DEVELOPMENT OF RESIDENTIAL FLOOD DEPTH-DAMAGE CURVE FOR KUANTAN, PAHANG

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DEVELOPMENT OF RESIDENTIAL FLOOD DEPTH-DAMAGE CURVE FOR KUANTAN, PAHANG

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ABSTRAK

Pembangunan pesat dan pengurusan banjir yang tidak cekap adalah faktor utama kejadian banjir. Anggaran kerosakan banjir yang tepat diperlukan untuk memastikan pengurusan risiko banjir yang mampat. Banyak kajian tentang bahaya banjir telah dilakukan di kawasan yang rawan di Malaysia, namun, kajian tentang kerentanan akibat banjir adalah terhad terutama pada penilaian kerosakan. Oleh yang demikian, matlamat kajian ini adalah untuk menilai kerosakan banjir dan membangunkan lengkungan kerosakan kedalaman banjir untuk membantu penilaian risiko banjir di Kuantan, Pahang. Kajian ini memberi tumpuan kepada kawasan kediaman di Kuantan. Tinjauan temuduga telah dijalankan untuk mengumpul data kerosakan dan maklumat berkaitan mengenai banjir 2013 di Kuantan. Purata kerosakan isi rumah adalah RM 8,200 manakala purata kerosakan struktur adalah RM 2,200. Kerosakan struktur bagi rumah satu tingkat adalah sekitar RM 2,183 manakala purata kerosakan isi rumah adalah sekitar RM 8,062. Analisis regresi menunjukkan bahawa kerosakan kandungan dipengaruhi oleh jenis pekerjaan, dan bilangan tingkat bangunan manakala kerosakan struktur dipengaruhi oleh jenis bahan binaan dan jenis pekerjaan. Dengan R^2 0.92 untuk, keluk kerosakan kedalaman banjir yang diperolehi bagi kerosakan isi rumah adalah baik tetapi lengkung untuk kerosakan struktur adalah kurang memuaskan (R^2 = 0.53) disebabkan oleh pengumpulan data yang kurang baik. Keputusan yang diperoleh daripada kajian ini boleh digunakan untuk membantu perancangan pengurusan risiko banjir masa depan di kawasan kajian.

ABSTRACT

Rapid development and inefficient flood management is the main factor for the occurring of flood event. A precise estimation of flood damage is needed to ensure a compressive management of flood risk. Many studies on flood hazard had been done in prone area in Malaysia, however, the study on flood vulnerability is limited especially on damage assessment. Hence, the aim of this study is to assess the flood damage and to develop a flood depth-damage curve to assist in the assessment of flood risk in Kuantan, Pahang. This study is focusing on residential area in Kuantan. An interview survey was conducted to collect damage data and related information regarding the 2013 Kuantan flood. The average content damage is RM 8,200 while the average structural damage is RM 2,200. The average structural damage for single-storey house is around RM 2,183 while the average content damage is around RM 8,062. The regression analysis shows that the content damage is influenced by type of occupation, and number of storeys while the structural damage is influenced by the type of building material and type of occupation. With R^2 of 0.92 for content damage, the flood depth-damage curve obtained for is good enough but the curve for structural damage is poor (R^2=0.53) due to the poor quality of data collection. The results obtained from this study can be used to assist in the future flood risk management planning at the study area.

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R^2	Coefficient of determination

LIST OF ABBREVIATIONS

RM	Ringgit Malaysia
USD	United Stade Dollar
DID	Malaysian Drainage and Irrigation Department
HEC-RAS	Hydrologic Engineering Center- River Analysis System
ArcGIS	Geographic Information System
HEC-FDA	Hydrologic Engineering Center- The Flood Damage Reduction Analysis
HAZUS-MH	Hazus-Multi Hazard
FLEMO	Flood Loss Estimation Model
STATA	Statistical software (Statistic and Data)

CHAPTER 1

INTRODUCTION

1.1 Background of study

Floods are natural disasters that often hit our country especially in the East Coast states of Peninsular Malaysia which is Kelantan, Terengganu, and Pahang. Normally these states will experience the monsoon season at the end of each year. The heavy rain that occurred during the season caused floods in the area (Zaidi et al., 2014).

Floods occur as a result of drainage systems and sewers that are not able to accommodate the volume of excessive rainwater and take a long time to stop. Floods often hit low areas such as near the river. Lots of property destroyed as well as livestock and plants. Those involved like farmers will suffer a big loss. Floods can also be life-threatening. Many are drowning because of playing with the flood waters that flow. It's become more dangerous to people that do not know how to swim. A safety parameter has been taken to mitigate the damage caused by the flood in the future such as deepen the river since most of the floods occurred due to the ripening of the river.

The floods occurred mainly in the city due to the disposal of waste and industrial waste into rivers and ditches. To address this problem, awareness of the community should be disclosed so that these negative activities do not continue to be done such as having a river-loving campaign and so on. An effective flood mitigation measures has to be taken to overcome this flood problem. Structural flood control such as levees and dam had been implemented to mitigate flood. Nowadays, the implementation of non-structural options such as flood modelling, early warning system and flood risk management has been given more attention worldwide to reduce the impact of flooding (Du, 2011).

Flood risk assessment consists of two main elements which are flood hazard and flood vulnerability. Flood hazard is normally illustrated in flood inundation or flood extend maps, while flood vulnerability emphasizes the impact of flooding in flood damage map. In Malaysia, the study on flood vulnerability assessment is still limited especially on flood damage estimation. There are many methodologies for estimating the flood damage worldwide, however, there is no common methodology that is applied to estimate flood damage in Malaysia. Estimation of economic loss is essential to help the development of new housing away from the future flood disaster and reduce the damage loss. Therefore, with the aim to assist in the assessment of flood vulnerability, the purpose of this study is to assess the flood damage and to develop a residential flood depth-damage curve for Kuantan, Pahang. A relationship between flood damages and the local condition of the study area is obtained for future flood risk management planning.

1.2 Problem Statement

The east coast of Malaysia usually experiences a flood during the monsoon season. Kuantan is one of the cities that were affected since it is located at the east coast part of Malaysia. The unpredicted massive flood, recently in 2013 occurred due to prolonged heavy rainfall and land-use change brought serious risk to society, especially to low lying areas at Kuantan and Kemaman. Kuantan was severely distressed. Around 14,044 people were evacuated and major damages occurred in terms of electricity, road's structure, buildings, and belongings thus government suffered from the significant financial cost for repairing flood damages (Jamaludin et al., 2013).

Kuantan covers a large area of residential properties and have many different races and culture. There were many phases in Kuantan residential development thus Kuantan has different type of residentials from village house, terrace house, and bungalow house that is construct with different materials such as wood or brick. When the flood event occurs in 2013, several residentials in Kuantan has been hit by flood and the damage to each house may different according to house’s construction material.

Many flood hazard assessments had been done in Kuantan area to mitigate the risk of flooding. However, none flood vulnerability assessment is available. The main challenge in conducting the flood damage assessment is the insufficient of damage data. In many cases, floods occurred many years ago before the data is collected. This caused the data collected from the respondents to be quite inaccurate as some of the respondents were unable to recall exactly the flood durations and flood depth levels during the flood.

Hence, this study aims to assess the residential flood damages of 2013 Kuantan flood by collecting the flood information using face to face interview technique. The factors that effected the level of flood damage are investigated and at the end, a residential flood depth damage curve is established.

1.3 Objective

The objectives of this study are:

1. To assess the residential flood damages of 2013 Kuantan flood
2. To study the relationship between flood damages and socio-economic/ property characteristics of the study area
3. To establish a residential flood depth-damage curve for Kuantan

1.4 Limitation of study

This study is focusing on Kuantan River Basin. Kuantan district is in East Coast of Malaysia usually experience rain frequently at the end of the year. The Kuantan River Basin is an important watershed that crosses the state city of Pahang in Kuantan. It usually receives massive precipitation starting from November to March during the north-eastern monsoon season (Zaidi et al., 2014).

The estimation of flood damage was done by analysing the historical flood that occurred in Kuantan, limited for residential only. The study focusing on the estimation of direct tangible damage including the damage on building, furniture, plant and transportation. The damage is presented as economic losses such as the cost to repair or reconstruct the building, furniture and transportation. Also, the cost of the furniture that had been damaged.

1.5 Significant of study

The assessment of flood damage obtained from the field survey illustrated the damage experienced by the residents of Kuantan during the 2013 flood. The information is useful for further flood risk study in the study area. The factors that influenced the level of damage at the study area has been identified and will be given more priority in the future works. The main output of this study i.e. the flood depth damage curve presenting the association of flood damage and flood parameters of the study area. This curve is the main element needed in the modelling of flood damage. It is hoped that the outcomes from this study can help engineers and researchers in government, as well as private agencies in improving the flood management practice in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Flood is the common catastrophe that happens throughout the world. Flood is a large volume of water overflowing more than its normal boundaries, particularly over normally dry land. Flood usually occur at a location near to the river. Many factors influence the total of damages arising from a flood. The parameter aspects of floods affecting damage include flood depth, flood time of year, flood speed, flood duration, sediment load, and caution time (Mcbean, 1987).

