MODELING FLOOD IMPACT ON RESIDENTIAL PROPERTY VALUE

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DEDICATION

This thesis is dedicated to my parents and friends.
For their endless love, support, and encouragement.

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ABSTRACT

In the context of the property market in Malaysia, environmental impact such as flooding is not clearly stated in the value of the property. It has not yet been ascertained whether flood factor affects buyer's preference and is taken into consideration in residential property transactions. This research examined the effect of flood on house price with special attention in high density areas such as Kajang city area in Langat River Basin, Malaysia. It aims to develop a flood impact model to assess the impact of flood on property value. This study used XP-Storm Water Management Model (XP-SWMM) software to establish a two-dimension (2D) flood map as well as the inundation area of the flood, and Statistical Package for the Social Science (SPSS) software to identify the relationship between the house value and flooding factor. The data include the property transaction from 2013 to 2018 and hydrological data such as precipitation and discharge (m^3/s) in the study area. Property transaction data from Valuation and Property Services Department was analysed using Pola Graph and Multiple Regression Analysis in SPSS. The simulation model was developed for Kajang city area. The flood simulation produced a streamflow graph that subsequently used in property impact assessment analysis. As an overall comparison, the peak flow and the shape of the hydrograph for the calibration and validation works are in good agreement. The study indicates that flooding always has a negative impact on property value, which the results showed a decrement in value by 7% on average every year starting from 2013 to 2018. There is also a slight difference in value between property in flood free and flood liable areas. This flood model impact provides a concrete assessment of the flood impact on property value, and such data is useful to guide professionals to determine the property value in flood-prone areas and also to potential buyers in making an informed decision in real estate investment.

ABSTRAK

Dalam konteks pasaran hartanah di Malaysia, kesan alam sekitar seperti banjir tidak dinyatakan dengan jelas dalam menilai suatu hartanah. Masih belum dapat dipastikan sama ada faktor banjir menjejaskan keutamaan pembeli dan diambil kira dalam urus niaga hartanah kediaman. Penyelidikan ini mengkaji kesan banjir terhadap harga rumah dengan perhatian khusus di kawasan berkepadatan tinggi seperti kawasan bandar Kajang di Lembangan Sungai Langat, Malaysia. Ia bertujuan untuk membangunkan model impak banjir untuk menilai kesan banjir terhadap nilai hartanah. Kajian ini menggunakan perisian *XP-Storm Water Management Model* (XP-SWMM) untuk mewujudkan peta banjir dua dimensi (2D) serta kawasan yang terlibat dengan banjir, dan perisian *Statistical Package for the Social Science* (SPSS) untuk mengenal pasti hubungan antara nilai rumah dan faktor banjir. Data yang digunakan termasuk transaksi hartanah dari 2013 hingga 2018 dan data hidrologi seperti taburan hujan dan aliran air (m^3/s) di kawasan kajian. Data transaksi hartanah daripada Jabatan Penilaian dan Perkhidmatan Harta telah dianalisis menggunakan Graf Pola dan Analisis Regresi Berganda dalam SPSS. Model simulasi dibangunkan untuk kawasan bandar Kajang. Simulasi banjir menghasilkan graf aliran strim yang kemudiannya digunakan dalam analisis penilaian kesan hartanah. Sebagai perbandingan keseluruhan, aliran puncak dan bentuk hidrograf untuk proses kalibrasi dan validasi adalah dalam persetujuan yang baik. Kajian menunjukkan bahawa banjir sentiasa memberi kesan negatif terhadap nilai harta tanah, yang mana keputusan menunjukkan penurunan nilai sebanyak 7% secara purata setiap tahun bermula dari tahun 2013 hingga 2018. Terdapat juga sedikit perbezaan nilai antara harta tanah bebas banjir dan hartanah di kawasan banjir. Impak model banjir ini memberikan penilaian konkrit tentang kesan banjir ke atas nilai hartanah, dan data sedemikian berguna untuk membimbing profesional menentukan nilai hartanah di kawasan yang terdedah kepada banjir dan juga kepada bakal pembeli dalam membuat keputusan yang baik dalam pelaburan hartanah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASM	-	Academy of Science Malaysia
ANOVA	-	Analysis of Variance
ARI	-	Average Recurrence Interval
CFE-DM	-	Centre for excellence in Disaster management
CRED	-	Centre for Research on the Epidemiology of Disaster
DID	-	Department of Irrigation and Drainage
DEM	-	Digital Elevation Model
DoA	-	Department of Agriculture
EPA	-	Environmental Protection Agency
EXTRAN	-	Extended Transport Model
FDA	-	Flood Damage Assessment
GIS	-	Geographical Information System
HPM	-	Hedonic Pricing Method
HEC-RAS	-	Hydrologic Engineering Centre – River Analysis System
IDF	-	Intensity Duration Frequency
IWRM	-	Integrated Water Resources Management
IRBM	-	Integrated River Basin Management
IFM	-	Integrated Flood Management
IDW	-	Inverse Distance Weighting
JUPEM	-	Jabatan Ukur dan Pemetaan Malaysia
JPPH	-	Jabatan Penilaian dan Perkhidmatan Harta
KS	-	Kolmogorov Smirnov
MSE	-	Mean Square Error
MRA	-	Multiple Regression Analysis
MSMA	-	Manual Saliran Mesra Alam
NAPIC	-	National Property Information Centre
NFIP	-	National Flood Insurance Program
NSE	-	Nash Sutcliffe Efficiency
RMSE	-	Root Mean Square Error
ROW	-	Right of Way

