PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 21 ISSUE 1 (2023), Page 58 – 71

ANALYSIS OF THE FLASH FLOOD EVENT AND RAINFALL DISTRIBUTION PATTERN ON RELAU RIVER BASIN DEVELOPMENT, PENANG, MALAYSIA

Muhammad Hafiz Md Saad[1], Mohd Khairul Amri Kamarudin[2], Mohd Ekhwan Toriman[3], Noorjima Abd Wahab[4], Frankie Marcus Ata[5], Mohd Armi Abu Samah[6], Ahmad Shakir Mohd Saudi[7], Sianturi Novdin Manoktong[8]

[1,4]*East Coast Environmental Research Institute,*
[2]*Faculty of Applied Social Sciences,*
UNIVERSITI SULTAN ZAINAL ABIDIN, TERENGGANU, MALAYSIA
[3,5]*Faculty of Social Sciences and Humanities,*
UNIVERSITI KEBANGSAAN MALAYSIA, SELANGOR, MALAYSIA
[6]*Kulliyyah of Science,*
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
[7]*Institute of Medical Science Technology,*
UNIVERSITI KUALA LUMPUR, SELANGOR, MALAYSIA
[8]*Faculty of Engineering,*
UNIVERSITAS SIMALUNGUN, NORTH SUMATRA, INDONESIA

Abstract

Typical disaster flooding and flash floods in Malaysia. Floods occur especially during the wet season within the geographical region area which is especially influenced by the northeast monsoon. So the sampling study was conducted in March 2019 in normal season. Cross-sectional measurements involving the measurement of river width, river depth and velocity were conducted at both sampling times. The main objective of this study was to identify the pattern of rainfall distribution and river discharge rate in the River Basin Relative when the flash flood event occurred. The average seasonal discharge value in the normal Relau River (Upstream) is 0.04 m^3s^{-1}, Relau River (Midstream) is 0.57 m^3s^{-1}, Relau River (Downstream) is 0.35 m^3s^{-1}. Whereas for Ara River (Midstream) is 0.78 m^3s^{-1}, Ara River (Downstream) is 0.19 m^3s^{-1}) and Kluang River (Upstream) is 0.18 m^3s^{-1}. The estimated value for flash flood shows that total water and sewer capacity that occurred during the flash floods was to increase the water level by five meters from the normal season water level with an estimated water velocity of $m^3s^{-1}$for this area. The reading shows the Relau River (Upstream) reading 5.18 m^3s^{-1}, the Relau River (Midstream) is m^3s^{-1} the Relau River (Downstream) is 18.20 m^3s^{-1}. While for Ara River (Midstream) is 24.53 m^3s^{-1}, Ara River (Downstream) is 25.35 m^3s^{-1}) and Kluang River (Upstream) is 26.22 m^3s^{-1}.

***Keywords**:* Cross-section, flood, river basin development, river discharge, rainfall

2 Lecturer at Universiti Sultan Zainal Abidin. Email: mkhairulamri@unisza.edu.my

INTRODUCTION

According to DID (2000), floods can be classified into two types, namely flash floods and monsoon floods. Hydrology, the main difference between the two categories of this flood is that it is taken for the level of expression to return to the normal level of flood discharge. Flash floods take a few hours to return to the normal level of expression compared to monsoon floods which can sometimes take up to a month to go to normal levels (Kamarudin et al., 2019a; Kamarudin et al., 2015a).

Floods became one in all the foremost frequent natural disasters worldwide. The rise in such a weather event (flood) is principally caused by global climate change (Hirabayashi et al., 2013). Floods have an enormous potential to wreck natural and man-made resources (Huang et al., 2008; Kamarudin, 2019a; Kamarudin et al., 2015b). Flood occurrences affect over 20,000 individuals annually worldwide (Sarhadi et al., 2012). Over 90% of property loss and distressed means of livelihood in Asia are caused by floods (Smith, 2013; Paul et al., 2019; Kamarudin, 2019b).

Otherwise, flash flooding is defined as a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise during a stream or creek above a predetermined flood level within six hour of the causative event (NOAA 2012). Between 2015 and 2017, flash flooding has resulted in additional fatalities than lightning, hail, tornadoes, and straight-line wind damage from thunderstorms combined (NWS 2017). Between October 2015 and October 2016, there are approximately $19 billion in losses from flooding disasters over the contiguous U.S. (CONUS; Novak 2017).

Flash floods are the fast inundating of low-lying areas within the mountainous regions; they're induced either by the large rainfall within the short period, sudden failure of dam and levee or debris flow (Elkhrachy, 2015). Although entire mitigation of flash flood is impossible, a flash flood susceptibility map (FFSM) prepared through appropriate methods may be a standard tool useful for the reduction of the detrimental impacts of flash floods and associated risks (Huang et al., 2008).

