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To cite this article: Nurul Fatimah Nor Azlan Shah *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1022** 012070

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# Flood Analysis and Non-Structural Approach for Flood Protection in Sg. Kelantan

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**Abstract.** Flooding is categorized as a natural disaster that occurs due to various climatic and geophysical factors. Malaysia is a lucky country as it experiences a tropical climate and generally protected from extreme drought. However, the states located along the east coast of the Peninsular Malaysia such as Kelantan, Terengganu, and Pahang always experienced a heavy flood, especially during the monsoon season due to high intensity of rainfall. The objectives of this paper were to simulate Flood Hydrographs for Various Storm Duration by using Hydrologic Engineering Centre-Hydrologic Modelling System (HEC-HMS), to investigate the location of floodplain at the catchment area of Sg. Kelantan by using River Analysis System (HEC-RAS), to identify the non-structural approach that can reduce the rate of flood based on its topography. By using HEC-HMS and HEC-RAS software, the peak discharge from each rainfall stations for different average recurrence interval (ARI) were calculated. Various non-structural measures to reduce the impacts of flood are discussed.

## 1. Introduction

Based on the United Nation Developed Program (UNDP, 2015), there are three Sustainable Development Goals (SDG) that can be related with this research. The SDG are number 13, 14 and 15. Number 13 is about climate action where some of the targets are the production of Carbon Dioxide (CO<sub>2</sub>) which must drop by 45% between 2010 until 2030 and reach zero by 2050, creating 18 million more jobs by 2030 that specifically focused on sustainable energy issues. The SDG goal number 14 is about life below water as almost 40% of the ocean is heavily polluted, depletion number of fish and loss of coastal habitats. Similarly, when the ocean is polluted with plastic or hazardous waste, the fish will absorb it and goes to its brain where it leads to abnormal behaviour of the aquatic animals and it will risk the health of those who consume the aquatic animals like the human himself. Next, SDG goal number 15 is about life on land as 2.6 billion people depend directly on agriculture for a living and almost 7000 of animals have been illegally traded that cause the biodiversity to crumble and critical



drought especially in Australia, Africa, and India. There are a variety of causes, effects, and alternatives in managing drought and flood. The main target is to balance the ecosystem and the climate after all the pollutions caused by humans give harmful impacts not only to nature and other living beings but also to themselves. The occurrence of El Nino and La Nina are the reason for the rate of drought and flood increase gradually in recent years.

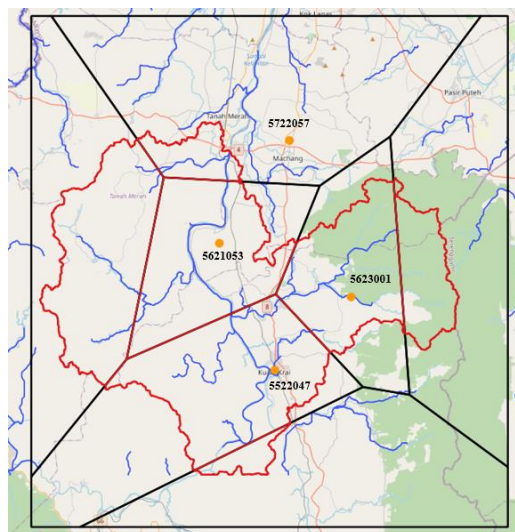
Since Malaysia is located at the equatorial climate region, it will experience two types of monsoon which are northeast monsoon and southwest monsoon annually. During La Nina, Malaysia will experience northeast monsoon from November until March with the speed of wind from 10 knots to 30 knots . Due to high humidity during the northeast monsoon, it will cause floods mainly on the east coast such as Kelantan, Terengganu and Pahang. The rate of a flood is depended on the intensity of the rainfall. The recent critical flood in 2014 where more than 20 thousands people have been transferred to more than 70 temporary relocation centres in Kelantan [1]. However, during El Nino phase, Malaysia will experience southwest monsoon from May until September with the speed of wind less than 15 knots. Extreme El Nino will cause drought and almost no rainfall during this phase. It is rare for Malaysia to experience extreme weather since it is located at the equatorial centre.