RSS	-	Residual Sum of Squares
SRTM	-	Shuttle Radar Topography Mission
USGS	-	United States Geological Survey
VPSD	-	Valuation and Property Services Department
VIF	-	Variance Inflation Factor
WTP	-	Willingness to Pay
XPSWMM	-	XP Storm Water Management Model

LIST OF SYMBOLS

d		Storm duration
F_k		Flood factor
i		Average rainfall intensity
N		Data counts
N_j	-	Neighbourhood
P_h	-	House price
Q		Observed – Simulated
Qo		Observed
Qs		Simulated
S_i		House Features
T		Average recurrence interval
Wi		Inverse square of distance
Zi		Weight of a point differs
β		Intercept / coefficient
ε	-	Error
$\sum$	-	Sum of
λ, K, θ, and η	-	Fitting constants

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

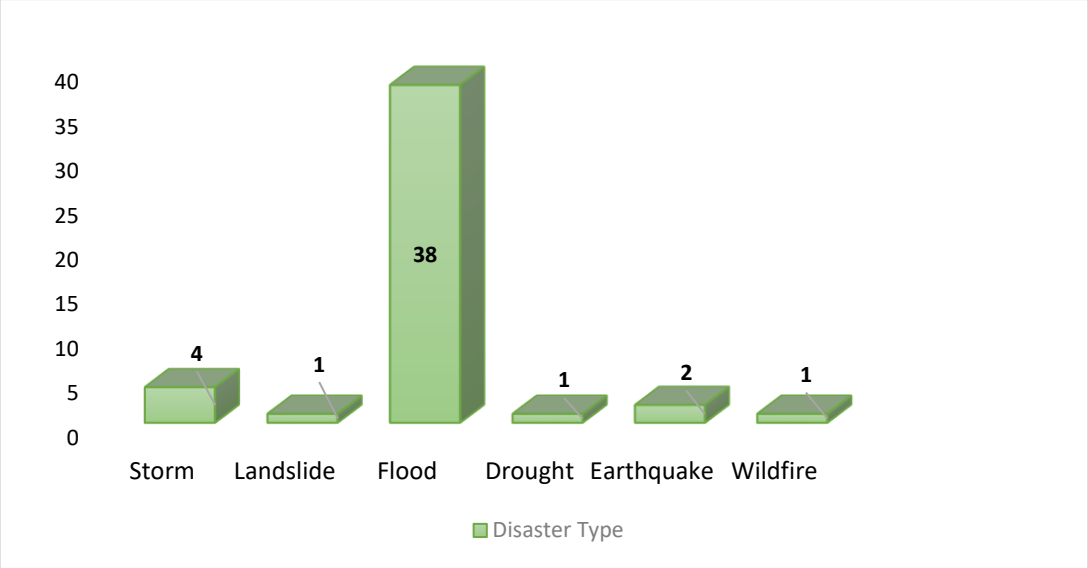

Figure 1.1 Disaster Statistics in Malaysia 1998 – 2018 (Source: (CRED, 2018)

The United Nation (2015) has noted that flood events are one of Malaysia's most frequent natural disasters with 62.5%. From 1998 to 2018, floods became the majority of natural disasters in Malaysia compared to other disasters like landslides, drought, forest fire, earthquakes and tsunamis (CFE-DM, 2019). Figure 1.1 shows that floods have the highest record compared to other natural disasters such as landslides, storms, and earthquakes. This is because Malaysia is in the eco-region zone where the northeastern and southwest monsoon wind changes will cause Malaysia to experience rain.