Flash floods occur within catchments, where the latency of the catchment basin is brief. In line with the American Meteorological Society, flash flood events generally do not give advance warning and so, they cause significant risk and destruction thanks to their complex and dynamic environmental settings and nature (Georgakakos, 1986; Collier, 2007). Flash flood occurrence is affected by various watershed characteristics (type of basin and drainage), anthropogenic activities (land use, deforestation, and engineering science construction) and the environmental condition like amount, intensity, spatial distribution, and time of rainfall. Recently, global climate change is altering the environmental condition which can result in flash flood condition at one place and drought condition at another place. Therefore, the past may not be a reliable guide to the long run. Thus, within the planning of flood management, especially of flash get urban areas (Wahab et al., 2019; Mohd et al., 2019). In Malaysia, most typical disaster flooding and flash floods. Floods occur especially during the wet season within the geographical region area which is especially influenced by the northeast monsoon (Saudi et al. 2015; Muhammad et al. 2016). In ongoing decades, the quantities of utmost climatic events like storms, flood, dry spells and heat waves have expanded around the world (Sungip et. al, 2019; Field et. al, 2012; Toriman et. al, 2009). The monitoring of river discharge is vital frequency for body of water resources direction, water residue rating at the basin scale, and flood purpose additionally as for the calibration and validation of hydrological models. Spada et al. (2017) stated that despite the most impact of discharge data on many environmental management takings, their evaluation nearly always relies on the employment of the so-called rating curves.

According to Chan (1997), the risk and vulnerability of urban communities to flash floods are increasing in Malaysia lately. This can be seen based on the increase in urban areas that consist of land use, not permeable water such as asphalt, cement and concrete surfaces. A clear flash flood disaster can lead to a loss to society and the environment. Losses suffered as a result of flood disasters can be categorized into two types, which are direct losses and indirect losses. Usually, the loss from flood disaster is very dependent on the socio-economic level of the population in the flood area (Rasdi et al., 2022; Azinuddin et al., 2022). According to Chan (2000), the impact of flood disaster was more felt by the residents of the lower income square areas compared to the medium and high income population. The main objective of this study was to identify the pattern of rainfall distribution and river discharge rate in the River Basin Relative when the flash flood event occurred. This is to see whether or not there is a correlation between these factors and the seasonal rate of discharge.

METHOD

This study was carried out in the River Basin Furnace at coordinates 5°19'26.2'N 100°16'50.9'E (Figure 1) consisting of the River, Ara River and Kluang Relau Rivers in Penang. The basin is located in the South western part of Penang. It can be said that almost every year the area is hit by lightning floods if it rains. Convective rain more than 60 mm in 2 to 4 hours duration may cause flash floods. However, monsoon rains are typical of long duration with intermittent heavy bursts and the intensity can occasionally exceed several hundred mm in 24 hours.