Furthermore, Kelantan always experience severe inundation compared to the other states during monsoonal season. Some of existing measures to mitigate flood in Sg. Kelantan are like levee and early flood warning and flood forecasting system. However, due to ineffective land use, the people still need to face loss of property and may lead to fatal accidents due to the severe flood event. Therefore, simulation of Flood Hydrographs for Various Storm Duration by using HEC-HMS, the location of floodplain at the catchment area of Sg. Kelantan by using HEC-RAS is determined and the non-structural approach that can reduce the rate of flood based on its topography and changes of climate at Sg. Kelantan may be identified.

## 2. Procedures to Determine the Basin Characteristics

### 2.1 Data used in QGIS

A Shuttle Radar Topographic Mission (SRTM) in .tif format can be obtained from US Geometry Survey (USGS) earth explorer. Generally, the four coordinates inserted cover the upstream of Sg. Kelantan at Kuala Krai before it split into two rivers which are Sg. Galas and Sg. Lebir until at the downstream of Sg. Kelantan at the Tumpat as shown in Figure 1. The time range is from 1<sup>st</sup> January 2014 until 31<sup>st</sup> December 2019. The rainfall stations in Figure 1 are obtained from the DID inventory list for the location of the rainfall stations.



**Figure 1:** Development of polygon using QGIS

However, there are only 10 stations that can collect the rainfall data. On top of that, from the QGIS, only some part of Sg Kelantan can be delineated, which is in Machang near to rainfall station 5722057, until the upstream of Sg. Kelantan which is near to rainfall station 5522047 in the district of Kuala Krai. Among all the rainfall stations portrayed in Figure 1, only rainfall stations 5522047 and 5722057 can record the rainfall data while the other stations are not operating. However, due to some limitations, instead of using real data that can be obtained from DID for hydrological data, parameters from HP 1 such as  $\lambda$ ,  $\kappa$ ,  $\theta$  and  $\eta$  have been used to developed the IDF curve. Thus, the nearest stations to the Sg. Kelantan such as stations 5722057, 5621053 and the 5522047 was be used to develop hydrographs and used to determine the depth of flood. Referring to Table 1, the characteristics of the catchment area have been categorized based on the location of the rainfall station and the size of the polygon.

**Table 1.** Characteristics of the catchment area

Station ID	5722057	5621053	5522047
Area (km <sup>2</sup> )	321.13	195.31	171.21
Stream Length, L (km)	14.48	23.93	11.37
Stream Slope, S (m/km)	0.896	2	52.77

2.2 Data used from Hydrological Procedure No. 1 (HP 1)

Table 2 represents the IDF parameters of  $\lambda$ ,  $\kappa$ ,  $\theta$  and  $\eta$  for three different rainfall stations to develop the IDF curve [2]. Moreover, only hydrographs and depth of flood for 50 ARI and 100 ARI will be developed in this project. Firstly, the rainfall intensity will be determined at each stations by using equation 1 and the results are shown in Table 3. For this project, the duration of 1hr, 3 hrs, 6 hrs, 12 hrs and 24 hrs have been chosen to determine the outflow discharge by using HEC-HMS from the rainfall depth developed from the IDF curve as shown in Figure 2. Then, the area reduction factor will be used by multiplying with the rainfall depth to get the catchment rainfall, P. Since all the P values are more than 75 mm, thus the same equations used from equation 2 until equation 5 to determine the basin characteristics for rainfall stations [2]. The results are shown in Tables 4 and 5. Finally, all the data act as input in HEC-HMS to compute the hydrographs as shown in simulation of HEC-HMS in Figure 3 and 4. After all the hydrographs developed from HEC-HMS, the outflow discharge is used as an input in HEC-RAS.

