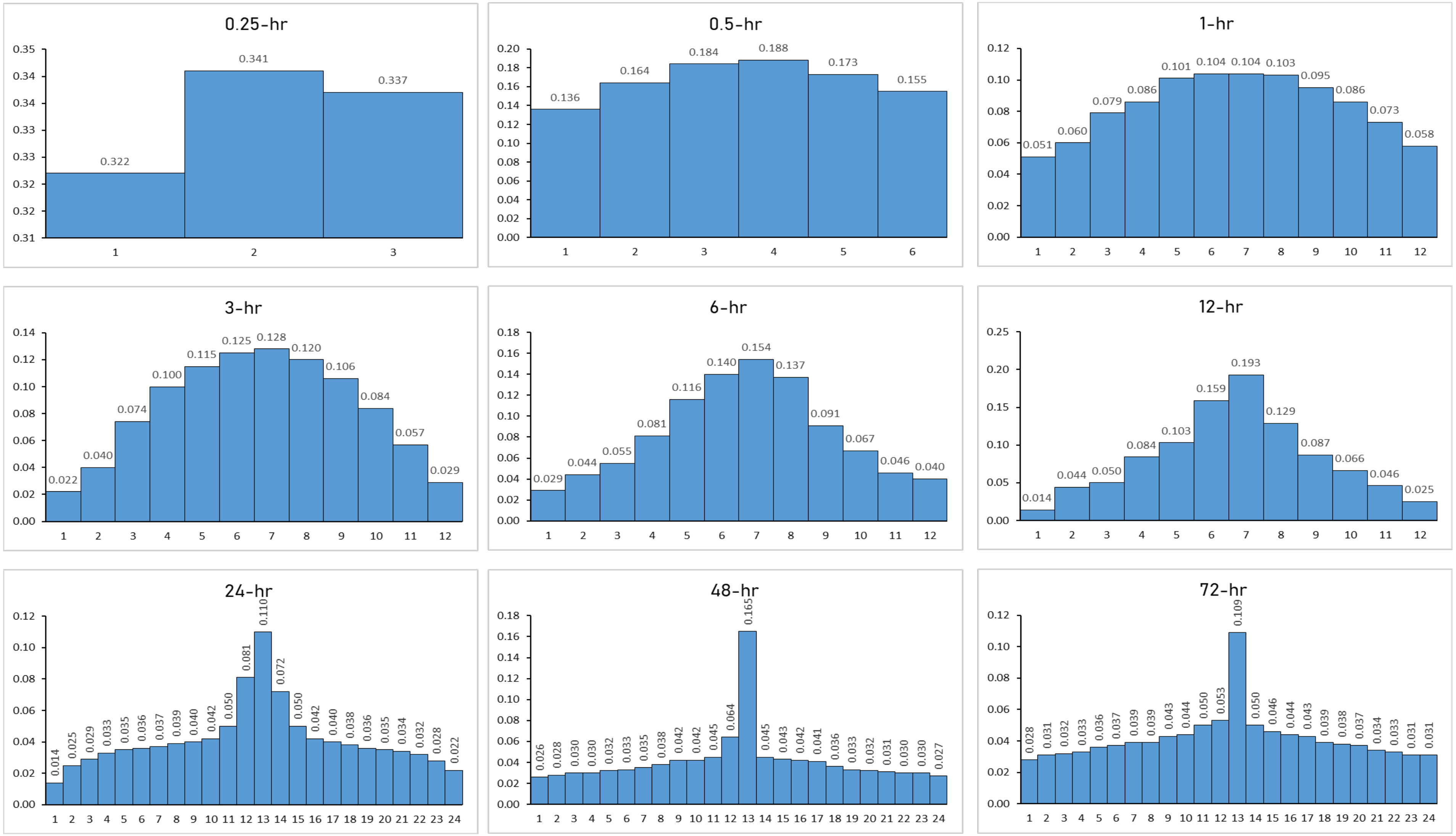

Figure D7: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 7.