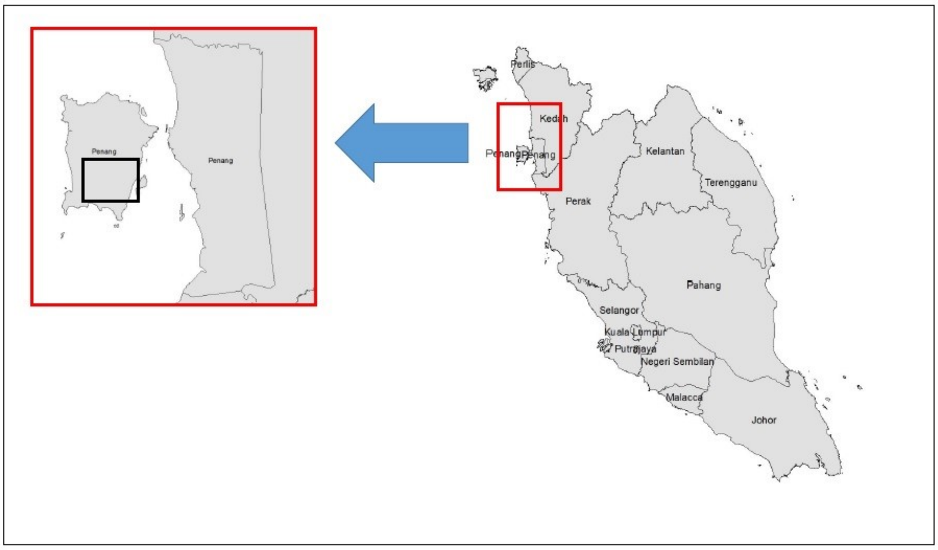

Figure 1: Location of Relau River Basin

There are seven main locations that are often hit by lightning bankers in this area such as the Sri Relau School area, Jalan Paya Terubong, the Relau Area, Sunshine Bayan Baru, Masjid Bayan Baru, Jalan Mahsuri, Persiaran Mahsuri and Jalan Tengah (Figure 3 and Table 2). These areas are often flooded because almost the whole area is covered with placement and the river is also not large and wide. This also caused the river to not be able to accommodate the amount of rain that fell in a long period. The situation will become worse if the occurrence of large tides in the sea that enter through the Kluang River as well as blocking the discharge of water from the land area.

Due to the low position of this area, namely the height at the mean sea level is 10 meters, often flood events will occur if river water levels increase due to heavy rain and abundant because the river is no longer able to accommodate excess water capacity. Due to the low altitude of this area, with a mean sea level of 10 meters, flood events often occur when river water levels rise due to heavy rainfall and floods because the river can no longer sustain excess water capacity such as the September 2017 flood event. In addition, flash floods have also been reported in November 2017, November 2018, September 2019. This situation continues to cause problems for residents as property damage occurs every time a flood occurs (Figure 2).

Figure 2: Flash flood events that have occurred in the study area

Due to the possibility that the problem will recur without inventory, a study sample has been carried out in the Relau River Basin (Figure 3 and Table 1). The status of the sampling system has been identified using the Digital Global Positioning System (DGPS) where the sampling has been carried out on Mac 2019. Mac month is chosen because at this time it is a normal season. This has made it easier for the work to be sampled because it is not exposed to the danger of flooding and so on if it is carried out in the rainy season.

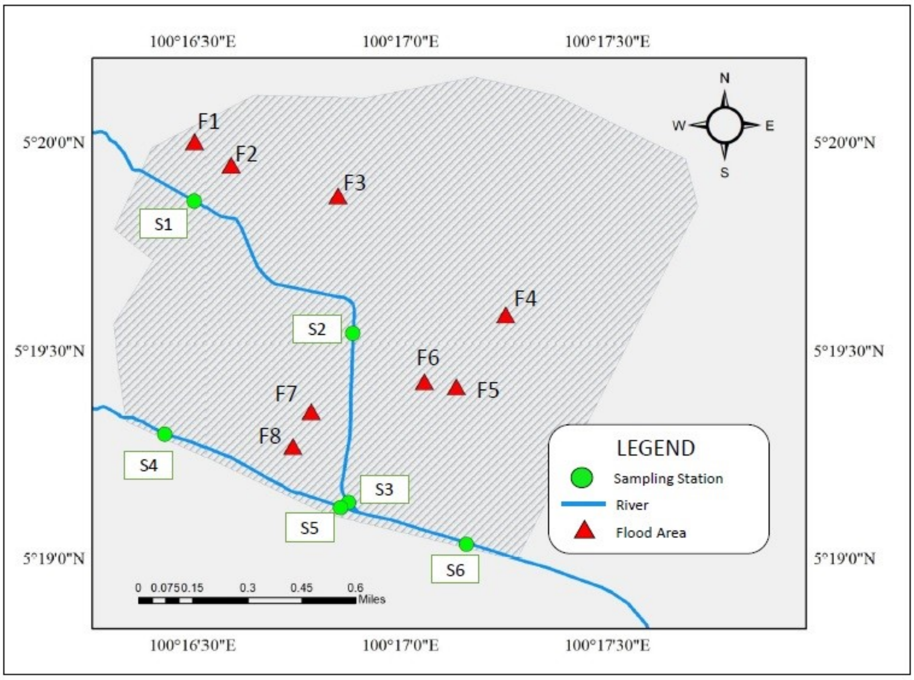

Figure 3: Map of sampling station and flood area

Table 1: Sampling station for the study areas

	Station	Latitude	Longitude
S1	Relau River (Upstream)	5°19'51.4"N	100°16'30.3"E
S2	Relau River (Midstream)	5°19'32.3"N	100°16'53.1"E
S3	Relau River (Downstream)	5°19'08.0"N	100°16'52.5"E
S4	Ara River (Midstream)	5°19'17.9"N	100°16'26.0"E
S5	Ara River (Downstream)	5°19'07.3"N	100°16'51.3"E
S6	Kluang River (Upstream)	5°19'01.9"N	100°17'09.6"E