Floods are part of a natural disaster. Natural disasters are defined as a catastrophe due to natural phenomena and human activity (Mohamed Shaluf, 2007).

Besides that, floods can be defined as a situation where an area is flooded and cause damage and be categorized as one of the natural disasters (Pustaka, 2007).

Floods are one of the five natural disasters that often happen in this country, apart from landslides, wildfires, oil spills and so on. Floods that hit the country can be categorized into flash floods and monsoon floods. The climate change phenomenon also contributes to the uncertainty of intensity and the magnitude of a weather phenomenon that can record extraordinary (extreme) conditions. Flooding can occur due to various factors such as heavy rainfall, high tide, obstruction of water flow in the drainage system as well as shallow river problems. Flooding is also caused by excessive flow of water may be due to rain or mud floods because of the land use changes (JPS, 2018). The flood event duration occurs either long or fast for flood water receding depending on the condition of the river or the terrain of the place. It can happen in a few hours or up to a few days. According to Tajul (2005), the estimated loss and damage is RM100 million due to the natural disaster occurring in Malaysia, which is Tsunami.

Uncontrollable human activities in nature also cause the occurrence of this flood. Among these is the construction of a mega project in a massive way to restrict river drainage and solid waste disposal by those who operate the manufacturing industries (Amaglo *et al.*, 2022). Typically, naturally occurring events such as floods may happen in areas near the river. However, a few still consider that floods are a rare phenomenon of nature and not too risky as a result of limited research reporting on this crucial issue (Pottinger and Tanton, 2011).

The increase in population in a country is also one of the factors leading to rapid development in urban and rural areas, including the construction of public facilities (Nation, 2018). Eves (2004), mention that the increase in the number of residents, thus creating demand for residential and commercial properties, has become the attraction of many developers to carry out development. However, the area is not suitable for development. This has resulted in a change in water drainage due to uncontrolled development resulting in the property being exposed to flood risk (Amaglo *et al.*, 2022).

The country is still facing various flood-related issues. Flood events significantly impact social and economic aspects, especially in developed and high population density, where it results in loss, property damage, and even loss of life. According to an update on the 'Flood Hazard Maps' study in 2014, Malaysia's floodplain area is 30,000 sq. km which is 9% of the total land area and affects 4.8 million people with an average damage value of RM1.5 billion a year (DID, 2014).

Among the natural phenomena that negatively impact property values are floods. Malaysia often faced flood problems that can be expected to occur every year in several states, including Selangor. Until 2018, Malaysia has already faced 51 flood events in the last two decades (CFE-DM, 2019). This has attracted the attention of many parties to study the cause of flood and the damage or loss that must be incurred because of the flood. The Malaysian Drainage and Irrigation Department classified the flood in Malaysia into two categories, monsoon flood and flash flood (Drainage, 2012). Those floods are different in terms of the period taken for the flow to return to a normal level. Monsoon flood can take a month, while flash flood only takes several hours to return to normal level (Shaharuddin *et al.*, 2006).

As for the impact of floods on property, it actually has a negative impact especially if it happens frequently and is a major flood which involves property loss. However, flood events only have a temporary effect in terms of physical damage to the property, but not on the value of the property. Property values in the area will have a huge impact with many experiencing declining prices and difficulty in getting demand for sale. (Beltrán *et al.*, 2019) in his study demonstrates that the price of affected property is lower than non-flooded property by average of 24.9% after the flood event occur.

Previous studies conducted by Beltrán *et al* (2019), found that the value of the property located in the flood-free area was higher than the property value in the flood-prone areas. This is because of the natural phenomenon of floods that can cause severe damage such as damage to floor finishing, damage to electrical appliances or furniture (Jiménez-Jiménez *et al.*, 2020). Investors also have to bear high risks such as property

value drops when investing in properties within flood-prone areas than in areas not affected by flood (Eves, 2004).