Flood occurs due to many factors and one of the major causes of flood in Kuantan is due to heavy rainfall. It is observed that the Northeast Monsoon mainly influences the rainfall in the eastern coastal region of Peninsular Malaysia. Heavy rainfall had caused the river basin to rise resulting the increasing of outflow discharge. The Kuantan River Basin is one of the factors responsible for the floods caused by long-lasting heavy rains northeast of the monsoon, as it results in an excess of runoff exceeding the basin's capacity and leads to low area and hampered of the economic life and social of humans (Zaidi et al., 2014). The flood event occurs during late 2013 has seriously damage the residential area around Kuantan.

Assessing flood damage is important in mitigating flood risk. Damage assessment must be performed to assess measures that can be taken to mitigate flood damage. In addition to assessing flood damage, analysing the measures and reducing them to the condition without a project must be carried out. Analysis is very difficult without a clear and reproducible assessment of flood damage, and risk management is less reliable.

2.2 Flood characteristic

Flood is one of the environmental hazard examples resulting from water cycle inequality generally related with urban area development and inadequate drainage design (Schueler, 1994). The assessment of flood risk needs to account for various types of flooding. Flooding can be separated into four type which is groundwater, fluvial, pluvial and coastal. Various types of flooding have different characteristics (Olesen et al., 2017).

2.2.1 Fluvial

Fluvial flooding is caused by rivers. The level of contamination in river water be dependent on the attributes of the catchment and can be affected, for example, by the presence of industrial areas in the upstream reaches. Fluvial flooding is potentially associated with high water levels and speeds. Flow of water at high speed may also contain debris that may pose a risk to residents and structures (Olesen et al., 2017).

The scale of fluvial flooding depends on the degree of run-off from hillslopes to stream channels, the run-off rate of downstream in stream channels propagation, and how the run-off contributions from sub catchments and various hillslopes combine to generate the downstream flood hydrograph through the channel network Large floods in the river are mainly caused by heavy rainfall on frozen, wet or impermeable soil (Dadson et al., 2017).

2.2.2 Pluvial

During rain events, pluvial flooding is caused by overloading the drainage systems. Overloading occurs mostly as a result of cloud burst or intense rain events of long duration. It is important to assess the risk of infectious disease contracting by the citizen when assessing the impact of pluvial flooding, especially when combined sewer systems are installed in the field of interest (Olesen et al., 2017).

Pluvial flooding occurs after short, intense runoffs that cannot be evacuated or infiltrated to the ground rapidly enough through the drainage system. In areas that are not obviously susceptible to flooding, pluvial floods frequently happen with little warning. Recently, pluvial floods have been recognised as the type most probable due to climate change to increase in harshness. The pluvial floods are also the hardest to control because they are hard to predict and providing enough warning times is challenging. Due to the increased commonness of impermeable surfaces, extensive pluvial flooding is more expected to occur in urban areas (Houston et al., 2011).

2.2.3 Groundwater

Rising groundwater will lead to flooding of unpolluted water in the basements. The water table could reach the surface at low points on the surface where the water table is naturally at a shallower depth. This can cause the emergence of groundwater and potentially lead to groundwater flooding. Areas that tend to be most likely to groundwater flooding are typically located on or near aquifers in low areas. It should be noted that flooding of groundwater can occur wherever water saturates the underlying soil and geology. How quickly groundwater begins to emerge will influence what the ground is made of. Once groundwater reaches the surface, distinguishing between groundwater flooding and flooding from other sources can often be very difficult. Due to the large volume of water that has to flow away to lower the water table, groundwater flooding usually takes longer to subside. Some of the groundwater flooding mechanisms are shown in Figure 2.1.

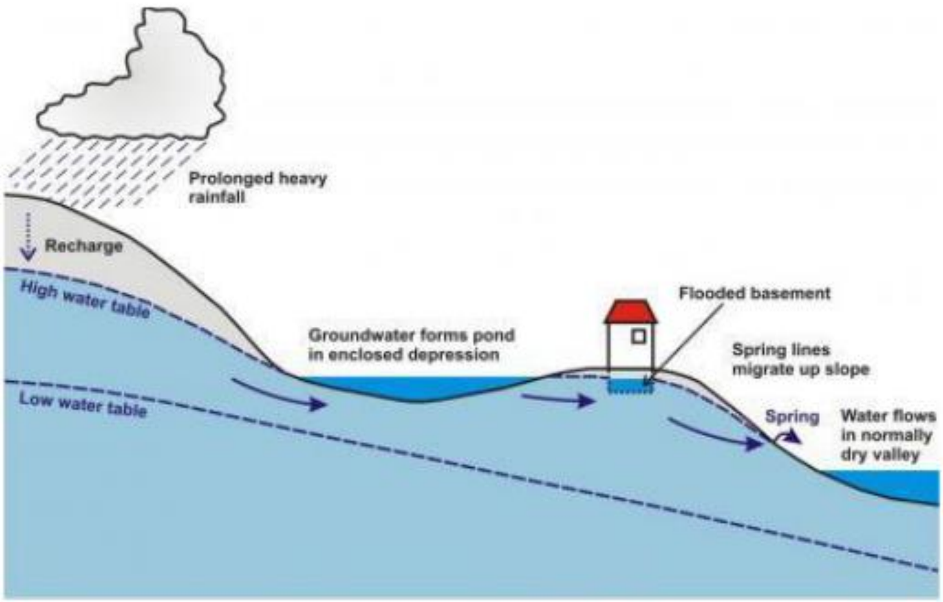

Figure 2.1 Groundwater flooding mechanism

Source: Environmental Agency (2014)

2.2.4 Coastal

The rise in seawater level causes coastal flooding, both caused by tidal surges and waves. Similar to fluvial flooding, there is a risk of high-water levels and strong currents from coastal flooding. However, there is not a very high risk of infectious diseases. As saltwater is more corrosive, there is a general risk of higher structural damage and damage to electrical components (Olesen et al., 2017).

2.3 Flood classification in Malaysia

Flood is Malaysia's most shocking natural catastrophe. In Malaysia, together with Sabah and Sarawak, there are a total of 189 river basins with main channels flowing straight to the southern Chinese sea and 85 are vulnerable to recurring flooding. Peninsular Malaysia have 89 of the river basins, 78 in Sabah and 22 in Sarawak. Malaysian Drainage and Irrigation Department (2009) mention that the estimated flood-prone area is around 29,800 km^2 or 9 percent of Malaysia's total area and affects nearly 4.82 million people, which is around 22 percent of the country's total population (Diya et al., 2014).

Malaysian Drainage and Irrigation Department has classified floods in Malaysia into two categories, which is flash floods and monsoon floods (DID, 2000). The strong difference between these two tragedies, based on the hydrological perspectives, is the time taken by the river flow to fall to the normal level. It takes only a few hours for flash floods to return to normal water level, while monsoon floods can last a month (Diya et al., 2014).

Due to geographical location and tropical climate conditions, Malaysia is vulnerable to flooding. Global warming results in abnormal torrential rainfall, sea-level rise, which increases flood risk (Zaidi et al., 2014). Usually faces two monsoons southwest monsoon and northeast monsoon periods. Northeast monsoon causes more heavy rainfall. Kuantan River Basin is a responsible flooding factor resulting from long heavy rainfall during northeast monsoon by producing excess surface runoff that exceeds the capacity of the basin to compensate for flooding to low laying areas and hamper social and economic life of human (Zaidi et al., 2014).

2.3.1 Flash flood

Flash flood considered as high speed flows and short warning time (Samsuri et al., 2018). Although some have limited the incidence of flash flooding to a specific geographical area such as mountain, as the impact is more shocking due to the flowing hazard, it is also widespread and catastrophic to a low land area (Samsuri et al., 2018). The most dangerous type of flood is known to be flash flood because it combines the flood destructive power with tremendous speed and unpredictable (Doocy et al., 2013).

According to Samsuri (2018), reducing forested areas and replacing natural surfaces with roofing and concrete will limited water absorption rates. Poorly maintained buildings with blocked drains and inappropriate drainage and waterways design and construction also led to flash flooding (Samsuri et al., 2018).

Natural causes such as local weather and non-natural causes, such as an ineffective urban drainage system and an expansion in urban areas, may trigger flash flooding. Many studies have reported the increase in urban built-up areas as a dominant factor in causing rapid river flow, a direct result of reduced vegetation coverage (Mohamad et al., 2012).

2.3.2 Moonsoon flood

Monsoon floods is flood that occurs due to the wind resulting in a lot of rain. Many areas in Malaysia generally affected by this monsoon flood and occur in some seasons. This season can be separated into two, which is northeast monsoon flood and southwest monsoon flood. Basically, northeast monsoon floods happen from October to February and bring heavy rainfall to Malaysia, especially Pahang, Terengganu, Kelantan, Sabah and Sarawak, while southwest monsoon floods happen from May to August and bring little rainfall to the west coast of the peninsula (Hua, 2014).

