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# Flood risk map (case study in Kelantan)

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**Abstract.** Floods is one of the most common natural disaster which causes heavy damage to properties and human well-being. Usually, the terrain characteristics and meteorological properties of the region were the main natural factors for this disaster. In this paper, Kelantan was selected as the case study for flood risk analysis in studying the flash flood occurrence in December 2014. Geographical Information System (GIS) analysis were used to evaluate the potential flood risk areas. Some of the causative factors for flooding in watershed are taken into account such as maximum rainfall per six (6) hours and terrain. At the end of the study, a map of flood risk areas was generated and validated.

## 1. Introduction

The advent of Geographic Information System (GIS) has been given more consideration and useful detail on the mapping of land use/ cover for the improvement of site selection and survey data designed for urban planning, agriculture, and industrial layout. The application helps in determining possible changes in land use/ cover data with accuracy and precision. The natural hazard occurrence mostly due to climate change which results in extreme phenomena such as flash flood and droughts [1]. In global perspective, storms and flood are the most destructive natural disasters [2]. The risk of flood will affect and gives threat to human well-being, from health, economy, infrastructure, and the environment [3]. The implementation of satellite imagery for processing such as through digital elevation model (DEM) or Light Detection and Ranging (LiDAR) will provide an early visual data of such places. Then the spatial interpolation and topographical analysis can be conducted to identify the flood prone area. In Malaysia, heavy monsoon rainfall seasons triggered floods along Malaysia's east coast as well as in different part of the country [4]. Kelantan was one of the worst hit areas along the east coast of Peninsular Malaysia [5]. In the end of year 2014, one of the Malaysia worst flood were recorded in Kelantan for the past 30 years [6]. Terrain characteristics of land and meteorological properties during monsoon of the region have been the main natural factors for causing the flood disaster. The objective of this study is to determine the flood prone area and the behaviour of the flood through spatial rainfall temporal data.

## 2. Flood Occurrence

Flood management is under the administration of Department of Irrigation and Drainage (DID), Ministry of Natural Resources and Environment (NRE). Every year it is approximately that 29 800 km<sup>2</sup> of Malaysian land is prone to flood incident [7]. Former chairman of the Kelantan Disaster Operations Committee, Datuk Seri Mustapa Mohamed stated that the loss of public property due to major floods in Kelantan is estimated at RM 1 billion [8]. Heavy rainfall brought by the Northeast monsoon starting from November to March every year is the main caused of flood in some places of Kelantan [9]. Millions of ringgit were donated and spent throughout the rescue and aid mission from many agencies where more than 45000 evacuees were involved in Kelantan alone [6]. It is categorized as annual flood as it occurs every year during Monsoon season which caused a lot of damage especially in year 2014.



### 3. Materials and Method

### 3.1 Study Area

This study was conducted in the State of Kelantan and further narrowed to Kuala Krai district. It is located between latitude 6.245647 and 4.557078, and longitude 101.355702 and 102.663516. Tumpat district is the highest point, while the lowest point, most east and west is the district of Gua Musang. Kelantan covers 15.099 square kilometres and comprises of fourteen (14) districts. It is general hot and humid all year around, with average low temperature of 21°C to 32°C.

### 3.2 Data Source

The main supporting data for this study was provided by the Department of Irrigation and Drainage of Kelantan and the elevation spatial data was obtained from United States Geological Survey (USGS) Earth Explorer web service. A number of steps were followed in compiling the geographic and tabular data input.

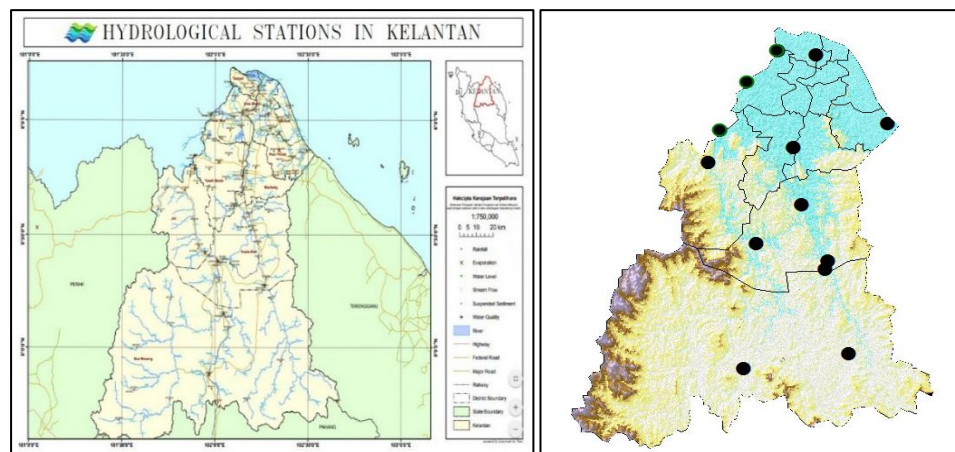


Figure 1: [Left] Map of hydrological station in Kelantan (source: DID) [Right] Location of MET station in Kelantan.