Table 2: Flood hotspot area in Relau River Basin

No.	District	Flood Hotspot Area	City
F1	Timur Laut	Sekolah Sri Relau	Bayan Lepas
F2	Timur Laut	Jalan Paya Terubong	Bayan Lepas
F3	Timur Laut	Kawasan Relau	Bayan Lepas
F4	Barat Daya	Sunshine Bayan Baru	Bayan Baru
F5	Barat Daya	Masjid Bayan Baru	Bayan Baru
F6	Barat Daya	Jalan Mahsuri	Bayan Lepas
F7	Barat Daya	Persiaran Mahsuri	Bayan Lepas
F8	Barat Daya	Jalan Tengah	Bayan Lepas

Source: Penang State Government (2019)

a) Hydrographic calculation

Calculation Area (A):

The area of each section is obtained by taking into account the depth absorbed by the vertical boundary and multiplied by between the vertical boundaries (Kamarudin et al., 2015a).

$$A = b \times d \qquad \text{.......... [1]}$$

A = cross sectional area (m2)
b = distance between vertical boundaries (m)
d = water depth (m)

b) Calculation of river discharge (Q)

The cross-sectional area (A) and average velocity (v) are known, the slope (Q) can be calculated from Q = vA. Because the water depth and flow velocity are not uniform for the entire cross-section. Accurate discharge measurements are obtained by dividing the cross-section into several sub-sections called sections. Each section is limited by surface water, river bottom and 2 vertical lines, called vertical. Each vertical is a common dimension of two continuous sections and the depth of water and the velocity of the stream are set for observation. Adequate velocity observations were made to obtain the average velocity at each vertical boundary (Figure 4). So, the average velocity of the section is:

V = (v0.2d x v0.8d)/2 or v0.6d .... [2]

The result of the average and wide velocity of each section gives the cut-off.

Q = (bd)(v0.2d x v0.8d)/2 .... [3]
or Q = (bd)(v0.6d)

And the sum of all the cutoffs gives the sum of the sums.

Q = (Q0,1)+(Q1,2) +(Q2,3)...+(Qn,n +1) .... [4]

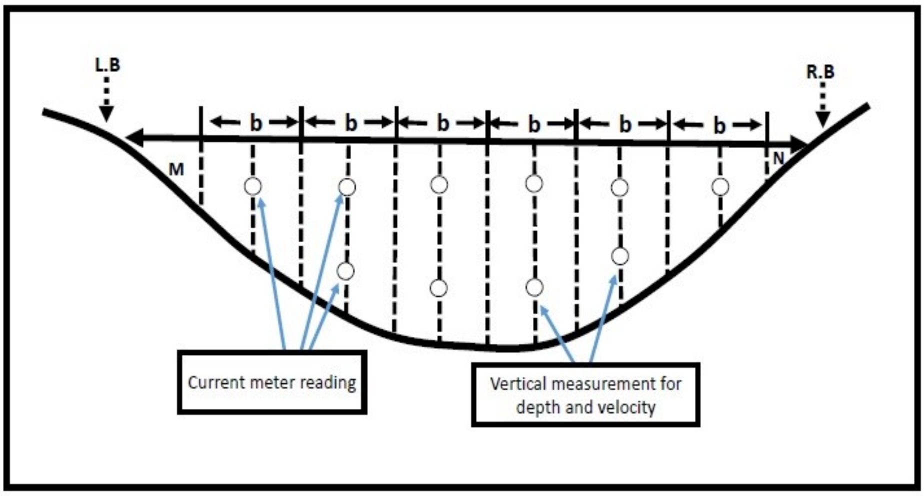

Figure 4: Discharge Measurement Theory
(Jamil et. al (2012)

c) Rainfall

An annual rainfall distribution is also available to see if there is any direct effect of the amount of rainfall and the occurrence of this flash flood. The average annual rainfall in 2013 to 2019 in Penang and the monthly rainfall in 2019 in Penang have been obtained from the Malaysian Meteorological Department.

RESULT AND DISCUSSION

Annual rainfall distribution is also available to see if there is any direct effect of the amount of rainfall and the occurrence of this flash flood. The average annual rainfall in 2013 to 2019 in Penang and the monthly rainfall in 2019 in Penang have been obtained from the Malaysian Meteorological Department.

Hydrological data results
a) River discharge

Calculations were performed using flow velocity data, widths and river depths to obtain the discharge rates and water capacity measured by the three rivers. The Relau River is a river that has been darkened. So, erosion and policy erosion is difficult here. The river is not too wide. Whereas the Ara River and Kluang River are common and relatively wide rivers. The discharge rates for these rivers have been recorded. Discharge rate is the amount of water that exceeds one cross section at a time (Gordon et al. 2004). The average seasonal discharge value in the normal Relau River (Upstream) is 0.04 m^3s^{-1}, Relau River (Midstream) is 0.57 m^3s^{-1}, Relau River (Downstream) is 0.35 m^3s^{-1}. Whereas for Ara River (Midstream) is 0.78 m^3s^{-1}, Ara River (Downstream) is 0.19 m^3s^{-1}) and Kluang River (Upstream) is 0.18 m^3s^{-1} (Table 3).