Figure 2.2 below shows the pattern of rainfall in Malaysia and how it is influenced by the two monsoons, the Southwest Monsoons and the Northeast Monsoons. Malaysia's own location consists of the Malaysian Peninsula and Sabah and Sarawak, divided by the South China Sea (Diya et al., 2014).

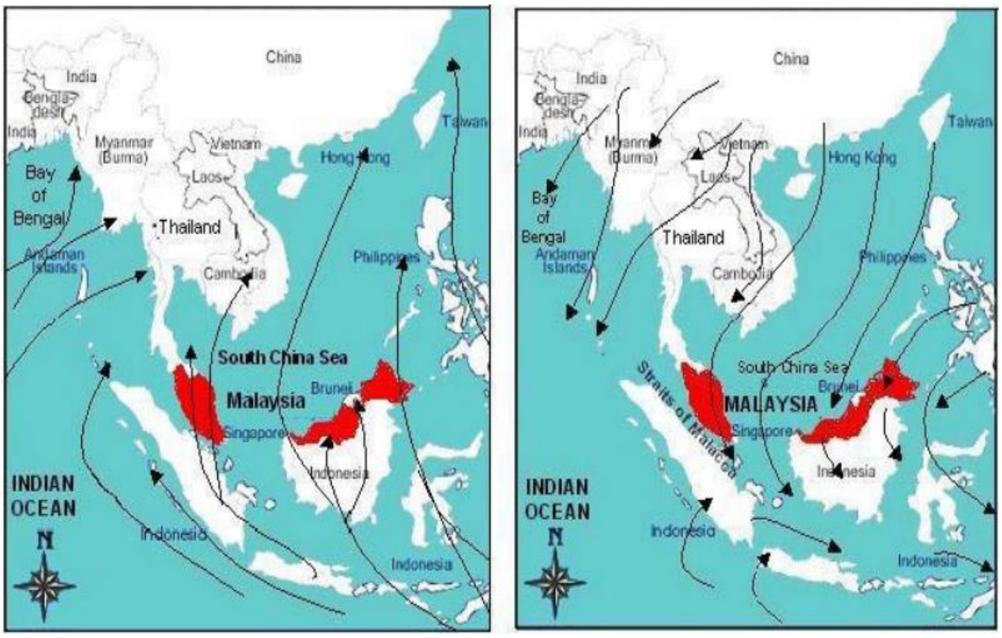

Figure 2.2 Southwest and Northeast monsoons

Source: Diya et al., (2014)

2.4 Flood risk assessment

Flood risk is the exceedance probability of events of a given magnitude and a given loss. Risk is therefore commonly defined as a two-aspect composition, hazard and vulnerability. In the fields of flood design and flood risk management, more attentions are given to comprehensive risk assessments that take into account the hazard and vulnerability aspect of flood risk (Apel et al., 2013).

2.4.1 Flood hazard

Flood hazard is defined by the excess probability of flood damage situations in a given area and over a specified period of time and flood situations characteristics (Apel et al., 2013). The flood hazard is to quantify the amount, area and location of floods that are predict to occur with a given return period. This means that the spatial distribution of the calculated flood depth can be used to describe the flood hazard as a function of the return period (Olesen et al., 2017).

2.4.2 Flood vulnerability

In general, vulnerability is expressed by the exposure of people and assets to floods and their susceptibility to flood damage (Apel et al., 2013). A way of expressing the vulnerability is by evaluating the cost of the damage. In general, the vulnerability assessment uses two basic approaches. The first way of evaluating vulnerability expresses the tendency to damage caused by floods, flood resistance and recovery only in terms of social, economic and environmental system properties (Solín et al., 2013). Zhou (2012) has proposed a framework for assessing flood risk and an adapted version of this is presented in Figure 2.3.

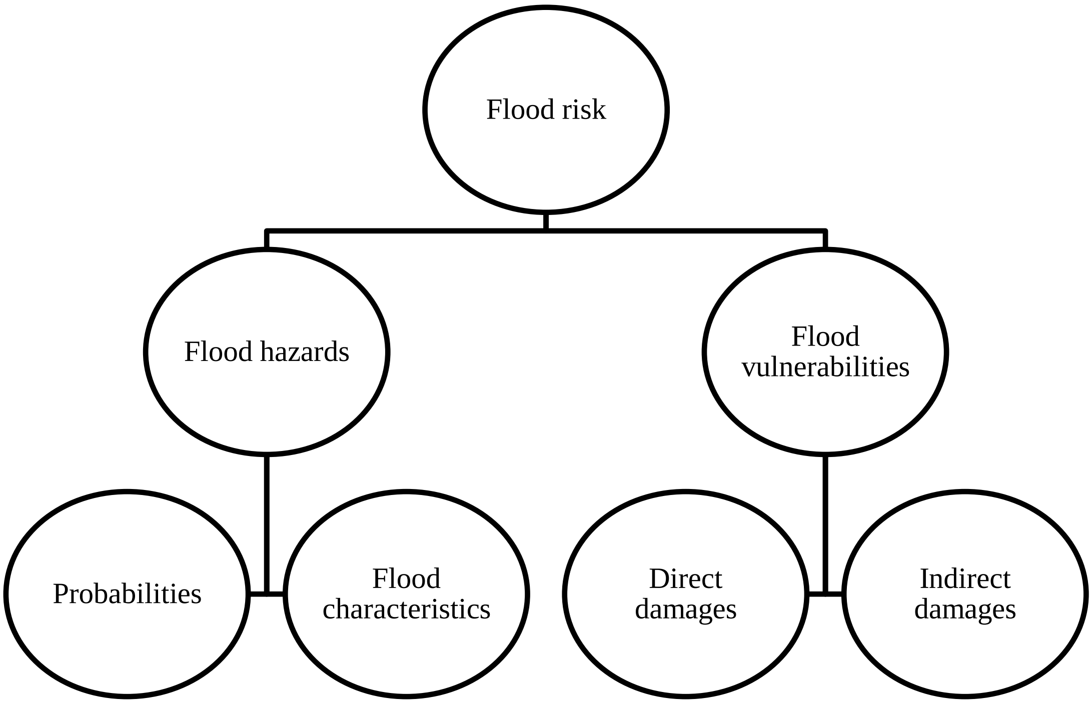

Figure 2.3 Framework for flood risk

Source: Olesen et al. (2017)

The flood frequency curve at a discharge gage is an example statement of a flood hazard, give various releases and the associated excess probability. Statements on flood hazard do not convey social information, built environment or natural environment consequences of such events. Since these effects rely on flood intensity, among other things, hazard statement should stretch beyond flood rate curves, they should provide data on flood intensity, such as flood size or stream speed (Thieken et al., 2006). Figure 2.4 illustrates the definitions of flood hazard, vulnerability and risk.

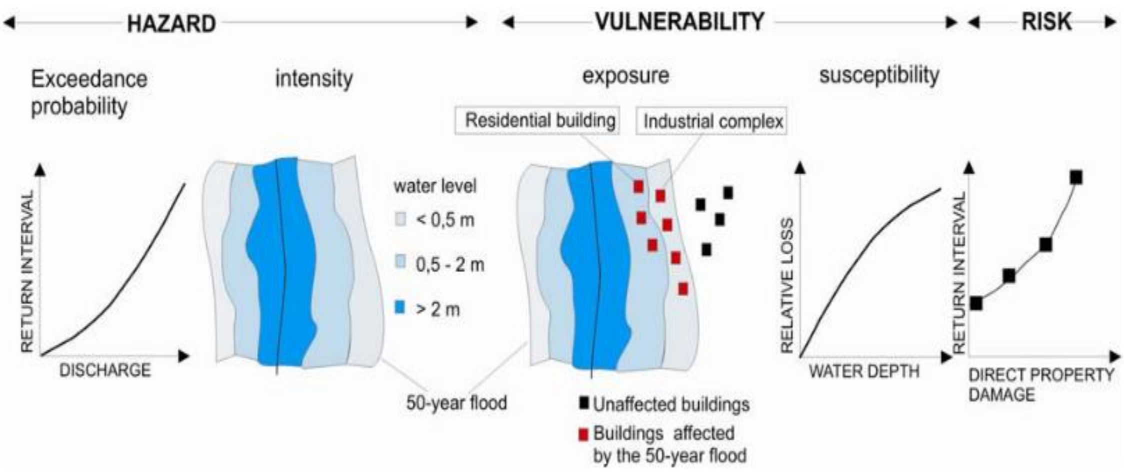

Figure 2.4 Flood risk as interaction of hazard and vulnerability

Source: Thieken et al. (2006)

2.5 Assessment of flood damage

Using the depth-damage function is the most well-known and globally accepted technique to estimate urban flood damage. Numerous variables affect structure and content damage resulting from flood hazard, typically only building use and flood depth are considered to cause damage and are included in the development of depth-damage curve. The building age, foundation type and height of the main level can be included as factors contributing to the damage estimation of a structure that is external to the depth-damage curve (Pistrika et al., 2014).