The effects of floods on property values and prices are actually indirect and can take a long time to recover and return to normal even if the flood problem has been resolved. Flood impact can diminish over time, especially when flooding occurs infrequently (Dudzińska *et al.*, 2020). This is actually related to the demand that will drop sharply for properties in the area that have been known to be flooded. The flood-affected properties in the lowest price-quartile seem to recover in 6–7 years. However, for properties in higher price quartiles, the recovery time looks to be even shorter (Beltrán *et al.*, 2019). Prospective buyers will try to avoid buying in the flooded area and will look for the surrounding area as an alternative if they still want property in the area. This in turn makes the owner will have difficulty in selling at the expected price. When this happens, there will be owners who have more ability to buy elsewhere to sell their homes at a lower price because the important thing is to be able to sell the property. If this happens frequently and creates a lot of transactions below the actual price, the property values in the area will follow the low prices and in turn the property values will be low and the property market in this area will collapse.

The weakness of irrigation and drainage systems in a development project may result in floods occurring easily in that area. The infrastructure system is a crucial element in development to ensure that the water supply is not overflowing, thus will not cause floods.

1.2 Problem Statements

The river drainage flows directly into the sea, where it is estimated that 85 of the drainage will be exposed to flood risk (DID, 2017). According to Eves (2004), the level of flood risk varies between areas adjacent to rivers and areas not near the river. Uncontrolled development can cause floods if there are weaknesses in infrastructure systems such as drainage. This also affects property value in the surrounding area.

Property owners are forced to bear a lot of harm due to floods. According to a study conducted by Chen *et al.* (2011), 30% of the damage to residential property was recorded because of floods. In Malaysia, the track of historical flood damage data is not well documented and is difficult to access (Romali and Yusop, 2021). According to the DID flood report in 2020, the area under risk of floods is 10.1 percent of Malaysia's total area, or 33,298 km2, with a population of 5.7 million. Meanwhile, the annual flood loss is expected to be RM1.15 billion (DID, 2020).

Department of Irrigation and Drainage of Malaysia also directed the preparation of Floods Hazard Map across the country. Enormous challenges need to be addressed in implementing flood control and management, but these are global challenges faced by most countries around the world. Nevertheless, some countries have gone a step further and have overcome this great and global challenge. Among them are the Netherlands and Japan which are synonyms for flood mitigation structures. At the same time, Australia and some European countries are well known for their flood control and management concept. It can be seen that with such continuous efforts, systematic and practical flood control and management system has been developed.

Similarly, in Malaysia, efforts for flood management have never ceased even from giving up on the concept of integrated flood management through the approach of IWRM (Integrated Water Resources Management), IRBM (Integrated River Basin Management), and IFM (Integrated Flood Management) (ASM, 2017). The latest approach also highlights the development of river and floodplain models in non-structural flood management. In line with the latest technological capabilities, as a result, the models used can understand and predict patterns of rivers and floods that have and will occur. The significance of this research is to develop flood simulation model in study area thus calibrate and validate the model which stated in objective one (1) and objective two (2).

Several studies have shown that impact of environmental-related causes effects on property value. Yet, very little study has been conducted on the impact of flood on house values in Malaysia, notwithstanding concern about possible life threats and

health hazards is distressing. The purpose of this research is to run a statistical analysis in estimating the impact of floods on property value which stated in objective three (3).

There is a method that can be used to evaluate the annual flood damage, which is the Flood Damage Assessment (FDA). This FDA is an important tool in evaluating the possible impact of flood (Olesen *et al.*, 2017). It is also important when assessing flood mitigation options. This appraisal is more towards expressing a damage cost assessment (Zhou *et al.*, 2012). A framework that has been proposed by Zhou *et al*., (2012) stated that the outcome for this Flood Risk Assessment is the expected annual damage caused by the flood.

Valuation experts are basically aware of this flood risk and just take it into account based on their instinct and experiences by discounting the property. However, the exact flood factor derived from comprehensive analysis would be a better alternative that can be used to assess the property value damage. Besides that, the lack of uniformity in the assessing damage process may result in the valuation process in the current market value assessment might be different (Zulkarnain, 2018).For the analysis of the flood impact on property values, three other methods can be applied extensively: repeat-sales method, multiple regression, and hedonic pricing model (HPM) method. That method had been applied widely in studies in Europe, New Zealand, Australia and the United States as shown in Appendix A.

1.3 Research Question

Several questions have been developed based on the problem statement above which are:

(a) What is the current flooding case situation in Malaysia?
(b) How to develop a flood simulation model for urban area?
(c) What factor or attributes that contribute to flood modelling process?
(d) How to investigate the flooding impact on property?

(e) What is the current property market situation in Malaysia?

