Journal of Spatial Hydrology
Vol.4, No.1 Spring 2004

GENERALISED LONG DURATION PROBABLE MAXIMUM PRECIPITATION (PMP) ISOHYETAL MAP FOR PENINSULAR MALAYSIA

Abdullah Al-Mamun and Alias Hashim
Jurutera Perunding Zaaba, 17 Jalan Daud, Kg. Baru, 50300 Kuala Lumpur, Malaysia.

ABSTRACT

Isohyetal maps were prepared to estimate Probable Maximum Precipitation (PMP) for long duration storms in Peninsular Malaysia. Historical storms of 1, 3 and 5-day durations from 21 rainfall recording stations operated by Malaysian Meteorological Service (MMS) were identified and analysed to calculate the PMP vales. Maximum rainfall for 1, 3 and 5-day storms in the Peninsula were recorded as 809, 1272.9 and 1494 mm, respectively. The widely used and most reliable hydrometeorological method was used to derive and transpose the PMP values from the storm locations to all MMS stations in the Peninsula. Maximum transposed PMP for a particular duration was obtained for six selected historical storms.

Rectified Skew Orthomorphic (RSO) coordinates of the rainfall stations and point PMP values were used for the Kriging method to generate the PMP envelop curves. The enveloping isohyetal lines were further adjusted and smoothen to consider the effect of topographical and geographical effect on the PMP values. Calculated point PMP values for 1, 3 and 5-day storms can, respectively, be as high as 1149, 1808 and 2121 mm in West Malaysia. These isohyetal maps shall give direct and fast estimate for PMP values even for the catchments where no rainfall gauging stations are available. However, results obtained in this study is applicable for the catchments located at elevation lower than 200 m mean sea level (MSL), and until any storm larger than the selected (in this study) occur in Peninsular Malaysia.

Keywords: Probable Maximum Precipitation (PMP), Storm Duration, Storm Maximisation, Historical Rainfall, Transposition and Isohyetal Map.

INTRODUCTION

The use of probable maximum precipitation (PMP) to design high risk/hazard water resources or hydraulic structures is a century old technique. Unavailability of long-term and reliable discharge data at the proposed dam or water reservoir structure results in more dependency on rainfall data. As such, it is of utmost importance that the procedure to estimate probable maximum flood (PMF) at the proposed structure. Ideally a hydrologist would like to calculate design storms with no risk of failure. In doing such, the common problem encountered is to identify the upper limit of rainfall amount for a particular storm duration. Scientists and hydrologists agreed to mathematically and physically quantify the limit of maximum rainfall for a particular region by the term PMP, which is defined as, "theoretically the greatest depth of precipitation for a given duration that is physically or meteorically possible over a given station or area at a particular geographical location at a certain time of year" (Hansen et al., 1982; WMO, 1986).

Considerable amount of input in terms of data, experiences and resources are required to derive PMP values for any hydraulic structure, which pose potential hazards to the downstream areas. Like many of the countries, PMP studies in Malaysia are carried out for individual projects. As different methodology can be used to calculate PMP values, wide range of variability was observed even for the PMP derived for nearby catchments of identical environment. Apart from that, essential data required to carry out the exercise are not adequately available for some catchments, which are located in the remote areas.

Long-term studies and research on PMP had been carried out in the USA and Australia. Periodical upgrading of local and generalised PMP Manuals and Guidelines took place in the form of Hydrometeorological Report (HMR) in the USA and as Bulletin in Australia. The latest hydrometeoroligcal report published by the US Department of Commerce is HMR 59 (Corrigan et. al., 1999) for California in 1999. Meanwhile Australian Bureau of Meteorology (BOM) has amended Bulletin 53 for generalised PMP in 1994. These publications contain detailed step-by step procedures to calculate PMP including the basic philosophy of PMP.

HMR 36 in the USA used a mass conservation model as a tool to estimate general storm PMP in topographic regions but was not able to account for local convergence, convection and synergistic effects caused by natural upper level seeding of low-level clouds in orographic regions (Hobbs, 1989). Until now no numerical model of atmospheric processes can completely replicate orographic precipitation, especially quantitative amounts in a reliable manner for the extreme storms (Katzfey 1995).

Collier and Hardaker (1996) estimated PMP values for the UK using convective storm model which considered solar heating, orographic uplift and meso-scale convergence as main process of the model. Commercial software are also available (e.g. BOSS HMR 52) to compute PMP for selected regions in the USA. Unfortunately the above-mentioned publications and models are not directly applicable for tropical regions such as Malaysia.

Few Hydrological Procedures (HP) for the design rainfall depth, duration, frequency, etc. are available from the Department of Irrigation and Drainage (DID) Malaysia. However, no study was carried out so far to develop any HP that could provide easy, reliable and quick information on the PMP values in Malaysia. A localised study on the statistical estimation of PMP (Harshfield Method) was carried out by Desa et. al. (2001) for the State of Selangor. In such a situation there was always a need to develop generalised PMP isohyetal map for Malaysia. Realising this need, the objective of this study was to develop isohyetal PMP maps for long duration rainfall, mainly to overcome the problem of inadequate information and to facilitate quick estimation of PMP values for ungauged catchments in the Peninsula.

