DEVELOPMENT OF FLOOD RISK MAP AT KUANTAN USING GEOGRAPHICAL INFORMATION SYSTEM

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To

My Family

For supporting and encouraging me through this entire journey

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ABSTRACT

The purpose of this study is to develop the flood risk map in Kuantan. The heavy prolonged rainfall in Kuantan has showed an increasing flood disaster over a year. Geographical Information system (GIS) is integrated with AHP is used to generate the potential flood risk area. Flood map was develop by applying data Digital Elevation Model (DEM) and Landsat 8 download from United States Geological Survey (USGS) to generate the slope map and land use map. Soil type map was obtained from Department of Survey and Mapping *(JUPEM*) and rainfall intensity data from Department of Irrigation and Drainage (DID). Rainfall distribution map in study area was generated in ArcGIS software using Inverse Distance Weighted (IDW) interpolation method. The spatial analysis and AHP analysis was used to score and compute weights of each criteria. Score for each criteria based on judgement to the parameter risk level against flooding. Using AHP, the percentage derived from the parameters were land use type is 41.55%, slope 28.95%, rainfall 16.93% and soil type is 12.58%. The value of consistency ratio is 6.9% was acceptable and indicate the judgement for each parameter is consistent. Flood risk areas were generating using flood risk index calculation. The result shows that, land use change, slope degree, rainfall intensity and soil type have significant influences on the flood mapping. The flood risk map using AHP was matched to an actual flood mapping developed by DID in determining potential location of flooding.

ABSTRAK

Kajian ini bertujuan untuk membangunkan peta risiko banjir di Kuantan. Curahan hujan lebat yang berterusan di Kuantan menunjukkan peningkatan bencana banjir saban tahun. Sistem Informasi Geografi diintegrasikan dengan Analisis Hirarki Proses *(AHP)* untuk menghasilkan kawasan berpotensi banjir. Peta banjir dibangunkan dengan mengaplikasikan data model ketinggian digital *(DEM)* dan *Landsat 8* yang dimuat turun dari *United States Geological Survey (USGS)* untuk menghasilkan peta kecerunan dan peta guna tanah. Peta jenis tanah diperolehi dari Jabatan Ukur dan Pemetaan Malaysia (JUPEM) dan curahan hujan diperolehi dari Jabatan Pengairan dan Saliran (JPS). Peta taburan hujan di kawasan kajian dihasilkan mengunakan kaedah interpolasi *Inverse Distance Weighted (IDW)* dalam perisian ArcGIS. Analisa keruangan dan AHP telah digunakan untuk menentukan skor dan pengiraan pemberatan setiap kriteria. Skor setiap kriteria adalah berdasarkan pertimbangan terhadap tahap risiko parameter terhadap banjir. Dengan menggunakan AHP, peratusan setiap parameter diperolehi iaitu jenis guna tanah ialah 41.55%, keceruanan ialah 28.95%, hujan ialah 16.93% dan jenis tanah ialah 12.58%. Nilai nisbah konsisten ialah 6.9% adalah memuaskan dan menunjukkan bahawa pertimbangan setiap parameter adalah konsisten. Kawasan berisiko banjir dihasilkan dengan menggunakan kaedah pertindihan pemberatan di dalam ArcGIS. Hajil kajian menunjukkan bahawa pembangunan guna tanah, ketinggian cerun, keamatan hujan dan jenis tanah mempunyai pengaruh terhadap pemetaan banjir. Peta risiko banjir dengan menggunakan kaedah AHP mempunyai persamaan dengan peta banjir sebenar yang dibangunkan oleh JPS dalam menentukan lokasi yang berpotensi untuk banjir.

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LIST OF ABBREVIATIONS

DID	Department of Irrigation and Drainage
GIS	Geographic Information System
DEM	Digital Elevation Model
MCDA	Multi-Criteria Decision Analysis
AHP	Analytical Hierarchy Process
SRTM	Shuttle Radar Topography Mission
LOB	Left Over Bank
ROB	Right Over Bank
HEC	Hydrologic Engineer Center
HMS	Hydrologic Management System
RAS	River Analysis System
USGS	United States Geological Survey
IWMS	Integrated Water Management System
USDA	United States Department of Agriculture
JUPEM	Department of Survey and Mapping
RSO	Rectified Skew Orthomorphic
IDW	Inverse Distance Weighed
NASA	National Aeronautical and Space Administration
ARI	Annual Recurrence Interval

LIST OF SYMBOLS

CR	Consistency Ratio
CI	Consistency Index
RI	Random Consistency Index
λ_{max}	Principle Eigenvector
n	Total number of criteria
K	Flood risk value
W	Weighing value of criteria
X	Scoring value

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Flood is natural phenomenon expected to become more frequent in recent years especially in urbanization area. It is a natural event or occurrence when water overflows or inundates land that is normally dry. Climate change is also expected to increase the intensity of rainfall events. The frequency of flood is change due to human activities. The risk of flooding in urban and coastal areas is likely increasing urbanization in a flood plain. Floods often have devastating impacts to economic; environment includes loss of human life.