(f) How the damage that affect the property during flooding affect property value?

(g) What is the statistical analysis method that can be applied in property impact assessment?

1.4 Aim and Objectives of the Study

The main aim of this proposed project is to study the impact of a flood on residential housing value by using Multiple Regression Analysis. Hence, this project was carried out to achieve the following specific objectives:

(a) To develop the flood simulation model at Hulu Langat River Basin (Merbau River) using XP-SWMM software

(b) To calibrate and validate the flood simulation model

(c) To evaluate the flood impact on residential property value in Kajang Area

1.5 Scope of the Study

The scope of the study focused on the simulation flood hazard model and the flood model impact on property values for Langat River Basin. Langat River Basin is one of the immediate development areas which consisted of important urban areas such as Bangi, Cheras, Kajang, Putrajaya and others, respectively. There are also two catchments: Semenyih and Hulu Langat, and eight water treatment plants to provide clean water supply to the consumers. However, this study focused on the Mukim Kajang area in the Hulu Langat catchment, as shown in Figure 1.2. Kajang is one of the developed areas in Hulu Langat area. This district often has flood cases reported every year mostly due to failure of the drainage system and rapid development surrounding the area. The drainage network, land use, contour, cross-section of the drainage and rainfall data are needed to simulate the model.

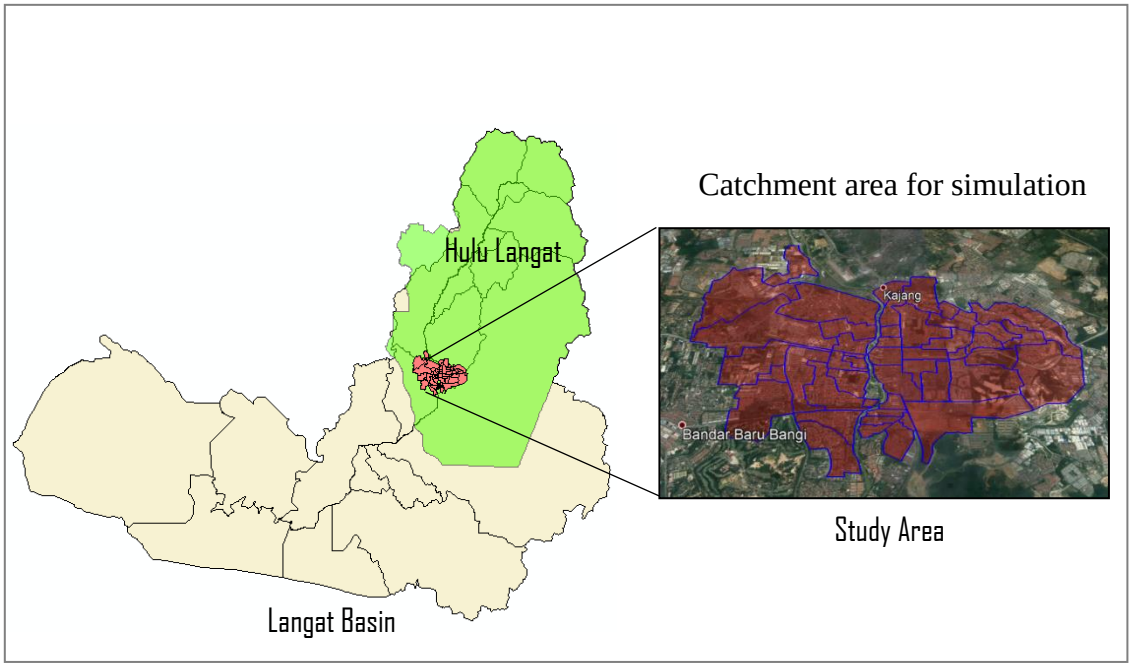

Figure 1.2 Study area

XPSWMM software was used in model development, mainly for hydrologic and hydraulic modelling that combines 1D calculations for upstream to the downstream flow with 2D land flow calculations. Therefore, what actually happens in the stormwater system when waters flow, populations increase, or disaster events hit can be seen. This simulation also used 30 years of data of the rainfall.