WORK METHODOLOGY

The most common methods used to derive PMP are storm maximisation (hydrometeorological) approach (WMO, 1973) and statistical approach – Harshfield method (WMO, 1986). Storm maximisation and transposition method requires more site-specific data and thus provides more reliable estimate than other methods. Where site-specific data are not available statistical (Harshfield) method can be applied that requires data for annual maximum rainfall series in the region for required storm durations. Factors that influence calculations of PMP values are rainfall records of intended storm durations, temperature, relative humidity, altitude, wind direction, dew point temperature, etc.

Long records of meteorological data are available from twenty one (21) principle automatic raingauge stations operated by Malaysian Meteorological Service (MMS). Physical information of these stations, including the selected historical storms used in the study, is given in Table 1. Due to quite different nature of location, data from the stations in the Cameron Highland was not considered for storm maximisation and transposition. Data required for storm maximisation method to calculate PMP are either readily available or can be calculated from the information available at these stations. Thus, storm maximisation, transposition and then enveloping approach was followed to calculate PMP in this study. This approach follows the natural storm mechanisms. However, the detailed theoretical and mathematical backgrounds of the storm mechanisms are not discussed in this paper. For storm maximisation, it is assumed that rainfall can be determined from the product of available moisture and storm mechanism. The record of historical storms is sufficiently large so that an optimum storm mechanism has been released. Areal reduction factor for the storms were ignored due to the possibility that the rainfall station might not have recorded the maximum intensity during the storm. Meaning that the station may not be always recording the rainfall intensity of the storm centre, at which rain intensity is higher than the surrounding areas.

There was chance that condition of maximum possible moisture availability may not prevail during a historical storm event and more precipitation might have occurred if the maximum moistures were available during the event. Mathematically it has been proven that rainfall is closely proportional to the moisture charge in the atmosphere at the time of storm. As such, the lack of sufficient storm data at individual locations is compensated for by storm transposition to achieve the level of PMP. Storm moisture maximisation factor was determined using the surface dew point temperature, in conjunction with an assumed saturated atmosphere above surface level. Surface dew point was used as a measure of moisture potential for severe storms because it is the critical factor for severe storm development in small areas. Maximum dew point for any location is chosen as the highest value persisting for 12-hour duration. It is believed that this time period is more representative for inflow of moisture necessary to generate historical storms, as well as reducing the error of instantaneous observations. However, the dew point temperatures are not readily available from MMS stations.

Knowing mean air temperature and mean relative humidity, these values are calculated from Equation 1.

$$T_m - T_d = 21.7 - 22(RH) \qquad \text{for } 0.70 < RH < 0.98 \qquad (1)$$

where, T_m and T_d are mean air and dew point temperature (^oC) and RH is the mean relative humidity in percentage (%).

Table 1: Information on the MMS Stations and Selected Historical Storms in the West Malaysia

<table>
<tr><th rowspan="2">Station No</th><th rowspan="2">Station Name</th><th rowspan="2">Elevation (m, MSL)</th><th colspan="5">Selected Historical Storms
Rainfalls are in mm</th></tr>
<tr><th>Location</th><th>Date</th><th>1 day</th><th>3 day</th><th>5 day</th></tr>
<tr><td>48600</td><td>Langkawi Airport</td><td>6.4</td><td rowspan="2">Air Tawar, Johor</td><td rowspan="2">29 Dec. 1970 to 3 Jan. 1971</td><td rowspan="2">488.0</td><td rowspan="2">1025.0</td><td rowspan="2">1453.0</td></tr>
<tr><td>48601</td><td>Penang Airport</td><td>2.8</td></tr>
<tr><td>48602</td><td>Butterworth Airport</td><td>2.8</td><td rowspan="2">Mersing, Johor</td><td rowspan="2">29 Dec. 1970 to 3 Jan. 1971</td><td rowspan="2">430.0</td><td rowspan="2">878.0</td><td rowspan="2">1203.0</td></tr>
<tr><td>48603</td><td>Alor Setar Airport</td><td>3.9</td></tr>
<tr><td>48604</td><td>Chuping, Perlis</td><td>21.7</td><td rowspan="2">Kuantan, Pahang</td><td rowspan="2">7 to 10 Dec. 1971</td><td rowspan="2">495.0</td><td rowspan="2">729.7</td><td rowspan="2">1100.0</td></tr>
<tr><td>48615</td><td>Kota Bharu Airport</td><td>4.6</td></tr>
<tr><td>48616</td><td>Kuala Kerai, Terengganu</td><td>68.3</td><td rowspan="2">Kota Bahru</td><td rowspan="2">30 Nov. to 4 Dec. 1981</td><td rowspan="2">809.0</td><td rowspan="2">1272.9</td><td rowspan="2">1471.0</td></tr>
<tr><td>48619</td><td>Kajiklim K. Terengganu</td><td>35.1</td></tr>
<tr><td>48620</td><td>Setiawan, Perak</td><td>7.0</td><td rowspan="2">Kuala Kertih</td><td rowspan="2">2 to 6 Dec. 1983</td><td rowspan="2">523.0</td><td rowspan="2">1170.0</td><td rowspan="2">1300.0</td></tr>
<tr><td>48625</td><td>Ipoh Airport</td><td>40.1</td></tr>
<tr><td>48632</td><td>Cameroon Highland</td><td>1545</td><td rowspan="2">Kajiklim K. Terengganu</td><td rowspan="2">26 to 30 Nov. 1986</td><td rowspan="2">500.5</td><td rowspan="2">1033.8</td><td rowspan="2">1494.0</td></tr>
<tr><td>48642</td><td>Batu Embun, Pahang</td><td>59.5</td></tr>
<tr><td>48647</td><td>Subang Airport</td><td>16.5</td><td rowspan="9" colspan="5">Bold and Italic values are the recorded highest rainfall of respective storm duration</td></tr>
<tr><td>48648</td><td>Petaling Jaya</td><td>45.7</td></tr>
<tr><td>48649</td><td>Muadzam Shah, Pahang</td><td>33.3</td></tr>
<tr><td>48653</td><td>Temerloh, Pahang</td><td>39.1</td></tr>
<tr><td>48657</td><td>Kuantan Airport</td><td>15.3</td></tr>
<tr><td>48665</td><td>Malacca Airport</td><td>8.5</td></tr>
<tr><td>48672</td><td>Kluang, Johor</td><td>88.1</td></tr>
<tr><td>48674</td><td>Mersing, Johor</td><td>43.6</td></tr>
<tr><td>48679</td><td>Johor Bahru Airport</td><td>37.8</td></tr>
</table>