Table 1: MET station information throughout Kelantan State.

BIL	STATION	DISTRICT	LATITUDE	LONGITUDE
1	Gunung Gagau	Gua Musang	4.756944	102.655556
2	Kg. Aring	Gua Musang	4.937500	102.352778
3	Kg. Laloh	Kuala Krai	5.308333	102.275000
4	Gua Musang	Gua Musang	4.879167	101.969444
5	Kg. Jeli	Jeli	5.701389	101.838889
6	Dabong	Kuala Krai	5.377778	102.015278
7	Tualang	Kuala Krai	5.275000	102.266667
8	Kuala Krai	Kuala Krai	5.534700	102.180556
9	Kusial	Tanah Merah	5.762500	102.150000
10	Jeti Kastam	Kota Bharu	6.133300	102.233000
11	Jenob	Tanah Merah	5.832778	101.883056
12	Rantau Panjang	Pasir Mas	6.022500	101.974978
13	Pasir Putih	Pasir Puteh	5.859700	102.494444
14	Kuala Jambu	Tumpat	6.149278	102.092750

### 3.3 Precipitation Data

The climate information was obtained from 14 meteorological stations located throughout Kelantan as shown in Table 1. The data include the latitude and longitude for each station associated with hourly records available throughout the one week disaster. The rainfall inverse interpolation surface was created based on Inverse Distance Weighting method.

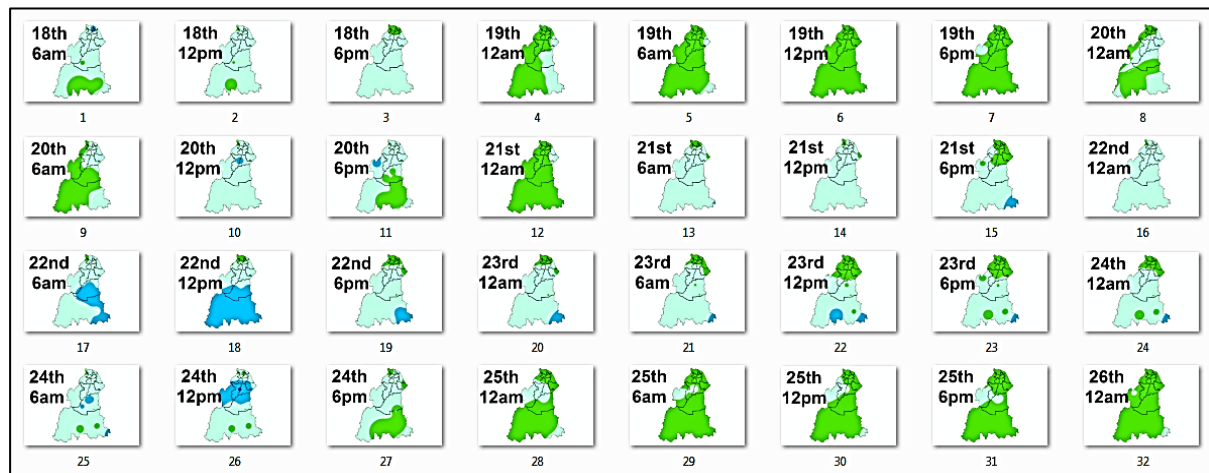


Figure 2: Interpolated rainfall data in Kelantan.

Table 2: Legend of the categorization of rainfall intensity for the interpolated rainfall data. (Source: MET Malaysia)

Categorization of Rainfall Intensity (in one hour, mm)			
Light	Moderate	Heavy	Very Heavy
1 – 10	11 – 30	31 – 60	>60

The interpolation process applied the range provided by the DID. This range is divided into four (4) basic categories – Light, Moderate, Heavy and Very Heavy which were measured in one hour average throughout a day. In this research, the implementation of rainfall intensity were made in 6 hours average, thus there are four (4) readings in a day.