**Table 2.** IDF parameters from HP1 (DID, 2015)

Station ID	5722057	5621053	5522047
$\lambda$	44.861	45.91	50.924
$\kappa$	0.215	0.22	0.217
$\theta$	0.016	0	0
$\eta$	0.629	0.595	0.644

2.3. Calculation on the data needed for hydrographs

Formula to calculate the rainfall intensity,  $i$  (mm/hr):

$$i = \frac{\lambda T^\kappa}{d + \theta} \tag{1}$$

IDF curve and Rainfall depth for each station as shown below (Figure 2):

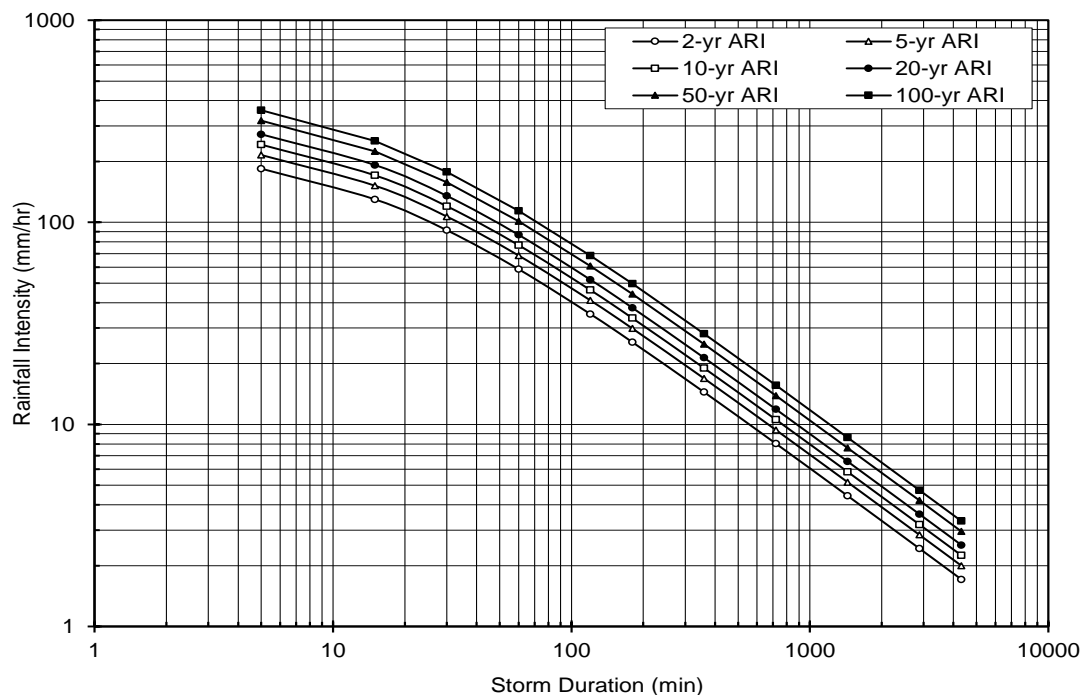


Figure 2. IDF curve for Sg Kelantan at Station 5722057

Table 3. Rainfall intensity developed from IDF curve

Intensity, <i>i</i> (mm/hr)	Return Period, <i>T</i> (year)					
	5722057		5621053		5522047	
Duration, <i>d</i> (hr)	50	100	50	100	50	100
1	108.56	126.45	102.99	119.55	119.01	138.33
3	169.40	197.31	155.85	180.90	175.98	204.54
6	224.30	261.25	201.89	234.33	225.23	261.78
12	296.99	345.92	261.31	303.31	288.26	335.05
24	393.25	458.03	338.08	392.41	368.94	428.82

Table 4. Catchment rainfall *P* for Station

Catchment Rainfall, <i>P</i>	Return Period, <i>T</i> (year)					
	5722057		5621053		5522047	
Duration, <i>d</i> (hr)	50	100	50	100	50	100
1	82.95	96.42	75.51	84.16	85.69	99.60
3	145.53	169.15	115.95	134.59	133.74	155.45
6	195.72	227.49	158.48	183.95	182.43	212.05
12	259.44	301.55	212.71	246.89	239.26	278.09
24	338.69	393.66	285.68	331.59	85.69	99.60