According to the Department of Drainage and Irrigation Malaysia (DID), approximately 29, 800 km2 in Malaysia covered by flood every year. Malaysia exposed to the monsoons season and heavy rainfall throughout the year. Kuantan experienced a disastrous flood in 1971, 2011 and 2013 due to prolonged heavy rainfall and land use development. The recent research shows the factors are land use degradation, heavy rainfall and poor drainage system (Zaidi *et al*., 2014). Kuantan received heavy rainfall during northeast monsoon and lead to severe flood resulting inundation of low-lying flood plains. Kuantan River passed 1630 km2 area and start from Sungai Lembing passing through city and discharge into the South China Sea.

Although there is still a lack of comprehensive study, the contribution of these factors at the risk to flooding. Hashim (2012) found that land use patterns change significantly starting in 1980 until 2002, river straightening and embankment construction increase the peak discharge at Panching and Isap River, Kuantan.

As an area expands to cope with population growth, land use changes to urbanization area are unavoidable. The rate of population growth has been higher in areas at risk of flooding. Climate change, increasing population growth and economic rising are predicted to exposed an area to flood hazard (Guneralp *et al*., 2015). The Department of Statistic Malaysia has indicated that Kuantan population expected to increase by 71.2% from 1980 to 2015 (Table 1.1 : Kuantan Population from 1980 - 2015). The high-density populated area increases the likelihood to flooding by increasing the urban expansion to flood plain area and capacity a drainage system.

Table 1.1 : Kuantan Population from 1980 - 2015

Year	1980	1991	2000	2005	2010	2015
Population	170,673	255,974	358,261	409,341	503,450	592,128

The heavy rainfall occurs in November to December 2013 causing 37,100 peoples in certain areas of Pahang, Terengganu, and Johor evacuated due to flooding (Weng Sang *et al*., 2015). Topography characteristics and hydrological properties of the area are environmental factors for the flood catastrophe. Flooding is a very common environmental hazard, because of flood plains and low-lying coasts and the development in flood plain (Smith and Petley, 2008). Apart from environmental factors, rapid and uncontrolled development may increase the impact of flooding disasters that cause losses in properties and human life.

Various method and tools are continuously study by researches as well as governmental and private sector to determine the risk factors and to reduce or eliminate the risk (Norén *et al*., 2016). Geographic Information System (GIS)

analysis and visual features often used in recent years for prediction flood prone areas and flood maps (Ozkan and Tarhan, 2016). The GIS has been proven as an effective for analyzing the hydrological aspects especially in mitigating the flood risk area. The GIS has a capability to stored attribute data using maps and has a function to organizing tools for a large database.

Various methods have been developed by researcher, municipalities and private sector for generating flood maps to predict hydraulic and hydrology modelling also to for flood risk mitigation planning. DID Sarawak has developed a flood map at Sarawak using InfoWorks River Simulation and LiDAR systems but the cost is higher due to time and labor cost to surveying a cross-section of the river (Bustami *et al*, 2009). Digital Elevation Model (DEM) is the most feasible method that retrieved from EarthExplorer website which is open access provided by United States Geological Survey (USGS) (Kuok *et al*, 2013). Mapping becomes tools by which researchers can check databases for instances to display the flooding risk factors such as topographic, slopes, contours, or land use features of an area. GIS is integrated with Multi-Criteria Decisions Analysis (MCDA) to estimate the of flood risk area. The spatial multi-criteria analysis use to score and show probability of flood risk area, while Analytical Hierarchy Process (AHP) use to calculate the priority weights of each factor (Fadlalla *et al*, 2015; Haryani *et al*, 2012; Nurdin and Suprayogi, 2015)

1.2 Background of Study

Flood occurrences seem to be getting more frequent in recent years especially in urbanization area. According to the DID Malaysia, approximately 29,800 km^2 areas in Malaysia covered by flood every year. Malaysia exposed to the monsoons season and heavy rainfall throughout a year.