The calculated dew point temperatures at the MMS stations during all storm events and maximum 12 hour persisting condition were reduced to equivalent mean sea level (MSL, i.e. 1000 millibars air pressure) dew point temperatures, using Figure 1. The moisture maximisation factor was calculated as the ratio of maximum precipitable water at the station to water available during the storm, based on associated dew point temperatures and a saturated atmosphere (as given in Equation 2). Precipitable water (in mm) between 1000 mb surface level and station height above that surface in a saturated pseudo-adiabatic atmosphere was determined from Table 2. It is assumed that cloud top height in the region is 12,000 m (200 mb air pressure) from the mean sea level. Table 1 reveales that all of the MMS stations are located at elevations lower than the available information for minimum height of 200 m, as in Table 2. Thus, due adjustment and assumptions were considered to calculate the precipitable water at the stations.

$$F_m = (W_{pm} / W_{ps}) \qquad (2)$$

where, F_m is the moisture maximisation factor, W_{pm} is precipitable water at maximum dew point temperature and W_{ps} is precipitable water at dew point temperature during storm.

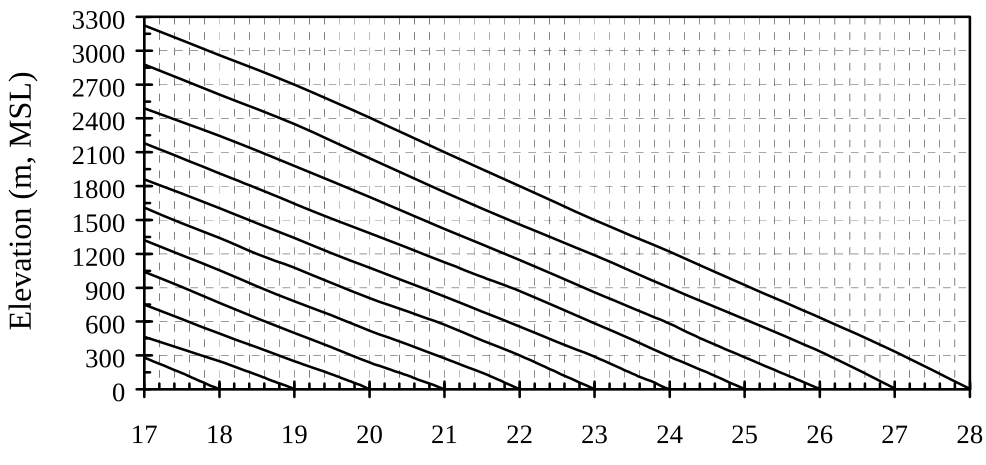

Figure 1: Pseudo-adiabatic Chart for Equivalent Dewpoint Conversion at MSL (1000 mb atms. pressure).

Table 2: Precipitable Water (in mm) as a Function of 1,000 mb Dew Point Temperature (°C)

Height (m)	Precipitable Water (in mm) at 1,000 mb Level for Equivalent Dew Point Temperature of														
	16	17	18	29	20	21	22	23	24	25	26	27	28	29	30
200	3	3	3	3	3	4	4	4	4	4	5	5	5	6	6
12,000#	37	40	44	48	52	57	63	68	74	81	88	96	105	114	123

assumed altitude of the cloud surface.

The selected storms were then transposed to other stations knowing that geographic and meteorological characteristics shall differ, to some extent, from the actual storm locations. There are debates whether it is logical to transpose storms from east to west coast of Peninsular Malaysia. In a technical note on this issue, MMS meteorologists also agree that there is a remote chance of shifting of storms from east to inland and west coast of the Peninsula. Identifying the record of severe storm during the same period in January, 1971 in Kuala Lumpur (in the west coast) and Mersing (in the east coast), it was decided logical and safe to transpose storms from east coast to the inland and west coast regions. A few of the PMP studies were carried out by the Australian experts where the possibility of transposing storms from any part of the Southeast Asian region was not ruled out. As such, implicit transposition was done identifying the location and atmospheric process of the storms. Meteorological records were then analysed and surrounding terrain features examined to identify similar regions where the storms could reasonably be transposed. As such, limits of transposition were established and storm transposition factor was determined from Equation 3.

$$F_t = (W_{pt} / W_{pm}) \qquad (3)$$

where, F_t is the storm transposition factor, W_{pm} is precipitable water at maximum dew point temperature at storm location and W_{pt} is precipitable water at maximum dew point temperature at transposed location during the storm.