This study applied the Hedonic Pricing Method (HPM) for the flood impact model. This method used to assess the effect of property value due to flood hazards. In this model, property transaction data for the last five years were needed to see the price changes by considering the other factors that can also affect the property values. Other than that, this model just be applied to residential properties. In this HPM, a regression analysis were used by collecting data of any other buildings in the same area to determine the correlation for each attributes to the transaction price (Monson, 2009). All the buildings characteristics were combined to associate with the expected overall transaction value (Monson, 2009). These correlations were measured to determine the significance of those attributes and will be used to create a flood impact model. The variable used in this model were the year of the property, land area, building area, land title, flooding and non-flooding area, number of storey, number of

bedroom and the property value itself. Yet, this study will not consider the economic factor such as inflation and government policy. Indeed, there is no way to limit the number of variables that go into property valuation. However, depending on the scope and purpose of the study, it may be constrained.

There are several limitations in this study that will contribute to accuracy of the analysis result. Firstly, the result of this study does not represent the overall situation in Malaysia. This study was conducted at the Merbau River catchment in the Kajang City area. The aim of this study is to identify the impact of the flood on residential properties only and does not involve any other type of property. The result is only limited to 1-storey and 2-storey terrace houses within the property transaction data obtained from VPSD (Valuation and Property Services Department) from 2013 – 2018 only. Other than that, the economic factor was not taken into consideration in determining the impact and value of these properties.

Then, for the 2D map modelling, XP-SWMM software was used and for the property impact analysis, SPSS software was used. A different approach might show a different result. From the context of modelling license, there were several constraints that limiting the analytical result made which is the study area can just do up to 10000 cells or pixels. Besides that, inflow data input only up to 40000 lines. For the data collection, the property transaction data from the Valuation and Property Services Department (VPSD) was limited and incomplete. Some of the data provided are incomplete and need to be dismissed when performing regression analysis.

1.6 Significance of the Study

This study provides information such as the inundation area or the most affected area due to the flood to assist the relevant parties especially the Department of Irrigation and Drainage (DID). It will be useful for planning and designing a new flood mitigation facility due to floods events, to manage or assess hydraulic process and existing water control facilities. This study also can be used to identify the solution to the current and future flood events problem and control land use activities.

This study aims to investigate how the natural phenomenon of floods can affect the value of housing properties. In addition, this study is also conducted to reference relevant parties such as the government on the type of damage caused by floods to facilitate the process of assisting. For the integration of flood simulation and the impact of a flood on property values, this simulation assist in identifying the inundation area and the most affected area due to flood. From that result, the Hedonic Pricing Model will be applied to that area.

Furthermore, other parties such as non-governmental agencies, and residence can make this study as a reference to estimate the amount of reinstatement of the premises after the flood and for the purpose of investment. Additionally, this study will compare the value of a residential premise in flood liable areas and areas with no flood. Transaction data in the study area were collected to compare the value of the property. This flood simulation and value impact model can assist people in the flood zone and the buyer to take precautions and be warned on the property's stagnation due to flooding.

1.7 Chapters Organization

This research process consists of five (5) chapters approach:

(a) Chapter One: Introduction

This chapter consists of the background of study, problem statements, research questions, aim and objectives of the study, scope of study and significance of the study and its contributions.

(b) Chapter Two: Literature Review

This chapter contains the review of literature on the flood cases, water runoff behavior, model selection for the study, and also the similar overseas case study. For the flood factor, the scenario and the flood cause were discussed. This section also showed how the water runoff changes due to urbanization.

Besides that, fundamental on the software and method that used on hydrology and property analysis also discussed in this chapter.

Other than that, in order to give an idea on property market, this chapter present the property market movement and trend in Malaysia throughout the years. This chapter also showed the method in property assessment and the attributes that will affect the property value.

(c) Chapter Three: Methodology

Chapter three consists of the research approach, study area, the data used, method applied throughout the analysis, calibration and validation works and also the research flow chart. This part describes on the XP-SWMM which is the software that was used on the flood simulation analysis. For the property analysis, the regression works in SPSS software was presented.

(d) Chapter Four: Result and Discussion

In chapter four, it consists of the analysis and discussion on the results. The development of the flood simulation map and result for the calibration and validation of the analysis were discussed in this part. This chapter also showed the parameter value used in order to establish the simulation.

For the property impact study, the statistical analysis that run in SPSS software were showed in this chapter. This includes the normality test, descriptive analysis, pearson correlation, multicollinearity, hypothesis testing, one-way ANOVA and multiple regression analysis.

(e) Chapter Five: Conclusion and Recommendation

This chapter conclude the overall findings of this study. In this chapter also included the recommendation for the purpose of future study.

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