Table 3: Water discharges occur during flash floods

Station	Location	Width (m)	Discharge (m^3/s)		
			Normal	Maximum	Flash Flood
S1	Relau River (Upstream)	2.7	0.04	2.88	5.18
S2	Relau River (Midstream)	11.5	0.57	25.63	27.28
S3	Relau River (Downstream)	8.2	0.35	12.75	18.20
S4	Ara River (Midstream)	14	0.78	18.97	24.53
S5	Ara River (Downstream)	12	0.19	19.73	25.35
S6	Kluang River (Upstream)	14	0.18	24.25	26.22

The width and depth of the river are still able to accommodate a rather large quantity of water with rather high velocity values. For maximum discharge that can be accommodated by the sample area as well, Relau River (Upstream) recorded a reading of 2.88 m^3s^{-1}, Relau River (Midstream) was 25.63 m^3s^{-1}, Relau River (Downstream) was m^3s^{-1}. Whereas for Ara River (Midstream) is 18.97 m^3s^{-1}, Ara River (Downstream) is 19.73 m^3s^{-1}) and Kluang River (Upstream) is 24.25 m^3s^{-1}.

However, if continuous rain events occur, the river is no longer able to accommodate the capacity of rainwater. Coupled with pulping runoff surface water in the surrounding area, water capacity increases rapidly and causes the occurrence of flash flood events. The increase in water in this area usually breaks down 0.5 - 1 meter rather than the maximum face.

Therefore, the estimated total water and sewer capacity that occurred during the flash floods was to increase the water level by five meters from the normal season water level with an estimated water velocity of m^3s^{-1} for this area.

The reading shows the Relau River (Upstream) reading 5.18 m^3s^{-1}, the Relau River (Midstream) is m^3s^{-1} the Relau River (Downstream) is 18.20 m^3s^{-1}. While for Ara River (Midstream) is 24.53 m^3s^{-1}, Ara River (Downstream) is 25.35 m^3s^{-1}) and Kluang River (Upstream) is 26.22 m^3s^{-1}.

The recent increase in water levels and low water levels has caused this area to be hit by flash floods due to the low rainfall. This situation is also shown in Figure 5 which is the value of discharge rates that occur during normal seasons, maximum capacity as well as readings during flash floods.

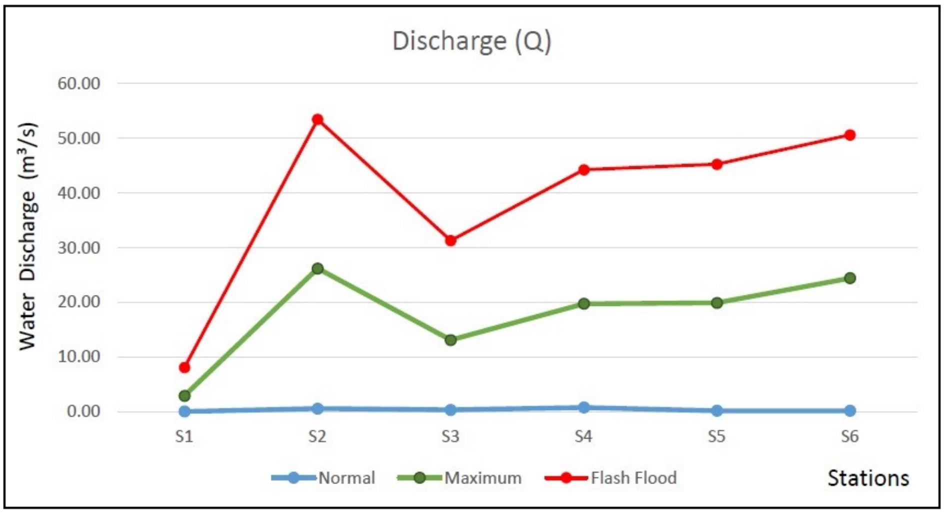

Figure 5: Rate of water discharge by station and season

b) Rainfall

Looking at the rainfall distributions as in Figure 6, the annual rainfall distributions show an increase from 2013 to 2017 which recorded average readings in 2013 of 2519mm, 2014 (2390mm), 2015 (2453mm), 2016 (2493mm), 2017 (2642mm), 2018 (2574mm) and 2019 (2530mm). Looking at this trend, 2017 recorded the highest figure of 2642mm. With heavy rainfall during that time, in September 2017, heavy flooding occurred in almost all areas of Penang with Georgetown becoming the worst affected area following Seberang Perai Central and Southwest. This incident was further aggravated by the high tide. Many property damages has occurred and many floodplain areas have been opened to cover flood victims.