The transposition factors were further adjusted (to F_{at}) based on the pattern of northeast and southwest monsoon, mean annual rainfall, 5 day maximum rainfall, and inflow barrier between the storm and transposed locations. Probable maximum precipitation (PMP) for any particular location and storm duration was calculated from Equation (4).

$$PMP = P_o F_m F_{at} \qquad (4)$$

where, P_o observed precipitation (mm).

Finally, Kriging method was used to develop the isohyetal contour lines of PMP and regional smoothing was done to take into consideration of regional variation in atmospheric parameters in the Peninsular Malaysia. The isohyetal PMP maps for 1, 3 and 5 day durations are shown in Figure 2, 3 and 4, respectively.

RESULTS AND DISCUSSIONS

The long duration historical storms of high rainfall mainly occurred in the east coast of the peninsula due to the effect of northeast monsoon ranging from November to January. The selected storms include at Mersing and Air Tawar in December 1970, at Kuantan in December 1971, at Kota Bahru in December 1981, at Kuala Kertih in December 1983 and at Kuala Terengganu in November 1986 (Table 1). Maximum 1, 3 and 5-day storms recorded in the Peninsula were 809, 1272.9 and 1494 mm, respectively. It was observed that dew point temperatures during the historical storms and the maximum 12 hour persisting condition for the MMS stations varied within 22-23 and 26-27 ^{o}C, respectively. Storm maximisation and transposition methods, as described above, produced different effects at the MMS stations. The maximum and minimum moisture adjustment factors were 1.70 at Alor Setar and 1.36 at Keluang, respectively. Similarly, maximum and minimum adjusted transposition factors were 0.92 at Mersing and Kota Bharu, and 0.62 at Alor Setar, respectively. The lowest combined factor (0.41) was observed for the MMS stations at Cameron Highland. Due to quite different nature of location these stations were ignored for PMP regionalisation process. It was understood that stations at Chuping, Alor Setar, Butterworth, Ipoh and Kuala Kerai will have the transposition effect from Kota Bahru storm. On the other hand remaining stations were given transposition effect from Mersing and Air Tawar storms. Computed maximum point PMP values of 1, 3 and 5 day durations in the Peninsular Malaysia would be 1149, 1808 and 2121 mm (Table 3).

As listed in Table 1, all historical storms occurred during the monsoon period (from November to January). From the PMP isohyetal maps (Figure 2,3 and 4) it was observed that the states of Terengganu (at northeast coast) and Johor (at southeast coast) would experience high PMP values due to direct influence of northeast monsoon. On the other hand states of Selangor (where the Capital of Malaysia is located), Negeri Sembilan, Perlis and Kedah would experience lower values of PMP due to obstruction by the mountain range which separates these states from the east coast.

Although the northern part of Perak (the wettest region in the Peninsula) is also separated from the east coast by mountains, due to high moisture availability, this region may experience high PMP values (as shown in Figure 2, 3 and 4).