Flood in Pahang expected to be worst since 1971. Recently, the years 2001, 2011 and 2013 has been considered to perceive worst flood disaster after 1971 (Zaidi *et al*., 2014). Flash floods have occurred more frequently in the Kuantan since 2009, with these types of floods often having a disastrous impact. The area alongside the river is low and more likely and frequent floods almost every year. The flood plain is the natural place for a river to dissipate its energy, and where the overflow water was temporarily stored. The development in this area increases the flooding risk exceeding to the flood plain. Flood occurrence in Kuantan also related to the natural phenomenon and human activities. The annual average rainfall in Pahang is 2650 mm per year.

The floods at Kuantan in December 2013 have caused heavy damages to economics, environment, and human lives. 22,291 victims in December 2013 were evacuated. Even though flood mitigation measures planned by DID, major floods event may seriously damage or destroy power plants, industrial plants, roads and bridges and may cause loss of lives, adverse ecological and environment impact.

1.3 Problem of Statement

They are several flood mitigation project implemented that have been adopted by DID, but the flood is a natural disaster is unavoidable. The government had to establish appropriate for implementing flood control works and flood relief operation such as blasting the estuary, to relief the flood to the sea. In addition, implementation of structural measures such as flood control dams, river improvements, is pumping installations to alleviate flooding in existing flood-prone areas. However, as more and more people live in flood plains, and the increasing properties and infrastructures, the potential for damage and loss are high.

DID has developed flood mapping to shows the area that affected by a flood. However, the flood mapping is only based on previous flood occurrence and 100 years ARI event. There is no solid research based on factors that influence to flooding. In order to determine the flood prone area, flood risk mapping with weighted parameters that contribute to flooding is developed. The integration between parameters and GIS becomes a new dimension on detecting flood risk area. Flood risk mapping at Kuantan is important to predict the possibility of an area affected and risk mitigation measures.

1.4 Aim and Objectives

This study aims to predict the potential flood risk area using spatial analysis with different rainfall intensity. In conducting this study, there are objectives to achieve;

i. To generate a land use map, slope map, rainfall map and soil map.
ii. To determine criteria weight values using Analytical Hierarchy Process.
iii. To evaluate flood risk map based on area.

1.5 Scope of Study

The scope and limitation of this study were explained in the following sub-sections.

1.5.1 Study Area

The study area is located in Kuantan district and has an area 303005.8 Ha located approximately Latitude 3^{o} 53’ N and Longitude 103^{o} 21’ E. Kuantan is the capital city in Pahang with a population over than 600,000 people. It has tropical climate and elevation ranging from 0 to 1495 m above sea level. Thus, the land use within this area is dominated by forest, particularly in a mountainous area. Precipitation occurs throughout the year with the heaviest in the monsoon season from October to February and temperature of 26.6 ^{o}C, and the annual rainfall is about 2650 mm per year.

The area consists of the wetland, clay soil, and mountainous area. The eastern part of the district is a coastal area with wetland area, which is low-lying land, and the western part is a mountainous area. Due to the landform, about 26% is a wetland, 34% is the area below 75 meters above sea level (flat area), 15% is between 76 to 150 meters, and 26% is above 150 meters or high area. The study area is passed by main rivers, namely Sungai Kuantan which is flows from West to East. The total area of the river basin is 2250 km^2. The river begins at the confluence with tributary from Sungai Lembing and Cereh. Kuantan river then flows southeast through Bukit Kuin, Pasir Kemudi, Kampung Padang, Sungai Isap, Permatang Badak and Tanjung Lumpur.

1.5.2 Analysis

This study involved the use of AHP and ArcGIS to generate flood risk map in the study area as this model rather simple and required fewer criteria compared to another model. In addition, the flood risk map represents the weighing values of criteria that have significant factors to flooding.

1.5.3 Data

In this study, the model using recorded annual rainfall data from 2011 to 2015. Elevation slope data generated from DEM and land use data generated from Landsat 8, both data was downloading from Shuttle Radar Topography Mission (SRTM) satellites. By overlaying the geographical data and hydrographical data, the total area of flood area is determined.

1.6 Significance of Study

The significant of the study is to develop the flood risk mapping using GIS in Kuantan, which is the previous study not using flood risk criteria that contribute to flooding. Flood map is a useful tool to provide information for risk mitigation and as tools to reduce flood damage (Tam *et al*., 2013). This study can provide preventive measures to avoid the anticipated floods problems to carry out an analysis of flood events before execution of any structural measures. This map will provide useful information on flood risk mitigation in land use planning.

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