In this evolving context of decision-making in flood risk management, flood damage assessments are gaining more importance (Merz et al., 2010). They are needed for assessment of flood vulnerability, flood risk mapping, optimal decisions on flood mitigation measures, comparative risk analysis, and financial appraisals during and immediately after flood (Merz et al., 2010). Even though assessment of flood damage is an essential part of managing flood risk, not much scientific attention has been focussed to it. The consideration of flood damage in the flood risk management decision-making process is still relatively new (Messner et al., 2007).

2.5.1 Types of flood damage

It is possible to categorise flood damage into direct and indirect damage. The physical interaction between flood water and people, property and other objects causes direct damage. Indirect damage is caused by direct impacts and occurs outside of the flood event in space or time. Both types of damage were further categorized into tangible and intangible damage, depending on whether or not monetary values can be assessed (Merz et al., 2010).

Today's typical approach is the economic estimation of direct damage, mostly by applying depth-damage curve. However, an integrated, unifying approach is lacking. A more or less standardized approach to damage estimation is desirable for consistent decision-making at least at higher aggregation levels, such as a river basin or a complete region (Pistrika, 2010).

Tangible damage is damage to man-made capital or resource flows that can easily be monetarily specified, while intangible damage is damage to properties that are not traded on a market and are hard to convert to monetary terms. While differentiating between direct and indirect and tangible and intangible damage is commonplace, understandings and outlines differ. Table 2.1 shows some examples of the different types of damage.

Flood damage assessments are done on different spatial scales which are micro-scale, meso-scale and macro-scale. For micro-scale, the evaluation is based on a single risk element. For example, damages are calculated for each affected building, infrastructure object and others, to estimate the damage to a community in the event of a certain flood situation (Merz et al., 2010). In meso-scale, the evaluation shall be based on spatial aggregations. Typical units of aggregation are units of land use, such as residential areas or administrative units, such as zip code areas. Their size is between 1 ha and 1 km^2 in the order of magnitude (Merz et al., 2010). For macro-scale, the basis for estimating damage is large-scale spatial units. Administrative units, e.g. municipalities, regions, countries are typically used (Merz et al., 2010).

Table 2.1 Damage classes

	Direct	Indirect
Tangible	Damage to non-public buildings and their contents, destruction of infrastructure together with roads, railways, agricultural land erosion, harvest destruction, livestock damage, evacuation and rescue measures, interruption of business in the flooded area, clean-up costs.	Public service disruption outside the flooded area, loss of production to non-flooded companies, disruption of traffic costs, loss of tax revenue due to company migration following floods.
Intangible	Life loss, injury, memory loss, psychological distress, cultural heritage damage, ecosystem adverse effects.	Trauma, loss of authority confidence.

Source: Merz et al. (2010)

According to McBean (1987), structural damage refers to building damage and building materials which are not considered if a person moves, such as the boiler, water heater. While damage to components that are not responsible for the static behaviour of the building structure is the definition of non-structural damage.

2.5.2 Method of flood assessment

Flood damage assessment is usually based on two methods. For the first method, flood damage is assessed from existing database of flood damage, collected from interview surveys or from other sources. The second damage estimation approach uses a model that relates flood damage to other related factors such as economic, nature of damage, and flood variables (Romali et al., 2018).

Although different approaches were used to estimate flood damage, the concept of estimation is basically the same, taking into account the economic value of the element at risk and the hydrological characteristics (Romali et al., 2018).

2.5.2.1 Survey

One sort of approach is to conduct a thorough and detailed survey of the affected population and properties in order to estimate the loss incurred. The most accurate way to collect data about residential damage is via interviews with recent flood victims. Surveys of post-flood damage have long been considered the most trusted way to predict flood damage. While such surveys may be of huge value to estimate the risk of future damage, funding and time are sometimes inadequate to survey a whole area affected by a major flood (Olesen et al., 2017). One approach is to conduct an in-depth survey of the affected population and properties in order to estimate the loss incurred. The most reliable way to predict flood damage has long been believed to be post-flood damage surveys (Win et al., 2018).

Win et al. (2018) mentioned in case study of the Bago River Basin, Myanmar that the questionnaire details were designed according to the three themes of flood, damage and demographic data. Under the theme of flood, flood height and duration were measured, while the information collected under the theme of damage was house damage, in-house damage, income loss, extra spending, and agricultural damage. Different factors, such as age, gender, education, occupation, revenue of each household member and expenditure, building typology, and possession by each household of paddy areas, were investigated under the demographic theme. The survey used randomly selected sampling to collect a representative sample in the flood-prone areas of Bago Township (Win et al., 2018). Table 2.2 shows the summary of questionnaire designed.

Table 2.2 Summary of questionnaire and the information collected

Themes	Information collected
Flood	Height, duration
Damage	House damage, In-house damage, Income loss, Extra expenditure, Agriculture damage
Demographic data	Age, Gender, Education levels, Type of occupation, Income of each household member and spending, Building typology, Possession by each household of paddy areas

Source: Win et al. (2018)

2.5.2.2 Modelling approach

The other method is modelling approach by using software to assess the flood damage. Many software that were HEC-RAS, ArcGIS and others. The U.S. Army Corps of Engineers developed a software modelling of flood damage analysis known as HEC-FDA and is acceptable for international resources. This model can estimate flood damage in economic terms and flood damage assessment index is flood depth (Mohammadi et al.,2014).

In the United States, the U.S. Federal Emergency Management Agency and the National Institute of Building Sciences have developed HAZUS, the most advanced and publicly available methodology for multi-hazard spatial risk assessment. HAZUS-MH (Multi-Hazard)'s main features include a full flood or earthquake model, the ability to test both probabilistic scenarios and deterministic, a completely integrated set of functions for the three models, geographic information system (GIS) functions, the ability to receive user-supplied input for all three models, real-time analysis, and state-of - the-art software (Win et al., 2018).

Several flood damage models have been developed in Europe to assess possible flood impacts. These models usually focus on monetary quantification of flood damage. Meyer and Messner (2005) evaluated methods for assessing flood damage used in the UK, the Netherlands, the Czech Republic and Germany. They show that while the approach differ in different details, they all follow the same concept using four components with information on which the damage estimate is based, first, on hydrological characteristics, mostly represented by flood depth, second is elements at risk, often estimated using land use or individual buildings, third is value of elements at risk and the last component is susceptibility of the elements at risk to the hydrological characteristics, usually defined using depth–damage curves (Meyer et al., 2005).

2.6 Flood damage curve

Flood depth-damage curve is flood depth versus flood damage creating a line or a curve. The curve or function of flood depth damage is relationship between the water depth above or below a building's first floor and the amount of damage that can be ascribed to that water (Davis et al., 1992). The depth of flood is equal to the height of flood water from ground. Depth-damage curve are normally described by interpolating flood depth and damage data generally obtained through systematic survey procedures that analyse historical flood events or data on insurance claims, or synthetic damage data (Notaro et al., 2014). An example of flood damage function curve in percent damage values for single family residential structures is shown in the Figure 2.5. Only structural damage is represented by this curve, content damage is evaluated separately using a depth-percent damage curve for a house content (Mancusi et al., 2016).

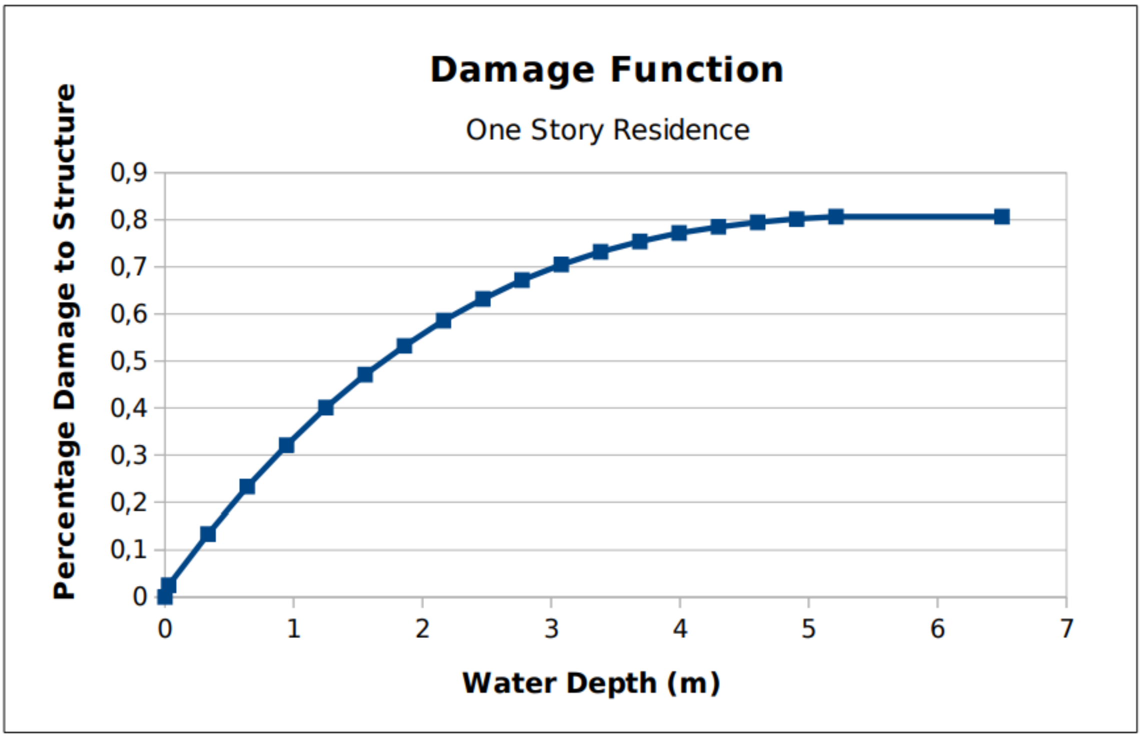

Figure 2.5 Example of flood depth-damage curve

Source: Mancusi (2016)

Damage curve describes the relationship between flood damage level and hydraulic characteristics, such as flood depth, or combination of water depth and velocity, or duration, or sediment load, with respect to different land uses, characteristics and types of damaged goods and social and economic conditions (Notaro et al., 2014). In practice, analyses are usually focused only on direct tangible damage to public and private properties, examples of buildings, cars, and roads as a function of flood depth that is considered to be a determinant of the occurrence of damage. Direct tangible damage is preferred because monetary costs are easily assessable and are linked to flooding hydraulic characteristics (Notaro et al., 2014).