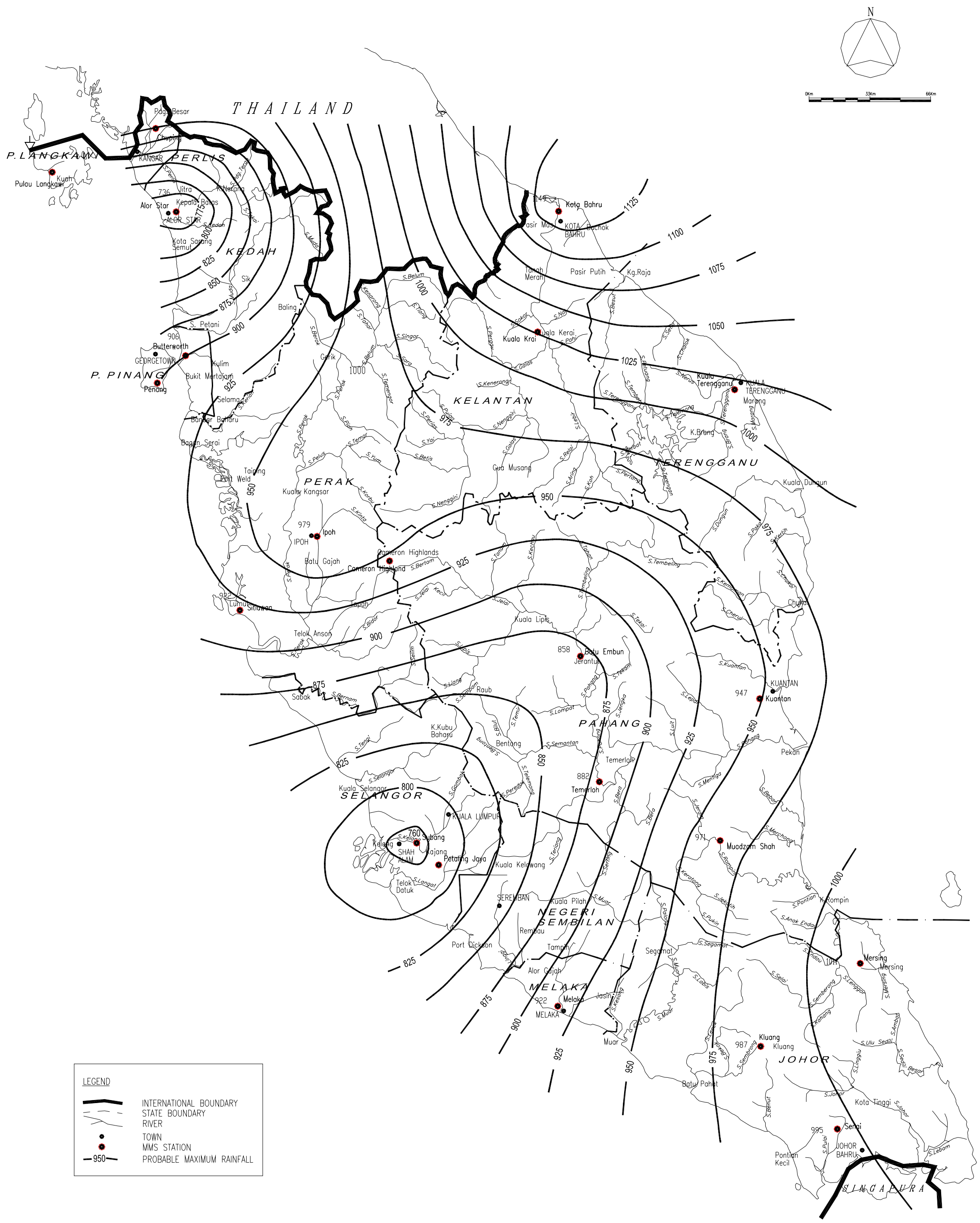

Figure 3: One Day Probable Maximum Precipitation (PMP) for Peninsular Malaysia

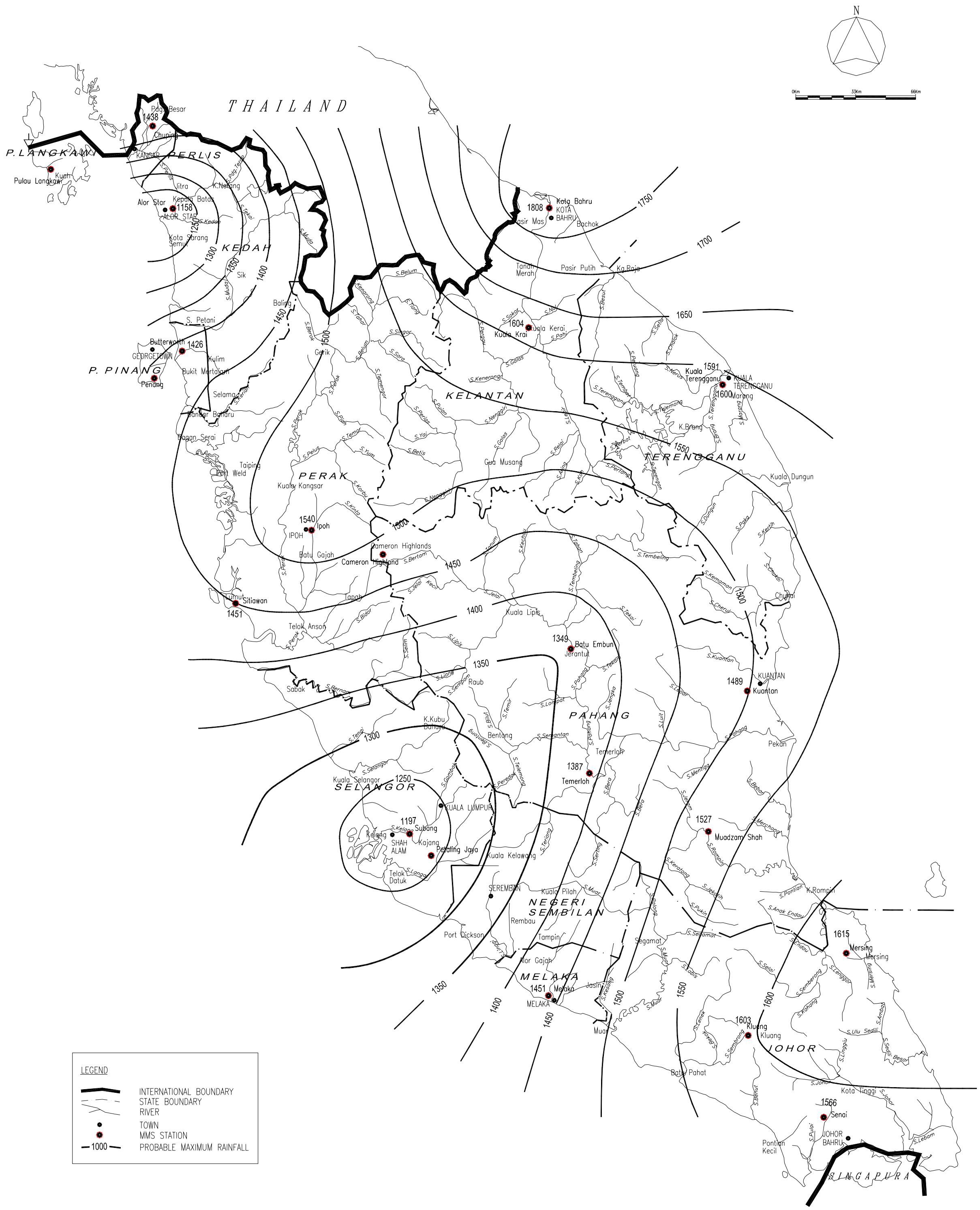

Figure 3: Three Day Probable Maximum Precipitation (PMP) for Peninsular Malaysia

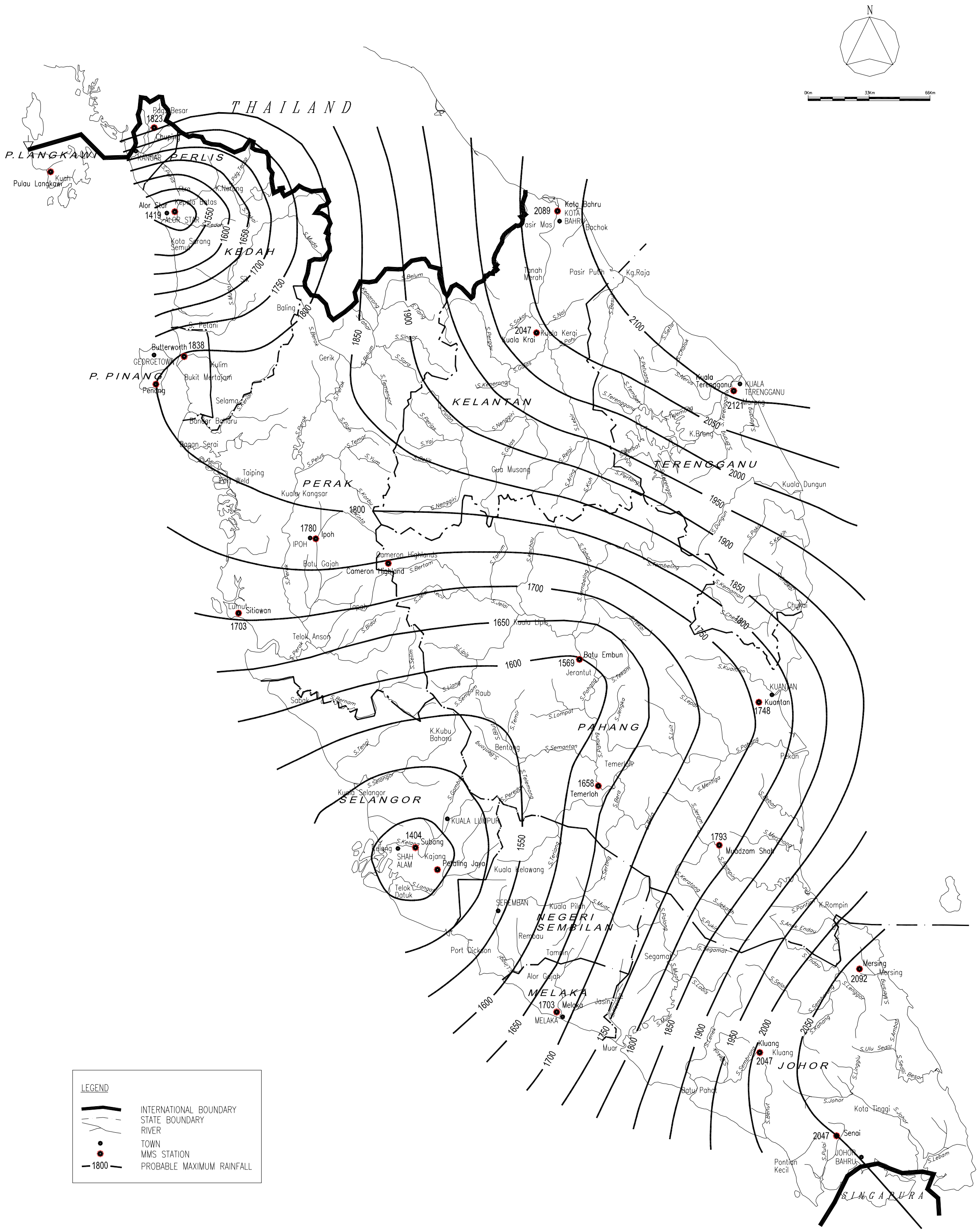

Figure 3: Five Day Probable Maximum Precipitation (PMP) for Peninsular Malaysia

A question often faced regarding the PMP estimates is "How do we know that the values are correct and not too high or low?" In reality, it is not possible to determine the exact value of the PMP while, it keeps on changing for the same catchment with the time, atmospheric changes and new records of heavy storms. The estimated PMP values only represent the best answer that available knowledge, technique and data support. The calculated maximum PMP values are 1.4 times higher than the recorded storms in the Peninsular Malaysia (comparing Table 1 and Table 3). In other words we can say that the estimated PMP values have a factor of safety around 1.4. In relation to the Factor of Safety (FOS) usually adopted in other engineering practices (e.g. in Structural Engineering generally a FOS of 1.4 - 1.7 and for Geotechnical design FOS of 1.5- 2.0 are considered) it can be concluded that the estimated PMP (which is very uncertain) values for the Peninsular Malaysia are reasonable.