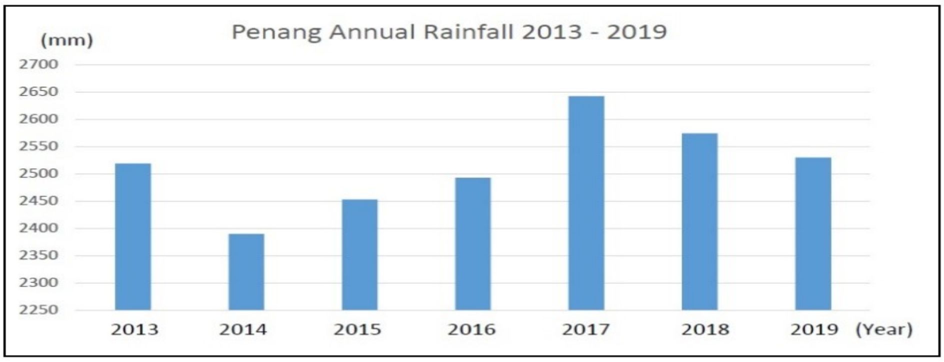

Figure 6: Annual rainfall 2013-2019
(Source: Malaysian Meteorological Department., 2019)

Following the incident, several drastic actions were taken by the Penang State Government, including accelerating the Flood Mitigation project and expected to be completed by October 2020. However, there are some constraints, particularly the size of some smaller rivers such as the Relau River that need to be deepened and was deployed to prevent such incidents from happening again. The initiative taken by the Penang State Government to address this problem is commendable because the effects of the flood can have devastating properties as well as the lives of residents.

During the duration of this project, flash floods were still occurring in some places especially in the River Basin Furnace but on a smaller scale and receding in a faster time. Figure 7 shows the monthly rainfall distribution for 2019 during which sampling is conducted. After 2017, a series of flash floods were recorded in the Relau River.

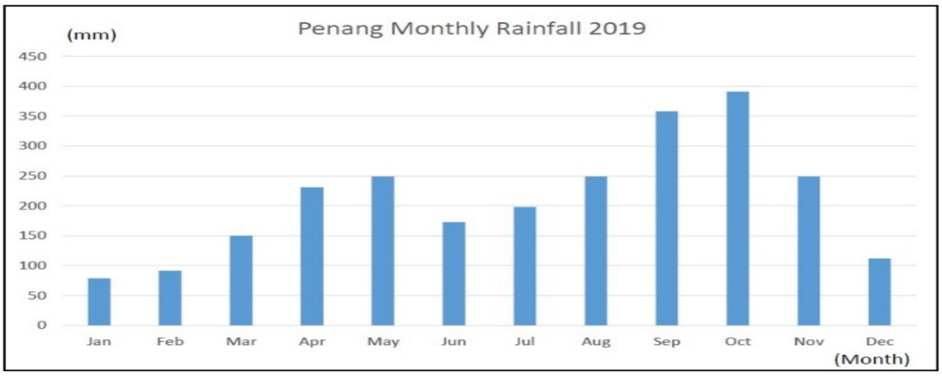

Figure 7: Monthly rainfall 2019
(Source: Malaysian Meteorological Department., 2019)

Rather than the data obtained, this situation shows that the amount of annual or monthly rain sprinkles gives a big impression in the occurrence of flash floods prevailing in the Relau River Basin. Although this situation is increasingly reduced, inventory measures still need to be taken while awaiting the flood reduction project is fully prepared.

CONCLUSION

This study shows that the discharge is directly proportional to the amount of rainfall. In addition, the occurrence of cliff erosion, dumping of rubbish into the river can also cause blocked water flow which in turn increases the level of the reservoir and the occurrence of flash floods. Hopefully, with the completion of the flood mitigation project in progress, this problem will be fully resolved in the future. This situation can serve as a role model for other places throughout Malaysia in particular and around the world to take appropriate steps in the event of such incidents.

ACKNOWLEDGEMENT

The authors would like to acknowledge UniSZA and MOHE for scholarship under research grants: (FRGS/1/2017/WAB05/UNISZA/01/1) - RR222.The authors would like to specially thank the Department of Irrigation and Drainage (DID) and Penang State Government for the secondary data and Universiti Sultan Zainal Abidin (UNISZA) who give permission to use research facilities and support in this research.