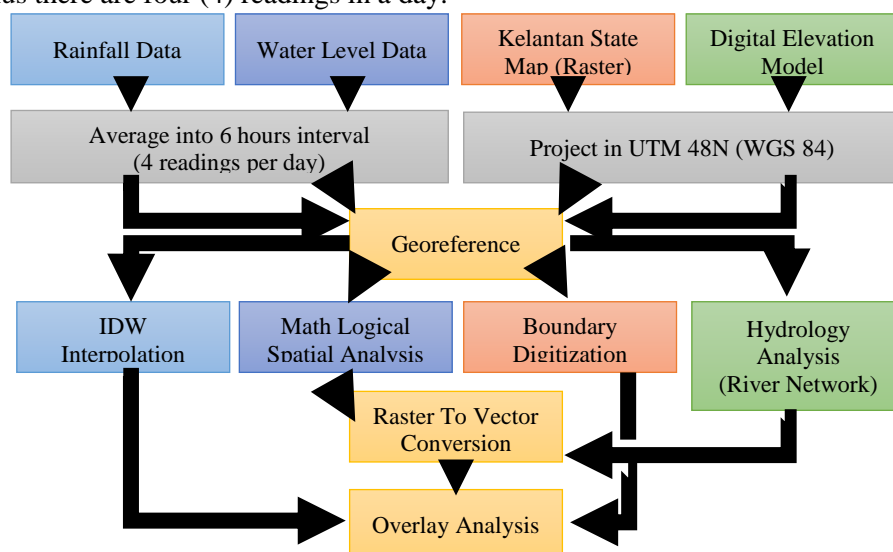


Figure 3: General flowchart undertaken to develop risk map

### 3.4 Method

The whole process started with four (4) data which were acquired from four (4) different sources. The rainfall data was obtained from MET Department of Kelantan, water level data was obtained from DID of Kelantan, Kelantan state map was obtained from Tourism Department of Malaysia, and ASTER digital elevation model (DEM) from USGS Earth Explorer web service. Basically they can be categorized into two (2) types of data, the tabulated data and spatial data. The tabulated data was first calculated into 6 hours interval from previously 1 hour interval and georeferenced onto the newly projected Kelantan State Map and DEM. The average rainfall data then were interpolated using Inverse Distance Weighting methods and reclassified into the ranged provided by MET Department. The DEM was then undergone a series of process to extract the river information and analysed in terms of its river intensity. Then the study area were narrowed even further into the highest affected district. The boundary of the district were digitized and used as reference boundary in clipping all other layers. The DEM is overlaid with the water level data to produce the area affected with floods using Math Logical spatial analysis and converted into vector format. Lastly, all layers were overlaid and analysed in terms of its temporal trend.

## 4. Result and Discussion

There were 64 maps representing 32 time intervals during the eight (8) days flood occurrence in Kelantan during the monsoon season on December 2014. Based on the Figure 4 (left), there are many huge rivers flowing from the higher elevation of the south and south-west of Kelantan. As it move towards the lower elevation which is the northern Kelantan, the volume of water getting bigger as the river meets with other smaller river. Figure 4 (right) represent the intensity of water volume and river intersection once the rivers met. The district that held the biggest intersection of rivers is Kuala Krai district. Thus the focus of flood is further focused on this district.

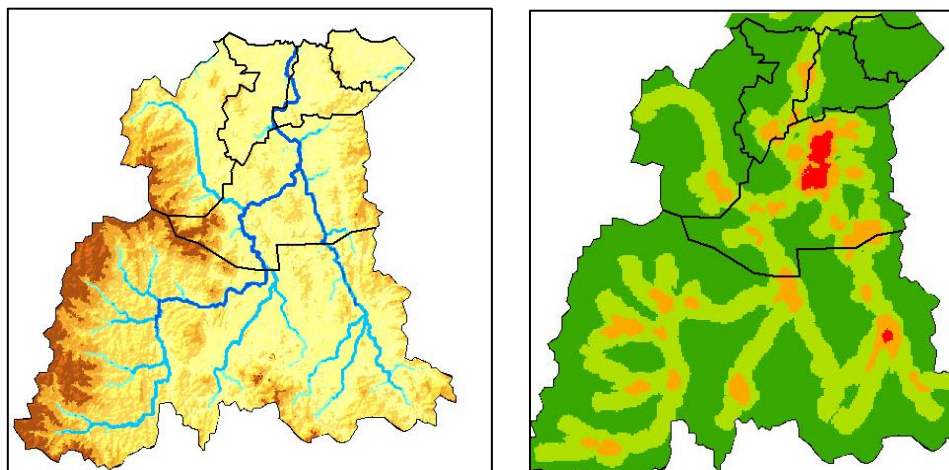


Figure 4 : [Left] River network generated from DEM. [Right] Intensity of river water volume.