Since Kelantan is located at the east coast of Peninsular Malaysia, below are all the related equations:

- If  $P > 75$  mm

$$Q = \frac{P^2}{P + 352} \tag{2}$$

- $T_c = 2.32 A^{-0.118} L^{0.9573} S^{-0.5074}$  (3)

- $R = 2.976 A^{-0.1943} L^{0.9995} S^{-0.4588}$  (4)

- $Q_B = 0.11 A^{0.85889}$  (5)

where P is the catchment rainfall in mm, Q is the direct runoff in mm,  $t_c$  is the time of concentration in hours hrs, R is the storage coefficient in hrs,  $Q_B$  is the baseflow in  $m^3/s$ , A is the catchment area in  $km^2$ , L is the stream length in km and S is the stream slope in m/km.

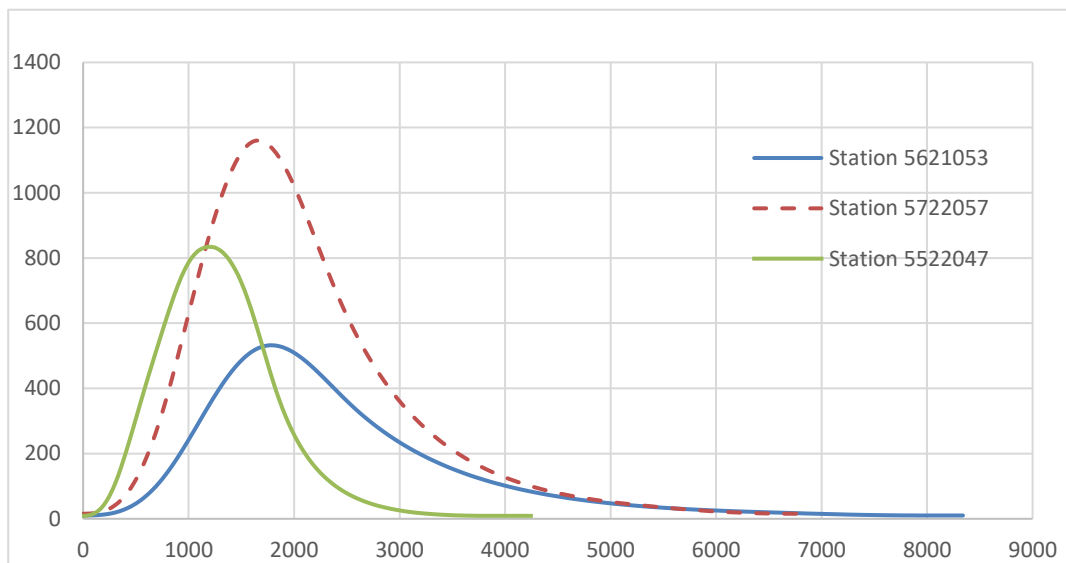
**Table 5.** Baseflow, Time of concentration and Storage coefficient for each station

Station ID	5722057	5621053	5522047
$Q_B$ ( $m^3/s$ )	15.64	10.21	9.11
$t_c$ (hrs)	15.96	18.23	6.43
R (hrs)	14.75	18.56	6.57