Two main types of such curves can be developed based on the type of information used in the development of depth-damage curve. Empirical curve, using damage data collected after flood occurrences, and synthetic curve, using theoretical damage data collected through inventories or interviews and according to hypothetical analyses and expert judgments (Pistrika et al., 2014). It is possible to combine both methods to evaluate synthetic models with empirical data, for example to extend empirical data with synthetic data that was done by the U.S. Army Corps of Engineers. Both approaches have both advantages and disadvantages (Merz et al., 2010). Table 2.3 show the advantage and dis advantage of empirical and synthetic flood damage.

Empirical curve is not allowed to be used directly in different places and times. This is due to the differences occurred between the flood and building characteristics. To solve this problem, general synthetic curves were created for different types of buildings based on a valuation survey. Assessment surveys assess the distribution of structural components at the height of a building (Nafari et al., 2017).

It is also possible to distinguish damage functions as absolute or relative. The absolute type indicates the damage in monetary terms directly, whereas the relative type indicates the damage as a percentage of the overall exposed value, which may refer to the full replacement value or the total depreciated value (Kreibich et al., 2010). Relative functions have benefits over absolute functions where they are more flexible to transfer to various areas or years because the damage ratio is independent of changes in market prices (Merz et al., 2010). Figure 2.6 provides an illustration of the different forms of the stage-depth damage curves and the need for data.

Table 2.3 Advantages and disadvantages of empirical and synthetic flood damage

	Advantages	Disadvantages
Empirical damage models	Real damage information is more precise than synthetic information. In damage modelling, effects of mitigation measures can be measured and considered.	Thorough flood damage questionnaire surveys are rare, allowing models to rely on poor data quality. Information on floods of various magnitudes and the lack of records of damage with high water depths often require extrapolation
Synthetic damage model	Damage information can be retrieved for different water levels in each building. Higher standardisation level and damage estimate comparability.	Detailed databases are necessary, or large surveys are needed in order to obtain adequate data for each category or type of building. If the analyses are subjective, the damage is uncertain.

Source: Merz et al. (2010)

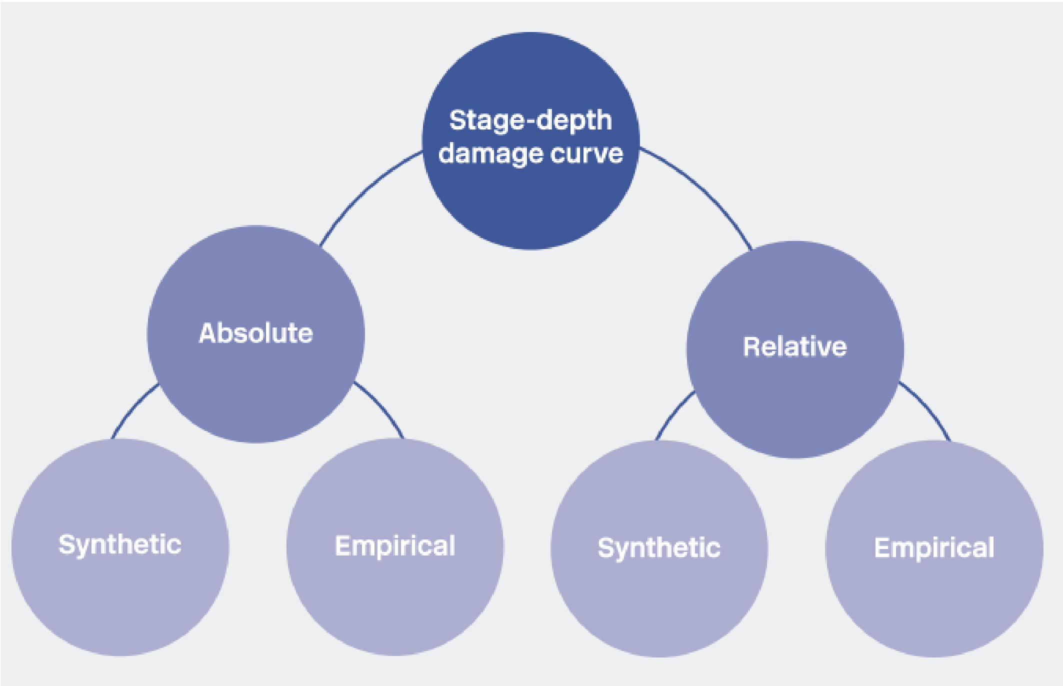

Figure 2.6 Overview of the different forms of stage-depth damage curves

Source: Olesen et al.(2017)

2.6.1 Flood parameters

Many factors may affect the flood damage. The flood influencing factors include flood depth, flood year, flood speed, flood duration, warning time, and sediment load. Among all of these relevant factors of flood damage, most historical appraisal procedures are focused on only one variable which is flood depth. Because the curves of depth-damage are the primary relationship used in estimating flood damage work, different curves of depth-damage curves were developed. These could be precise to some structures, such as a single house, or averaged for a number of identical buildings, such as one storey houses with basements (Davis et al., 1992).

Flood damage is affected by many other variables including flood speed, flood duration, pollution, sediment concentration, flood warning time and information content, and the quality of external response in flood conditions (Thieken et al., 2005). However, except for conceptual models these elements are barely included in flood loss models. Figure 2.7 shows the idea of the damage to a structure is depends on the load impacted on the structure and its resistance on the other can be categorised as the affecting factors (Thieken et al., 2005).

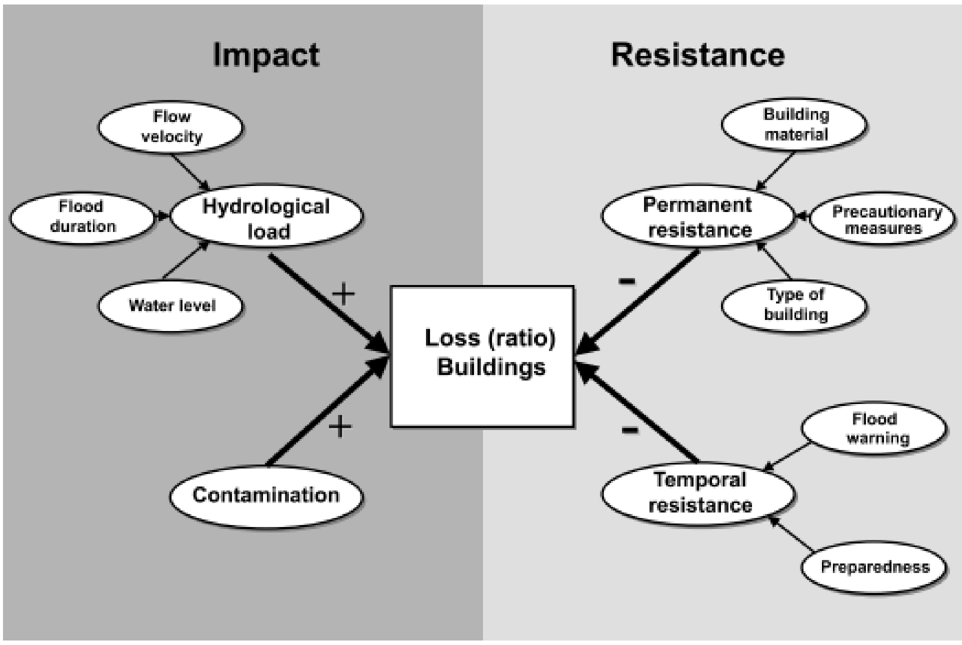

Figure 2.7 Factors that affecting the flood loss (ratio) of buildings.