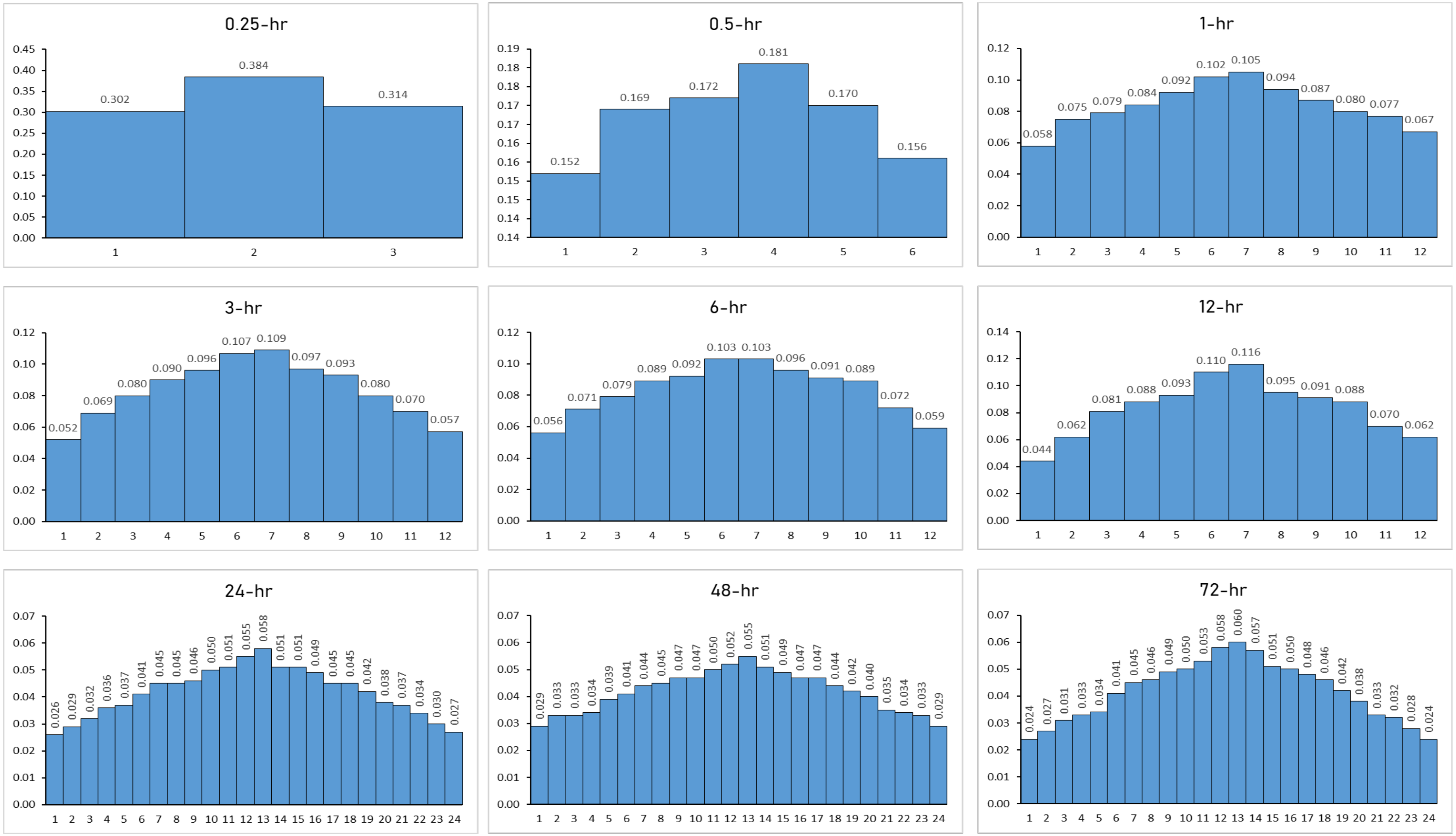

Figure D8: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 8.