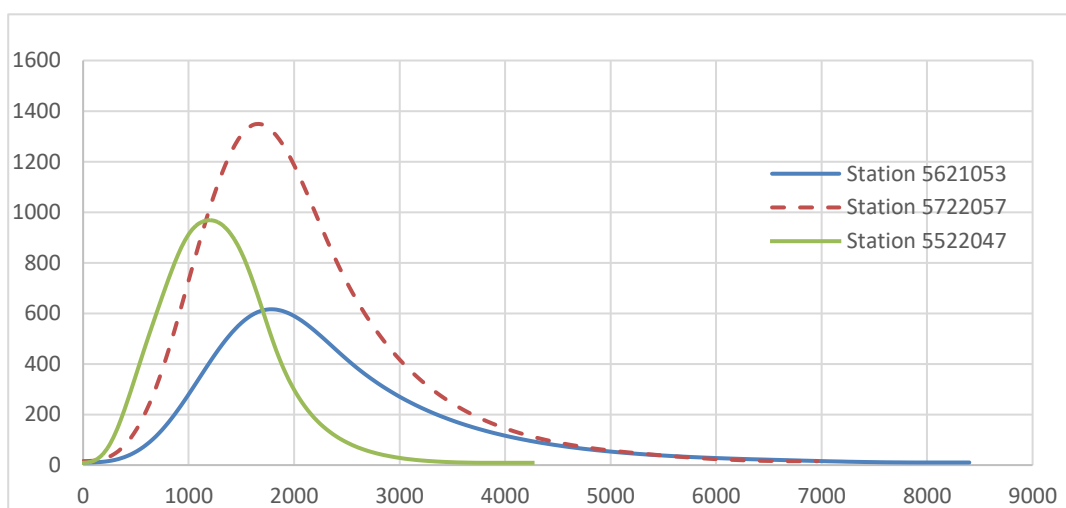
### 3. Simulation of HEC-HMS and HEC-RAS

#### 3.1 Output from HEC-HMS

Figures 3 and 4 are the plotted hydrographs from HEC-HMS and the combination of hydrographs from 24 hours duration and different ARI from rainfall stations. Based on this data, only critical hydrographs will be simulated in HEC-RAS. For station 5722057, the critical outflow for 50 ARI and 100 ARI is at 24 hours with value of  $1151.2 m^3/s$  and  $1348.4 m^3/s$ . Similarly, the critical outflow for station 5621053 is at 24 hours for 50 ARI and 100 ARI with value  $532.1 m^3/s$  and  $616 m^3/s$ . In contrast, for station 5522047, the critical outflow for 50 ARI is at 12 hours with value  $914 m^3/s$  while for 100 ARI is at 6 hours with value of  $1113.1 m^3/s$ . Furthermore, based on the outflow, the highest outflow is at station 5722057, which is also the lower course area followed by station 5621053 and 5522047.



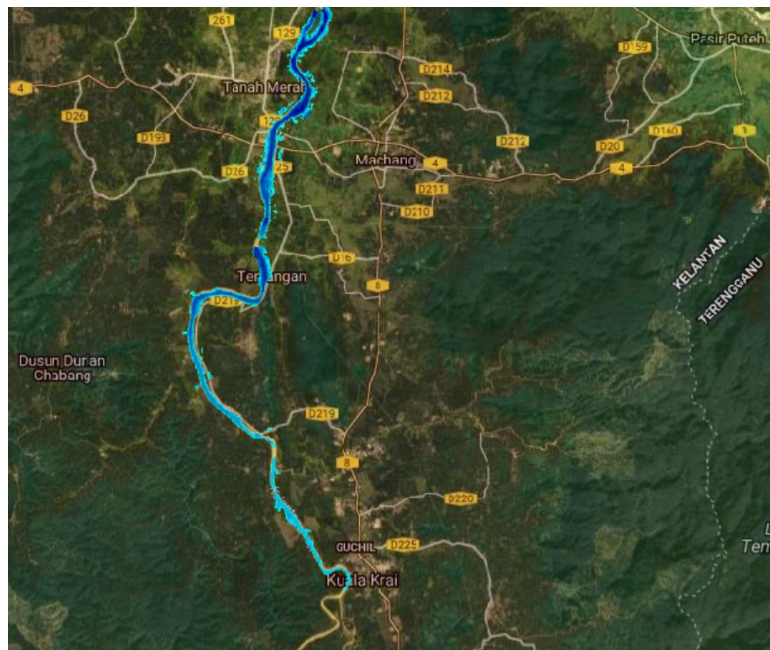
**Figure 3.** 24 hours duration of hydrographs for 50 ARI