Source: Thieken et al., (2005)

Thieken (2005) mentions the parameter influencing flood damage in the study of flood damage and affecting factors. The study shows that building precautionary measures which is retrofitting can lower the risks of flood damage significantly, whereas a much less influence or inconsistent picture shows from the flood warning and emergency measures. Temporary and permanent resistance influence damage to a small degree compared to the flood impact and the characteristics of the affected property (Thieken et al., 2005).

The same applies to socioeconomic variables and velocity of flow. Although there is some proof that similar factors which is flood and property characteristic predominantly affect flood losses in other countries and during other events, more flood data analysis research is needed to prove the universal validity of the results presented. Different flood occurrences, such as river floods, flash floods, storm surges, flooding due to levee breaches or rapid rise in groundwater, are likely to cause flood damage of various types and extent (Thieken et al., 2005).

Poussin (2014) mention on factors of influence on flood damage reduction behaviour by households that the flood experience has a positive and extremely important impact on the number of measures taken by the respondents to prevent and prepare for emergencies (Poussin et al., 2014). Flood experience appears to be related positively to the number of measures implemented for non-structural mitigation, whereas generally no intentions for additional measures are found (Poussin et al., 2014). These intentions is related positively to the severity of past flood experiences in terms of the cost of repairing the homes of respondents following floods although the flooding itself does not improve the intentions to take additional measures (Poussin et al., 2014).

2.6.2 Determination of Flood Damage

The relationships of flood depth-damage generally expressed the damage as a percentage or specific currencies as for Malaysia in Ringgit Malaysia. However, the damage as currencies only useful for damage such as building and transportation at the current time. This is because the price of the materials and currencies are always change from time to time.

Pristika (2014) expressed the damage in percentage using the formula in Equation (2.1):

$$\text{Damage percentage} = \frac{\text{Cost of repairs}}{\text{Market Value of Building}} \tag{2.1}$$

The damage percentage is described as the proportion of pre-disaster market value property of the overall cost to replace the damaged components of a flood-affected property.

Notaro et al. (2014) analysed the uncertainty in urban flooding analysis related to the understanding of the depth-damage curves. The analysis was implemented into a case study in which data were collected on damage and flooding. The flood damage was expressed in terms of currency which Euros (Notaro et al., 2014).

2.7 Previous study on flood depth-damage curve

New Orleans District for the Lake Pontchartrain Hurricane Protection study, use standardized depth-damage curves developed (Davis et al., 1992). In 1978, more than 7000 homes were surveyed in New Orleans along the lakefront. The contractor inspected each structure visually and estimated damage expected from different levels of flooding. Curves were differentiated by type of structure and flood type. Periods of heavy rainfall associated with hurricanes, thunderstorms, or long frontal activity may result in potentially severe flooding in New Orleans District. Depth-damage curves have been derived for three types of residential buildings, one floor, two floor, and mobile home. Besides damage caused by flood depth, the effects of salt water and tidal surge may also result in damage. The impact of construction materials on the profound damage curves was not determined. The structures are described as residential buildings, and everything is built into them permanently. The damage values of structures are defined as the depreciated replacement values. Household content is defined as all that is not permanently installed within the structure. The value ratio of content to structure varies with the structure value (Davis et al., 1992).

A study by McBean (1988) on the flood depth-damage curves where it was analysed to estimate the factors of adjustment for alternative features of flooding events. The analyses have shown that the total damage should rise by 6% for longer floods than 24 hours. The study also found that the content loss was estimated to be 66% of total damage at 2.4 meters for ice or high-speed flow destruction. Total destruction also includes the structure value of property loss minus the land value. They state that potential variables which includes floor area, previous flood exposure, family revenue, and did not explain substantial percentages of potential flood damage reliable in different classification of housing.

In July 2002 in Moschato, an Athens, Greece district, a research was conducted to demonstrate a step by step methodology for designing deep damage functions using flood data (Pistrika et al., 2014). The percentage of damage is determined on the basis of relief payments by category of flood affected property. The repair cost of building materials damaged by flood and market value of the affected construction materials also estimated to generate the flood depth-damage curve for building structures. The depth-damage function of Moschato is compare with other depth-damage function of Palermo to find the difference and similarities between the two areas.

One of the best-known damage models in Germany is the rule-based Flood Loss Estimation Model FLEMO, developed by a research group from Potsdam's German Geoscience Research Centre. The model focuses on evaluations of direct tangible damage. The model uses a multifactorial approach based on rules to estimate the loss of damage based on flood depths with intervals of damage given as a relative percentage of the value of the unit (Schröter et al., 2014).

Depth versus damage curves were developed in Colombo, Sri Lanka for a flood risk assessment. The main elements in the damage assessment were building fabrics, building content, distributed infrastructure and vehicles. Three categories have been assigned to the building fabric, namely semi-permanent, single storey and two storeys. The content of the building was classified into 7 types based on functions such as warehouse / storage, industrial, shops, offices, residential, educational and health. The ratio of content assets to fabric values ranged from 1.67 for warehouse or storage to 0.20 for educational purposes. Data obtained as losses per unit length or area; or as losses per point. In the return periods 5 to 100 years, the resulting flood damage around 37 to 549 million USD for the 140 square km urban area, with average flood depths ranging from 0.48 m to 1.28 m (Dias et al., 2018).

2.8 Conclusion

From the literature review, many regions have done the assessment of flood damage. Two methods have been introduced to assess the flood damage which are by interview survey or modelling. In Malaysia, there is least study about flood vulnerability compare to flood hazard. Therefore, this study is to support the flood mitigation in Malaysia by develop the depth-damage curve for Kuantan district in Pahang. The depth-damage curve is the best method to show the relationship between the flood depth and flood damage.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discuss the methodology to assess the residential flood damage of 2013 Kuantan flood, to establish the relationship between flood damages and socio-economic/ property characteristics of the study area and to develop a flood depth-damage curve. The methodology used is shown in Figure 3.1.

The steps to achieved the outcome of this study start from identifying the objective of this study, literature review, questionnaire design based on to achieve the objective. After the questionnaire design is complete, it was distributed to Kuantan residents that experienced 2013 flood. When the data collection is complete the next step can be proceeded which are data analysis and analysis of result.

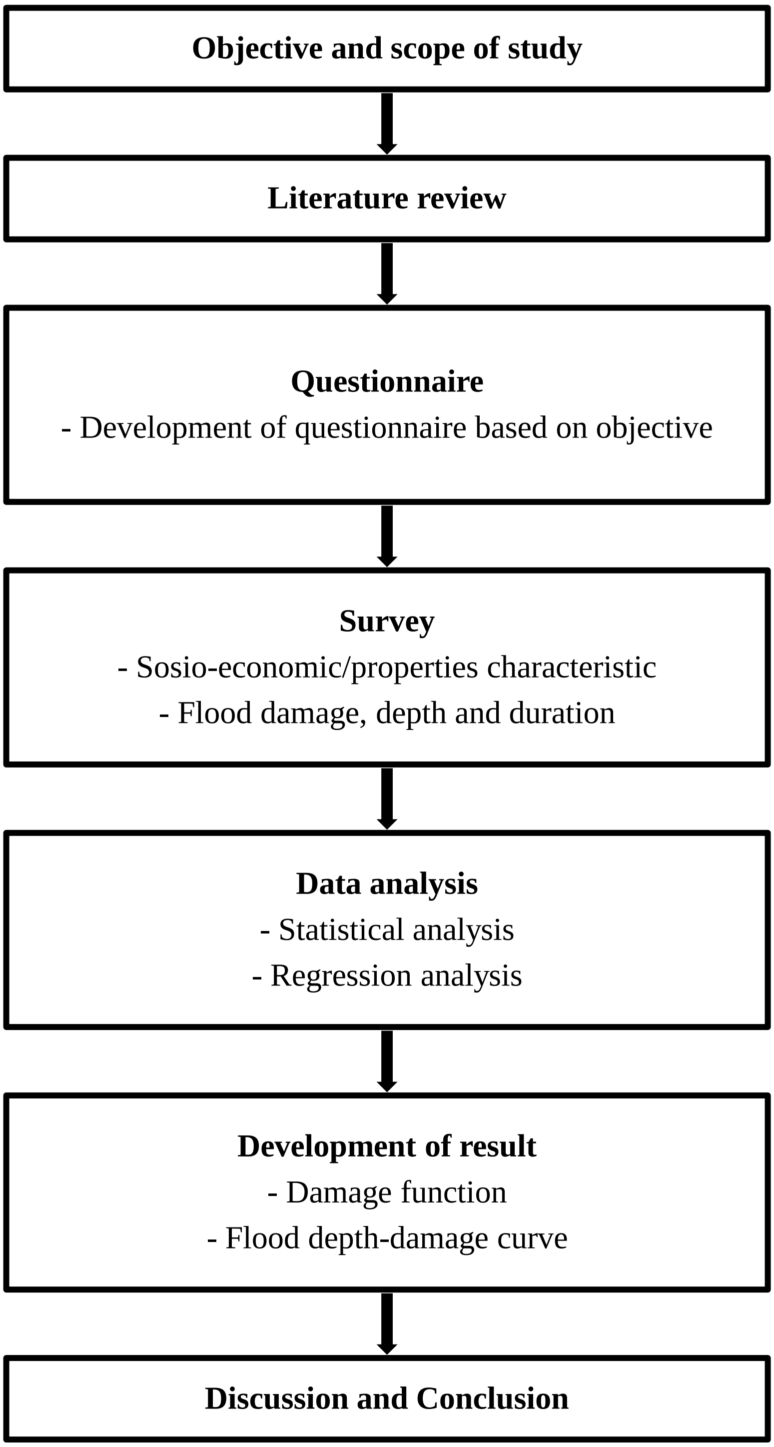

Figure 3.1 Flow chart of methodology study

3.2 Description of study area

Kuantan River is located in Kuantan District in the north-east part of Pahang State, Peninsular Malaysia. One of the important Pahang river basins, covering 1630 km^2 of catchment land from Ulu Kuantan district to the South China Sea. It consists of several tributaries and rivers in Kuantan District's main rural, agricultural, urban and industrial areas and runs into South China. Kuantan, due to the strategic situation and rapid development that has transformed and modernized the city, is considered a social, economic and commercial centre for the East Coast of Malaysia (Marcus Ata et al., 2018). Figure 3.2 show the Kuantan district in Pahang.