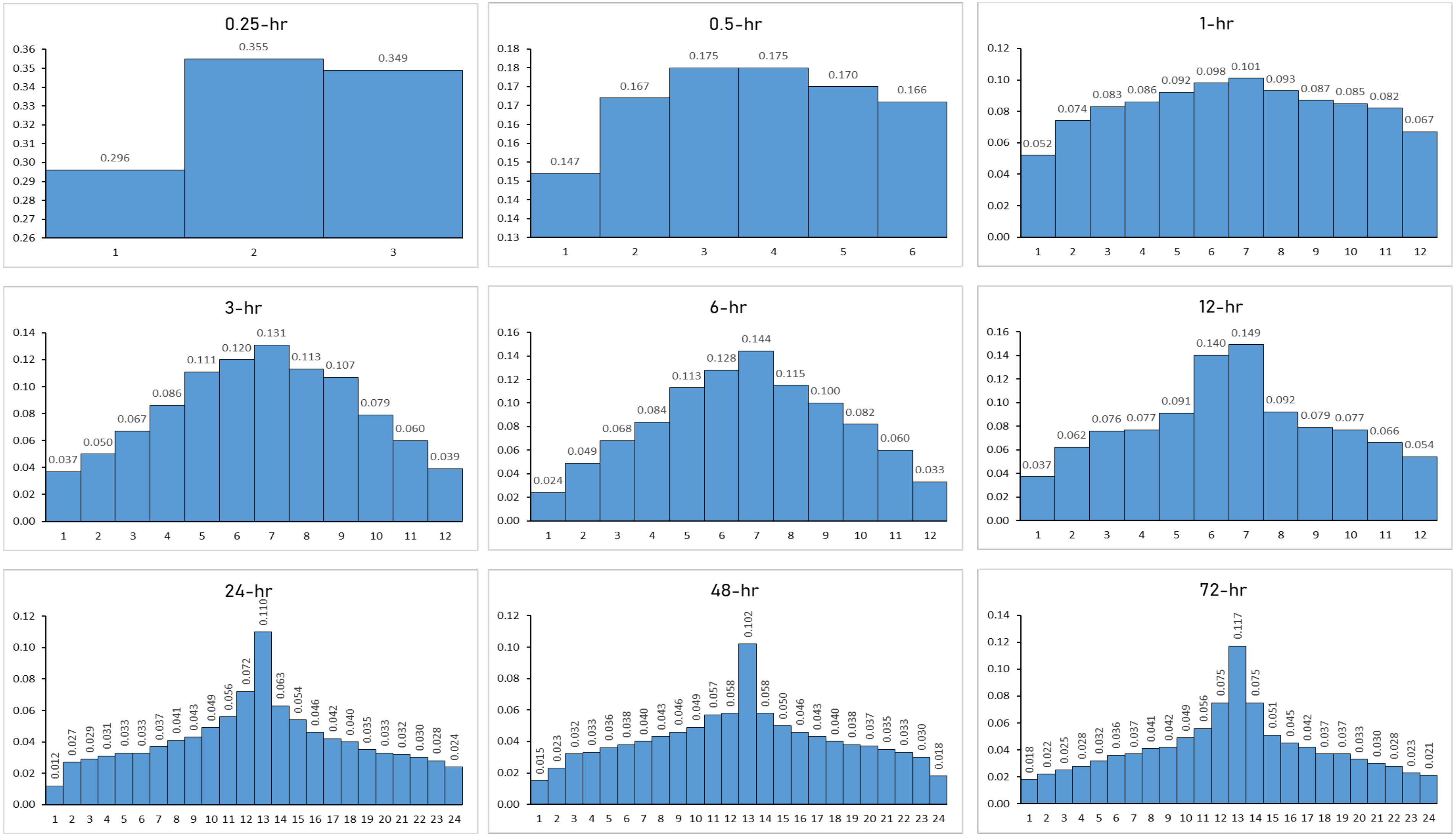

Figure D9: Block Diagram of Normalized Temporal Storm Profile Corresponding with Storm Duration (0.25 to 72-hr) for Region 9.

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