Table 3: Calculated PMP Values (mm) for Different MMS stations in Peninsular Malaysia

Stn. No	Station Name	Max. F_m	Min. F_m	Max. F_{at}	Min. F_{at}	Maximum Calculated PMP (mm)		
						1-day	3-day	5-day
48600	Langkawi Airport	1.42	1.38	0.68	0.67	769	1209	1449
48601	Penang Airport	1.54	1.42	0.86	0.83	955	1502	1927
48602	Butterworth Airport	1.54	1.39	0.81	0.79	906	1426	1838
48603	Alor Setar Airport	1.70	1.38	0.64	0.62	736	1158	1419
48604	Chuping, Perlis	1.53	1.37	0.81	0.80	914	1438	1823
48615	Kota Bharu Airport	1.54	1.42	0.92	0.90	1149	1808	2089
48616	Kuala Kerai, Terengganu	1.52	1.40	0.91	0.89	1019	1604	2047
48619	Kajiklim K. Terengganu	1.42	1.38	0.89	0.88	1011	1591	2121
48620	Setiawan, Perak	1.46	1.39	0.81	0.80	922	1451	1703
48625	Ipoh Airport	1.59	1.37	0.80	0.76	979	1540	1780
48642	Batu Embun, Pahang	1.52	1.37	0.77	0.75	858	1349	1569
48647	Subang Airport	1.41	1.37	0.68	0.67	760	1197	1404
48648	Petaling Jaya	1.41	1.37	0.68	0.67	760	1197	1404
48649	Muadzam Shah, Pahang	1.52	1.41	0.85	0.83	971	1527	1793
48653	Temerloh, Pahang	1.41	1.37	0.80	0.79	882	1387	1658
48657	Kuantan Airport	1.53	1.41	0.83	0.82	947	1489	1748
48665	Malacca Airport	1.54	1.42	0.81	0.80	922	1451	1703
48672	Kluang, Johor	1.52	1.36	0.91	0.87	987	1603	2047
48674	Mersing, Johor	1.52	1.37	0.92	0.89	1011	1615	2092
48679	Johor Bahru Airport	1.52	1.37	0.90	0.86	995	1566	2047

A study carried out by Riedel and Schreiner (1980) revealed that extreme average recorded rainfall of 75 storms in the USA was 60 % of the PMP estimates for those sites. Only 6 storms exceeded 80% of the estimated PMP values. Thus, it is always advisable to compare the estimated PMP values with other methods and previous studies available within or nearby catchments. However, weighted average has to be taken for the catchments crossing several isohyetal lines of the PMP map (Figure 2, 3 and 4). Results of this study should be verified for the catchments with average altitude of higher than 200 m MSL. Although spatial variation of rainfall is obvious, areal reduction factor (ARF) for the storms were not considered due to the understanding that the rainfall stations might not have recorded the maximum intensity during the storms.

The calculated PMP values and maximum recorded rainfall in the world and in Malaysia are compared in Figure 5. It was observed that the 1, 3 and 5-day PMP values calculated for Peninsular Malaysia do not exceed the maximum rainfall recorded elsewhere in the world for the same durations. This means that the predicted PMP values for Malaysia are not over estimated.