Figure 3.2 Kuantan district

Sources: google maps

3.3 Questionnaire design

A survey questionnaire is design based on the objective of the research which is to assess the residential flood damages of 2013 Kuantan flood, to study the relationship between flood damages and socio-economic or property characteristics of the study area and develop a residential flood depth-damage curve for Kuantan. The questionnaire survey is developed to get the data that can be analyse to achieve the objective. The questionnaires are divided into two sections which is Section 1 and Section 2.

3.3.1 Section 1: Residential Information

In this section, the questions were divided into two part which is Section A and Section B. Section A consist set of questions to collect the respondent background information. Some data that collect from Section A are respondent's gender, age, ethnic group, education level, job and salaries. Section B consist set of questions to collect the residential information such as types of house, number of house's storey, type of constructions material of the house, distance of house from flood sources, and household quantity.

3.3.2 Section 2: Residential Damage Survey Information

In this section consist set of questions that needed to collect the data about flood damage. The data that will be collect is the depth of the flood in unit metre and total household that has been damaged in unit of Ringgit Malaysia and percent of the household's damage. The damage of flood to the house and respondent's transportation also will be collect in this section to get more precise estimated flood damage.

3.4 Data collection

For the data collection, a set of questionnaires have been developed and consist of two section which is Section 1 and Section 2. At least 100 respondents of residential in Kuantan that have experienced the 2013 flood were target to answer the survey questionnaire. Kuantan area which has been interview survey were around Permatang Badak, Sungai Isap Bukit Rangin, Bukit Setongkol and Kampung Galing Besar as shown in Figure 3.3. This questionnaire is distributed by hand to respondents in residential of Kuantan. Data obtained from the questionnaires were analysed with an appropriate method which may result in the successful of the research.

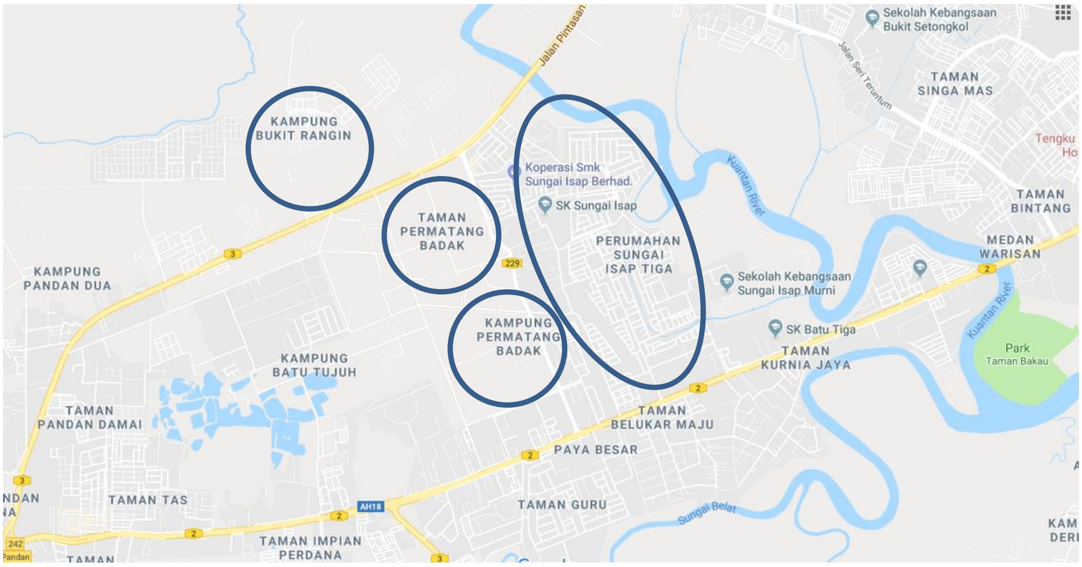

Figure 3.3 Area of interview survey

3.5 Data analysis

After the survey is done and the data was collected, the data analysis was conducted. The data analysis consists of transferring the data collected from questionnaire in to a group or set of data according to the properties of the data such as depth of flood, total damage calculated, and others. After that the data analysed used to study the factor that affected the flood damage and generate the flood depth-damage curve for residential in Kuantan. The result generate from the data is important finding for this research study.

The equation (3.1) and (3.2) were used to calculate the percentage of both content and structural damage respectively. The equation is based on the study by Win et al (2018).

$$\text{Content damage} = \frac{\text{Content damage}}{\text{Estimated household content}} \times 100\% \tag{3.1}$$

$$\text{Stuctural damage} = \frac{\text{Structural damage}}{\text{House's price}} \times 100\% \tag{3.2}$$

3.5.1 Statistical analysis

Statistical analysis is analysis on data collected to calculate the average value of content damage and structural damage. Number of houses also categorise into three category which is number of levels that consist of one storey and double storey house, house type and house construction materials type.

3.5.2 Regression analysis

The data collected were enter into STATA software in variable form. There are two type of variables which is dependent and independent. The dependent variable which is content damage and structural damage is depend on the independent variables such as respondent income, house type, house construction materials and others for regression analysis. This was done to study the relationships between dependent variable with independent variable and identified if there any independent variable that influence the flood damage. Through the analysis of correlation coefficient of the regression analysis, linear regression equations have been generated manually. The model performance is reasonable if the significant values for the variables was observed to be less than 5% or 0.05.

3.6 Development of flood depth-damage curve

Damage to floodplain structures is strongly related to the depths achieved by the flooding in the structures. There are many other important parameters, but depth explains most of the variance of damage when construction and use stratify the structures. In addition, the components of the structure and their elevation relative to the ground may differ considerably. For example, some residential two-storey structures may have the first-floor laundry room, while others may have the second-floor laundry room. Since the laundry would likely have either gas or electrical high voltage, various components within the structures could be damaged at different depths relative to the structure's first floor or ground level (Lehman et al., 2016).

The flood depth-damage curve developed in this study is by plotting the flood depth (in meters) versus flood damage (in Ringgit Malaysia). There are two categories of curve developed which is content damage curve and structural damage curve. The content damage is household that have been damage by flood while the structural damage is the structures of the damage house that the total cost has been repaired.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study was conducted in Kuantan area which were hit by flood event during 2013. The data were collected by distributing the questionnaire that has been design to achieve the objective which is to assess the residential flood damages of 2013 Kuantan flood, second is to study the relationship between flood damages and socio-economic/ property characteristics of the study area and third objective is to develop a residential flood depth-damage curve for Kuantan.