REFERENCES

Azinuddin, M., Som, A. P. M., Saufi, S. A. M., Zarhari, N. A. A., Amin, W. A. A. W. M., & Shariffuddin, N. S. M. (2022). Investigating overtourism impacts, perceived man-made risk and tourist revisit intention. *Planning Malaysia, 20*(3), 239-254.

Chan, N. W., & Parker, D. J. (1997). Aspek-aspek sosio-ekonomi berkaitan dengan bahaya dan bencana banjir di semenanjung Malaysia. *Proceedings of Persidangan Kebangsaan Kajian Sains Sosial,* 29-30.

Chan, N.W. (2000) Faktor paling signifikan terhadap keterukan subjektif impak banjir. Dlm Perbandaran dan perancangan persekitaran. Mohd Razali Agus & Fashbir Noor Sidin (pnyt). Kuala Lumpur: Utusan Pub. (ms. 249-261)

Collier, C. G. (2007). Flash flood forecasting: What are the limits of predictability?. *Quarterly Journal of the Royal Meteorological Society: A journal of the atmospheric sciences, applied meteorology and physical oceanography, 133*(622), 3-23.

Department of Irrigation and Drainage Malaysia (DID). (2000). Urban stormwater management manual for Malaysia.

Elkhrachy, I. (2015). Flash flood hazard mapping using satellite images and GIS tools: a case study of Najran City, Kingdom of Saudi Arabia (KSA). *The Egyptian Journal* *of Remote Sensing and Space Science, 18*(2), 261-278.

Field, C. B., Barros, V., Stocker, T. F., & Dahe, Q. (Eds.). (2012). Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change. Cambridge University Press.

Georgakakos, K. P. (1986). On the design of national, real-time warning systems with capability for site-specific, flash-flood forecasts. *Bulletin of the American Meteorological Society, 67(*10), 1233-1239.

Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., ... & Kanae, S. (2013). Global flood risk under climate change. *Nature Climate Change, 3*(9), 816-821.

Huang, X., Tan, H., Zhou, J., Yang, T., Benjamin, A., Wen, S. W., ... & Li, X. (2008). Flood hazard in Hunan province of China: an economic loss analysis. *Natural Hazards, 47*(1), 65-73.

Jamil, N. R., Toriman, M. E., Idris, M., & How, N. L. (2012). Analisis ciri-ciri luahan Sungai Chini dan Sungai Paya Merapuh Tasik Chini, Pahang bagi waktu normal, waktu basah dan selepas banjir. *e-Bangi, 9*(1), 34-47.

Kamarudin, M. K. A., Muhammad, N.S., Saad, M. H. M., Abd, N., Wahab, (2019a). Environmental Awareness Level Among University Students in Malaysia: A Review. *International Journal of Engineering & Technology, 7*(5S4), 509-511

Kamarudin, M. K. A., Nalado, A. M., Toriman, M. E., Juahir, H., Umar, R., Ismail, A., ... & Saudi, A. S. (2019b). Evolution of river geomorphology to water quality impact using remote sensing and GIS technique. *Desalination and Water Treatment, 149*, 258-273.

Kamarudin, M. K. A., Toriman, M. E., Juahir, H., Azid, A., Gasim, M. B., Saudi, A. S. M., Umar, R., Sulaiman, N. H., Ata, F. M., Mustafa, A. D., Amran, M. A., Yusoff, W. A., Azaman, F. (2015b). Assessment of river plan change using RS and GIS technique. *Jurnal Teknologi, 76*(1), 31-38.

Kamarudin, M. K. A., Toriman, M. E., Rosli, M. H., Juahir, H., Aziz, N. A. A., Azid, A., ... & Sulaiman, W. N. A. (2015a). Analysis of meander evolution studies on effect from land use and climate change at the upstream reach of the Pahang River, Malaysia. *Mitigation and Adaptation Strategies for Global Change, 20*(8), 1319-1334.

Malaysian Meteorological Department. (2019). Cuaca di Pulau Pinang. Retrieved from https://weather.com/msMY/weather/monthly/l/b29f1c3fb5f58be7dde46f764e2da5354dee4e851f07516e50bbac763c092bd0

Malaysian Meteorological Department. (2019). Pencerapan Permukaan. Retrieved from http://www.met.gov.my/projection/rain

Mohamed A., Rahim S. A., Aitman D. A., Kamarudin M. K. A. (2016). Analysis of seasonal soil organic carbon content at Bukit Jeriau Forest, Fraser Hill, Pahang. *Malaysian Journal of Analytical Sciences, 20*(2), 452-460.