**Figure 4.** 24 hours duration of hydrographs for 100 ARI

*3.2 Output from HEC-RAS*

Flood mapping for 50 ARI design flood is similar to flood mapping for 100 ARI design flood as shown in Figure 5 as the peak at all three stations for 100 ARI only excess 200 mm/hr from the peak for 50 ARI design flood. Furthermore, the highest rainfall intensity is at station 5722057 near to Machang district followed by station 5522047 near to Kuala Krai district and station 5621053 near to Temangan district. Some of the factors are due to less impervious and less vegetation at the area as lot of development at the area such as development of residential area, shop housing and improper urban stormwater management. Therefore, if the authorities decided to develop this area, a proper urban stormwater management system need to be included during the design stage until the construction stage. Thus, it will help to reduce the outflow velocity and the impacts to the environment and to the human itself.



**Figure 5.** Flood mapping for 100 ARI Design Flood

#### 4. Suggested Protective Measures

In Malaysia, the highly impacted area is the east coast of Peninsular Malaysia like in Kelantan, Terengganu, and Pahang due to the monsoon season as the effect of La Nina event. To overcome this natural disaster, many initiatives have been taken to reduce the impact on the affected area and most importantly, to prevent from any fatal impact on human lives. For instance, the SM such as river improvement and tidal gate to cater for excess water level that occurs during the monsoon season. On top of that, the NSM that is highly effective during the disaster is flood forecasting to ensure the residents have enough time to evacuate themselves.

However, although all the precautions have been taken and the number of loss of lives has been reduced, people still need to face the loss of property due to the natural disaster and bear the cost for repair and maintenance for their homes and offices as the flood forecasting only occurs after the flood level reaches its critical level. Hence, one of the factors that affect the rate of the flood is the land use nearby Sg. Kelantan. In [3], mangrove forests and Nypa swamps are in the downstream area that is also in Tumpat district while stream in Kuala Krai and Machang districts have the least riparian vegetation covers at the bank of the river. However, the mangrove forest is not planted at the lower course of the study area, which is in Machang.

Finally, the causes of drought and flood due to climate changes have been identified, simulation of hydrographs for various duration have been produced from HEC-HMS, the location of the floodplain has been identified for 50 ARI and 100 ARI by using HEC-RAS. The common NSM has been practiced for a long time in Sg. Kelantan such as the Early Forecast Warning System (EFWS), relocation and education of awareness. However, heavy rainfall that led to serious flood occurrence may cause total loss to the residents like what has happened in 2014. Based on the geographical condition along Sg. Kelantan, the Pergau dam can help reduce excess flow of freshwater from Sg. Kelantan.

Early Forecast Warning System (EFWS) is one of the famous NSM used in Malaysia, especially in Kelantan, Terengganu, Johor and Pahang. Furthermore, there are other NSM can be applied such as planting riparian vegetation, maintenance of river channel depth and estuarial clearance to provide free flow and discharge of flood. In addition, the authorities can educate the public especially during seasonal logging to protect the land surface from erosion. To conclude, the measures applied in a country is

dependent on the capability for a county to manage flood disaster. Thus, to save cost, to improve flood management and reduce environmental impacts, NSM would be the best choice instead of SM.

## 5. References

- [1] 2014 *Terkini: Banjir di Kelantan, Terengganu, Pahang tambah buruk* Berita Harian (December 23)
- [2] National Hydraulic Research Institute of Malaysia 2010 *Reviewed and Updated the Hydrological Procedure No. 1* (Malaysia: Department of Irrigation and Drainage) pp 57, 74, 87-90
- [3] Onrizal O, Ismail S N, Hamid, M A and Mansor M 2017 *The Current Status Riparian Vegetation along Bank of Kelantan River after the Worst Flood for Decades* (Malaysia: Universiti Sains Malaysia) pp 60–65

## Acknowledgement

The authors would like to express their deepest gratitude to the Ministry of Higher Education (MOHE) through the Fundamental of Research Grant Scheme (FRGS19-035-0643) to fund this research for flood analysis.