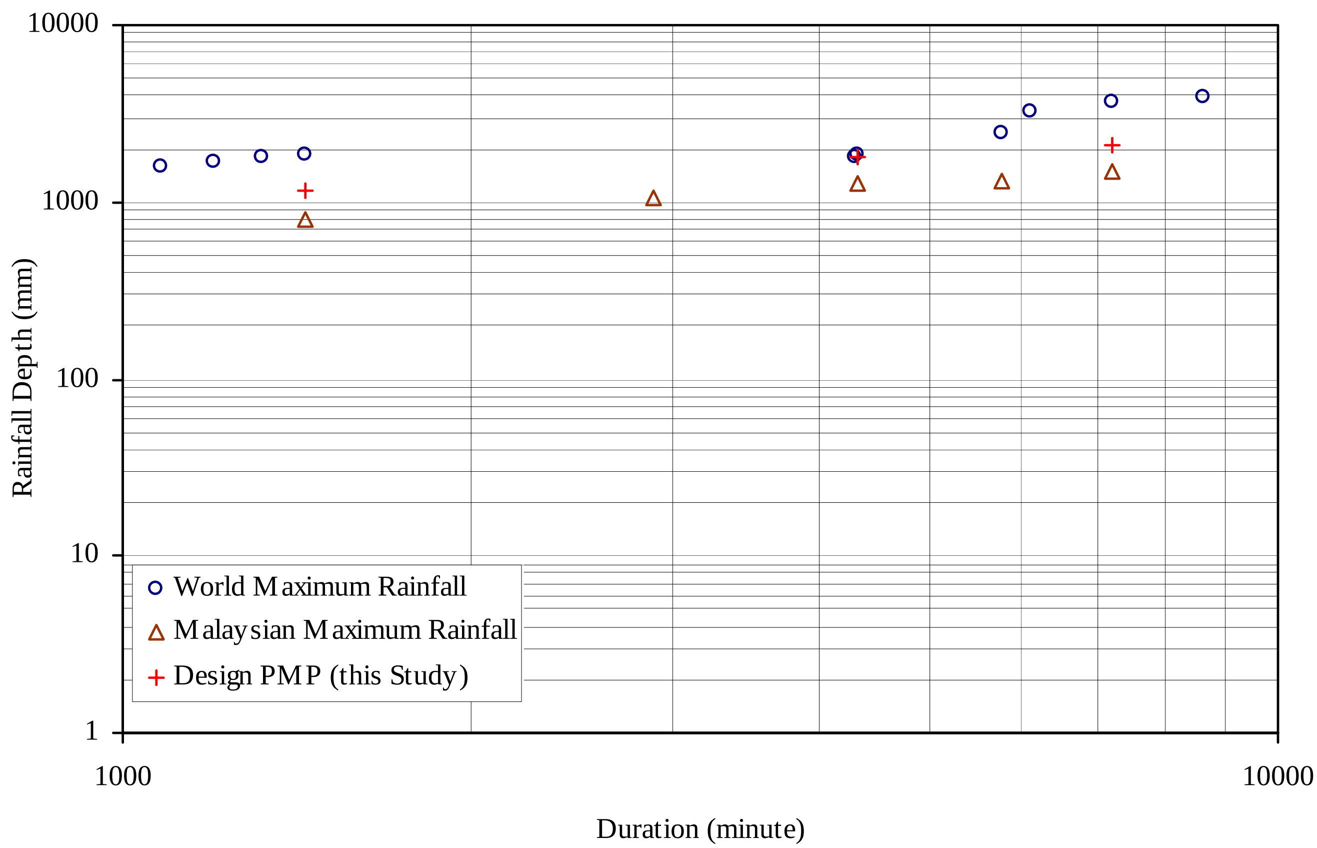

Figure 5: Comparison of Maximum Rainfall around the World (BOM, 2001).

CONCLUSION

Probable maximum precipitations (PMP) for 1, 3 and 5-day storms at the MMS stations of Peninsular Malaysia were derived by hydro-meteorological method from the historical storms in the region. Isohyetal lines of generalised point PMP maps were prepared to ease estimation of design rainfall for the ungauged catchments. Although spatial variation of rainfall is most likely, areal reduction factor for the storms were ignored due to understanding that the rainfall stations might not have recorded the maximum intensity during all recorded storm events.

Maximum rainfall of 1, 3 and 5-day durations in the West Malaysia was recorded as 809, 1272.9 and 1494 mm, respectively while maximum calculated PMP values for 1, 3 and 5-day storms can, respectively be as high as 1149, 1808 and 2121 mm. However, the factor of safety, compared to the observed rainfall did not exceed 2 which is in accord with the factor of safety considered in other civil engineering practices where uncertainties are involved in estimating design parameters. The stations considered to develop the isohyetal maps are located at elevations below 200 m, MSL. As such, the proposed isohyetal maps can be used readily to estimate probable maximum precipitation for any catchment located in the Peninsular Malaysia at elevation lower than 200 m, MSL. These maps will provide the point PMP values only. Appropriate temporal pattern has to be developed based on the distribution of historical rainfall events in order to calculate probable maximum flood (PMF) for the catchment of interest.

REFERNCES

Bureau of Meteorology Australia (2001). *Notable Point Rainfall Events*, 22 March 2001, Hydrometeorological Advisory Services, Australia.

Bureau of Meteorology Australia (1994). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*

Corrigan P., Fenn D.D., Kluck D.R. and Vogel J.L. (1998). *Probable Maximum Precipitation for California: Calculation Procedures*, Hydrometeorological Report No. 59, US Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, MD; October 1998

Collier C.G., and Hardaker P.J. (1996). *Estimating Probable Maximum Precipitation Using a Storm Model Approach*, J. of Hydrology, vol. 183, 1996, pg. 277-306.

Desa M.M.N., Noriah A.B. and Rakhecha, P.R. (2001). *Probable Maximum Precipitation for 24 hrs Duration Over Southeast Asian Monsoon Region - Selangor, Malaysia,* Atmospheric Research J., vol. 58, 2001, pg. 41-54.

Hansen E.M., Schreiner L.C. and Miller J.F. (1982). *Application of Probable Maximum Precipitation Estimates.* United States east of the 105th meridian, Hydrometeorological Report No. 52, National Weather Services; U.S. Department of Commerce ; Silver Spring, Md., pg. 228.

Hobbs P. (1989). *Research on Clouds and Precipitation: Past Present and Future*. Part 1, Bulletin of American Meteorological Society, Vol. 70, pg. 282-285.

Katzfey, J.J. (1995). *Simulation of Extreme New Zealand Precipitation Events. Part II: Mechanisms of Precipitation Development*. Monthly Weather Review, Vol. 123, pg. 755-775.

Riedel J.T. and Schriener L.C. (1980). *Comparison of Generalised Estimates of Probable Maximum Precipitation with Greatest Observed Rainfalls.* Technical Report, NWS No. 25; National Weather Services; U.S. Department of Commerce; Silver Spring, Md., pg. 66.

World Meteorological Organisation, WMO (1986). *Manual for Estimation of Probable Maximum Precipitation.* Operational Hydrological Report No 1; second edition; Geneva; pg. 96

World Meteorological Organisation, WMO (1973). *Manual for Estimation of Probable Maximum Precipitation.* Operational Hydrological Report No 1; Geneva; pg. 190.