The trend of water level in Kuala Krai district has an undulation of 15 meters in height. The water level has a few influence in its rises but the main cause is the rainfall. The rainfall might occurs in other places, but as it move towards the sea, it will eventually meet and combine with other rivers. Therefore, although the meet area does not raining, but due to the rainfall in higher ground, the flood might still occurred. Begin from the first interval (6 hours) of 18<sup>th</sup> of December from 12am until 6am, the water has already rises to 25 meters in height, then it lowers slowly until the end of 20<sup>th</sup> December and start to ascend until 25<sup>th</sup> December with the water level almost 35 meters.

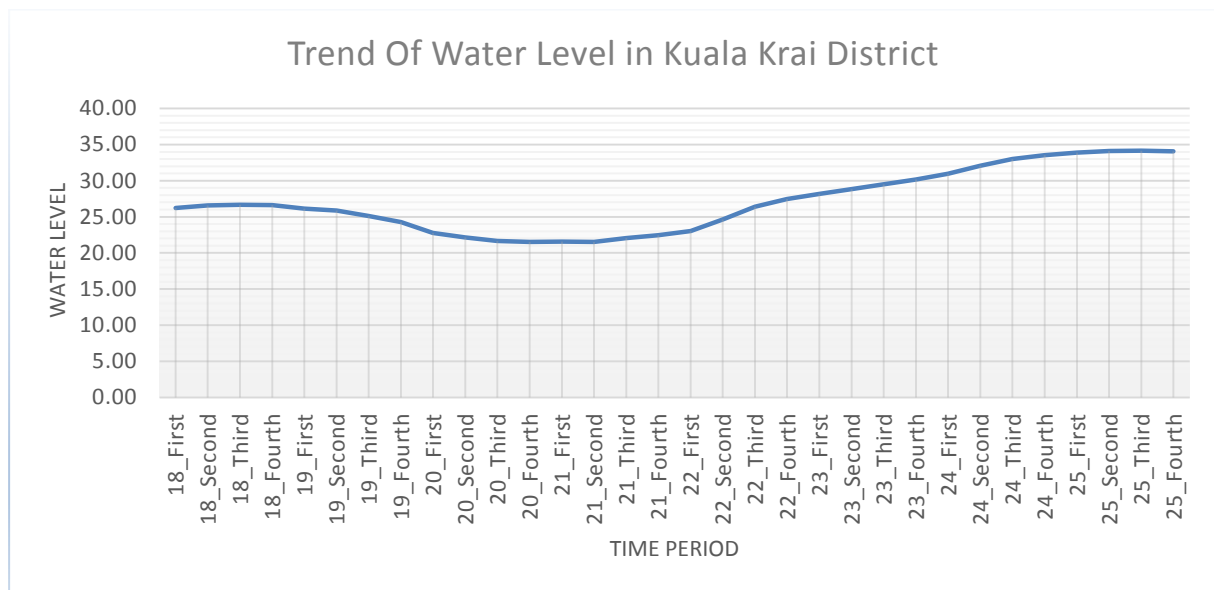


Figure 5: Graph shows the trend of water level in Kuala Krai District

Kuala Krai district approximately in the middle of Kelantan where it held three (3) major river called as Galas River and Lebir River. This river meets in the center of Kuala Krai district and flow in a river called as Kelantan River. The width of the mouth of Galas River is more than 180 meters while Lebir River is approximately 145 meters, this indicates that it held huge volume of water. Figure 6 shows the flood occurred in Kuala Krai district. Top left figure shows the water level recorded is at its lowest point which is slightly more than 20 meters. This is due to the least rainfall for the past two (2) days in the whole state of Kelantan especially in the southern part. But then the water level started to rise back again and this time it reaches the highest point of flood level which is almost 35 meters. This is due to the continuous raining for four (4) days in most part of Kelantan from the dawn of 21<sup>st</sup> December until the dusk of 24<sup>th</sup> December, and still continue in Jeli and Kuala Krai district for another one day (Figure 2). Although the rain completely stop or at its least during the 25<sup>th</sup> December, the water level kept on rising as the water flow downwards to the northern area.