Mohd, F. A., Abdul Maulud, K. N., Karim, O. A., Begum, R. A., Awang, N. A., Ahmad, A., Wan Mohamed Azhary, W. A. H., Kamarudin, M. K. A., Jaafar, M., Wan Mohtar, W. H. M. (2019). Comprehensive coastal vulnerability assessment and adaptation for Cherating Pekan coast, Pahang, Malaysia. *Ocean & Coastal Management, 182,* 104948.

NOAA. (2012). Hydrologic Services Program, definitions and general terminology. National Weather Service Manual 10-950, 5 pp., https://www.nws.noaa.gov/directives/sym/

Novak, D. R. (2017). The $1 billion dollar flood disasters of 2016. Major Weather Impacts of 2016, Seattle, WA, Amer. Meteor. Soc., 2.2A, https://ams.confex.com/ams/97Annual/webprogram/ Paper317351.html.

NWS. (2017). Summary of Natural Hazard Statistics in the United States. NOAA, accessed 15 October 2018, http://www.nws.noaa.gov/os/hazstats/sum17.pdf.

Paul, G. C., Saha, S., & Hembram, T. K. (2019). Application of the GIS-Based Probabilistic Models for Mapping the Flood Susceptibility in Bansloi Sub-basin of Ganga-Bhagirathi River and Their Comparison. *Remote Sensing in Earth Systems Sciences, 2(*2-3), 120-146.

Penang State Government (2019, July 1). Penang Flood Hotspot Area. Retrieved from http://www.data.gov.my/data/ms_MY/dataset?organization=penang-state-government &_organization_limit=0&groups=alam-sekitar

Rasdi, A. L. M., Som, A. P. M., Azinuddin, M., Nasir, M. N. M., & Khan, N. F. A. H. (2022). Local community perspective on responsible tourism and destination sustainability. *Planning Malaysia, 20*(3), 255-269.

Recanatesi, F., Petroselli, A., Ripa, M. N., & Leone, A. (2017). Assessment of stormwater runoff management practices and BMPs under soil sealing: a study case in a peri-urban watershed of the metropolitan area of Rome (Italy). *Journal of environmental management, 201,* 6-18.

Sarhadi, A., Soltani, S., & Modarres, R. (2012). Probabilistic flood inundation mapping of ungauged rivers: Linking GIS techniques and frequency analysis. Journal *of Hydrology, 458*, 68-86.

Saudi, A. S. M., Azid, A., Juahir, H., Toriman, M. E., Amran, M. A., Mustafa, A. D., ... & Saudi, M. M. (2015). Flood risk pattern recognition using integrated chemometric method and artificial neural network: A case study in the Johor River Basin. *Jurnal Teknologi, 74*(1), 34-56.

Smith, K. (1997). Environmental hazards: assessing risk and reducing disaster. *Environment International, 3*(23), 422-432.

Spada, E., Sinagra, M., Tucciarelli, T., & Biondi, D. (2017). Unsteady State Water Level Analysis for Discharge Hydrograph Estimation in Rivers with Torrential Regime: The Case Study of the February 2016 Flood Event in the Crati River, South Italy. *Water, 9*(4), 288-290.

Sungip, F. N., Kamarudin, M. K. A., Saad, M. H. M., Abd, N., Wahab, A. P. M. S., Umar, R., & Harith, H. (2018). The Impact of Monsoon Flood Phenomenon on Tourism Sector in Kelantan, Malaysia: A Review. *International Journal of Engineering & Technology, 7*(4.34), 37-40.

Szewrański, S., Kazak, J., Szkaradkiewicz, M., & Sasik, J. (2015). Flood risk factors in suburban area in the context of climate change adaptation policies–Case study of Wroclaw, Poland. *Journal of Ecological Engineering, 16*(2), 1-15.

Toriman, M. E., Kamarudin, M. K. A., SA, S. M., Idris, M. H., Jamil, N. R., & Gasim, M. B. (2009). Temporal variability on lowland river sediment properties and yield. *American Journal of Environmental Sciences, 5*(5), 657-663.

Wahab, N. A., Kamarudin, M. K. A, Toriman, M. E., Juahir, H., Saad, M. H. M., Ata, F.M., Ghazali, A., Hassan, A. R., Abdullah, H., Maulud, K. N., Hanafiah, M. M., Harith, H. (2019). Sedimentation and water quality deterioration problems at Terengganu River basin, Terengganu, Malaysia. *Desalination and water Treatment,* 149, 228-241.

Received: 28th Feb 2023. Accepted: 31st March 2023