On the bottom left side of the meander is the town of Kuala Krai. The distance between the points of two river intersection to the town of Kuala Krai was just one kilometre away. Based on the flood figure shown on bottom right, this town was highly affected by the flood as the water engulf major part of the town and also the access to the area. Although the flood occurrence is only during the monsoon season, but in visual interpretation, this town is the most hazardous area in Kuala Krai district. On the other part of the river, the area on the left side of the river is free from flood.

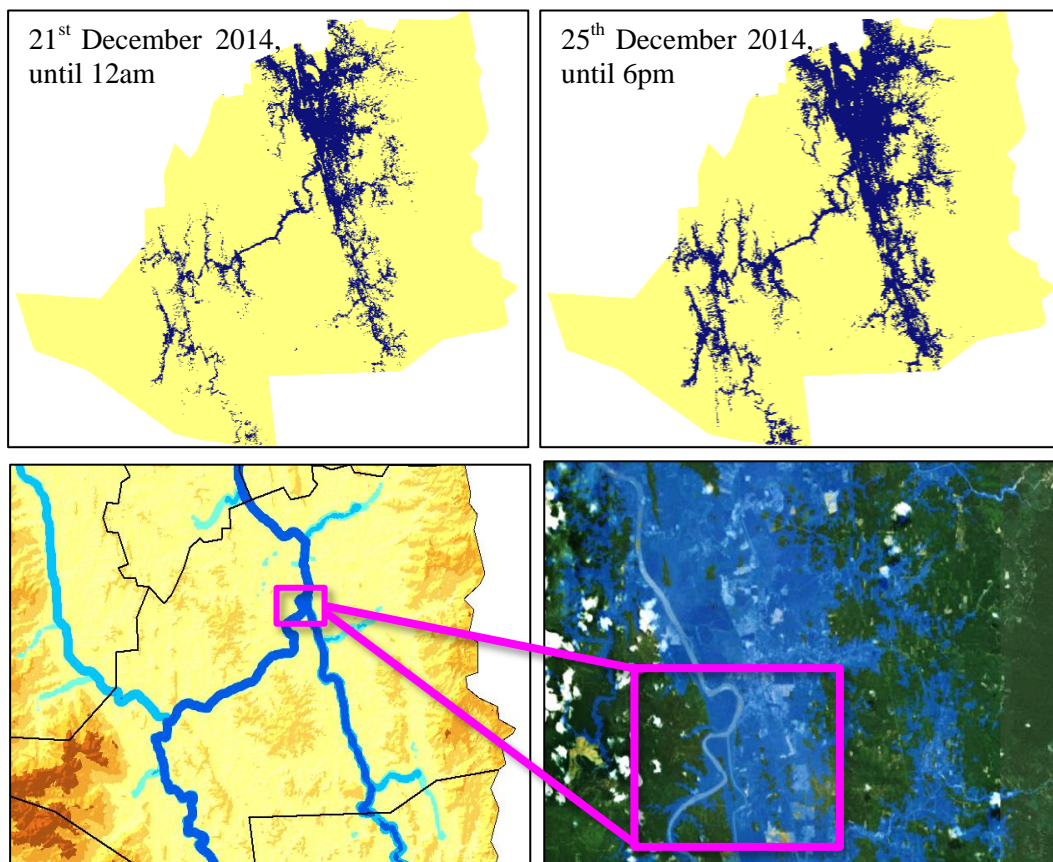


Figure 6: [Top Left] The lowest water level. [Top Right] The highest water level. [Bottom Left] The intersection of Galas River and Lebir River. [Bottom Right] The town of Kuala Krai which were affected by flood (in blue colour)

## 5. Conclusion and recommendation

The study area of Kelantan State gives a clear indicator of hazard area based on precipitation and water level data. Figure 6 shows the area of a districts that need to be given the highest priority in evacuative action. The flood occurrence based on the bottom right figure which were presented in dark blue colour represents the high potential area for flood. The area is highly vulnerable as the water from the higher ground moves and fill the area continuously. Towards the 25<sup>th</sup> of December, where the rainfall on most districts has subsided, the flood still increases and reach its highest reading. Based on the figures, the potentiality of flood area decreases as the elevation of the ground increase toward southern part and further away from the river. This result could be a valuable tool for assessing flood risk in the future. For future study, the flood risk study can be further improve with the factors of river depth, sedimentation and watershed along the river, together with additional information of astronomical tides. These information can be overlaid together to further relates the causes of extreme rises of water and study for future predictions and mitigation plan.

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