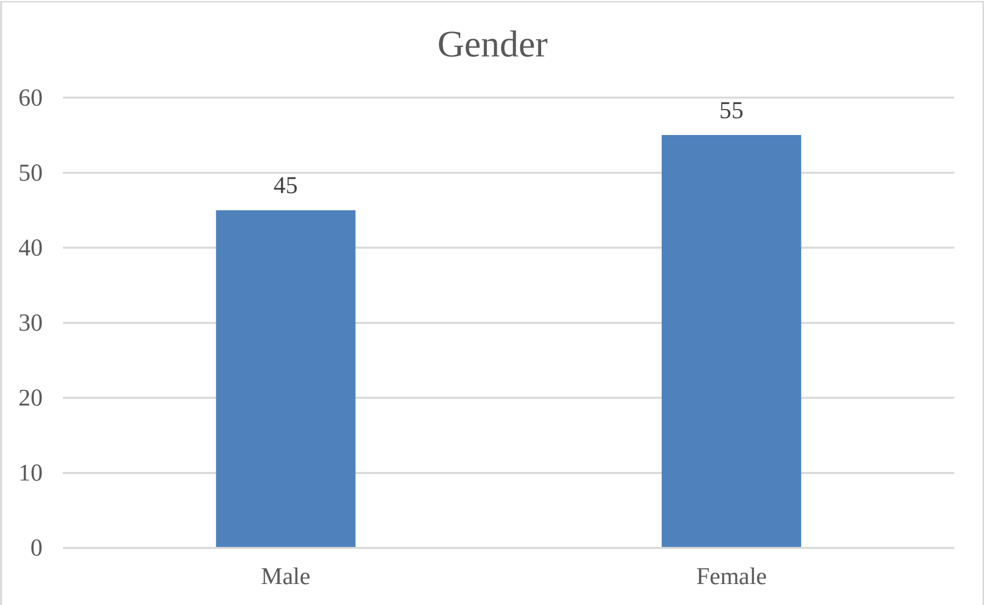

Figure 4.1 Gender distribution of respondents

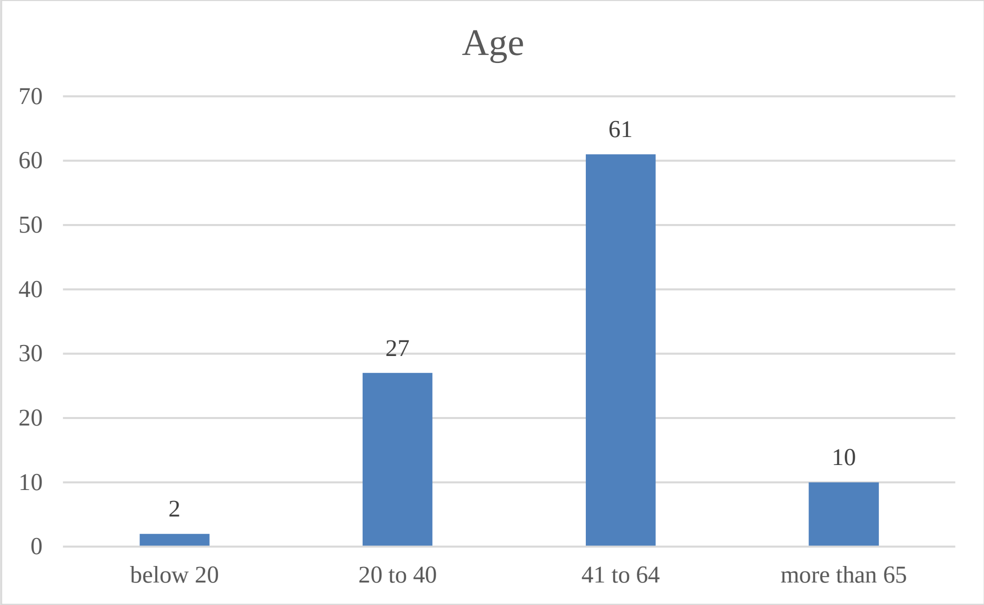

Figure 4.2 Age distributions of respondents

The data collected from 100 respondents has been summaries. Figure 4.1 shows the distributions of respondent's gender which 45 respondents are male and 55 respondents are female. From Figure 4.2, 61% of the respondents aged between 41 to 64 years. As the study areas are an old Malay residential, all respondents are Malay.

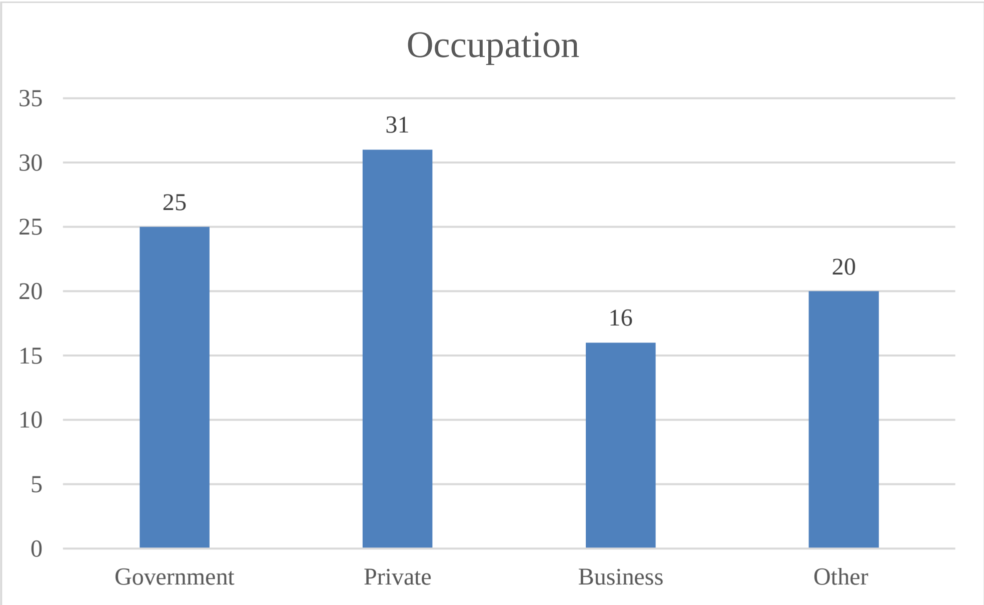

Figure 4.3 Occupation distributions of respondents

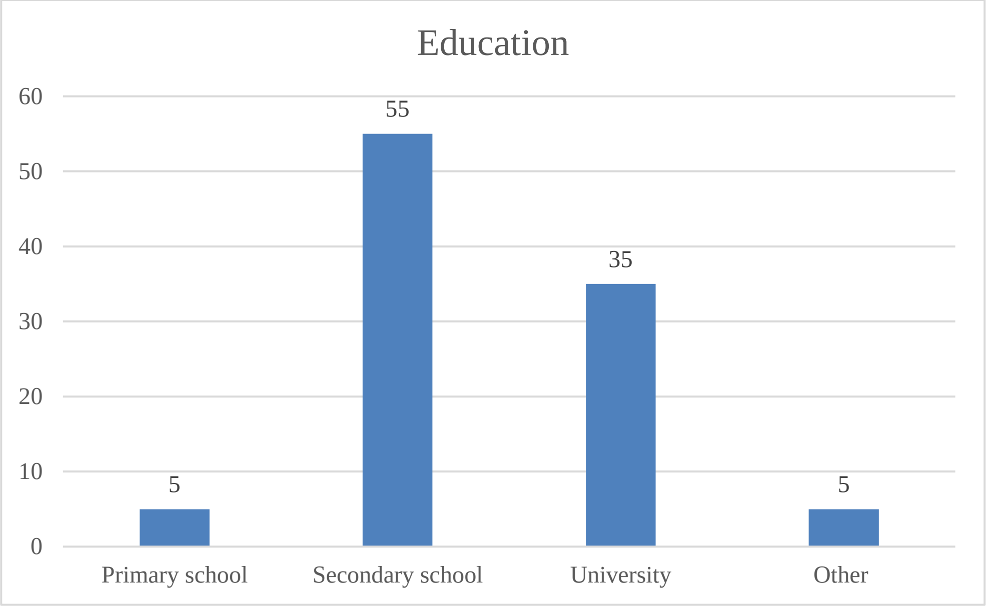

Figure 4.4 Education levels distributions of respondents

The average household income of the respondents is around RM 3500 and most of the respondent work at private sector than other three sectors as shown in Figure 4.3. Figure 4.4 show the most of the respondent have major education level at secondary school and the minor level at university.

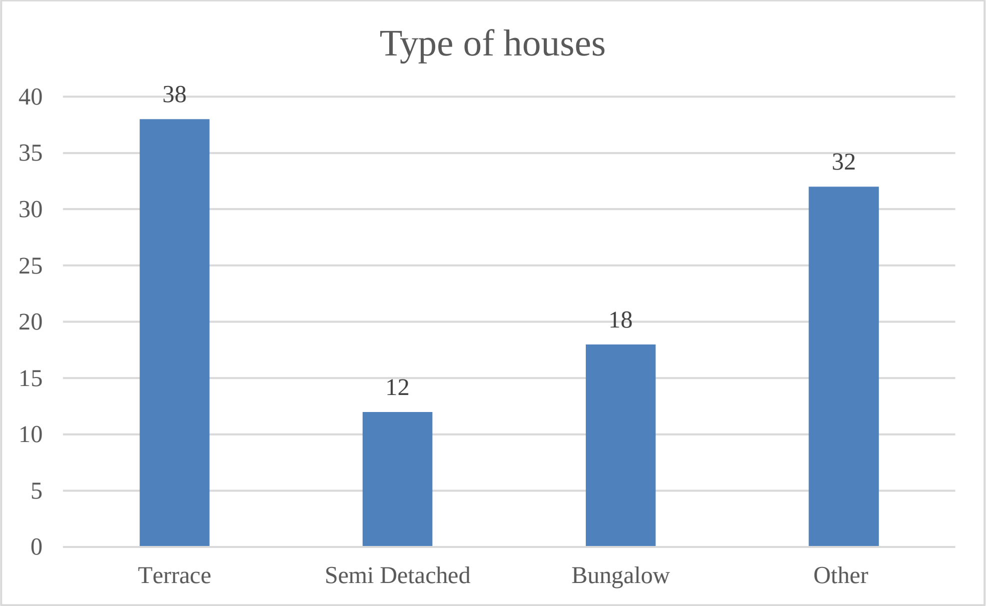

Figure 4.5 Type of houses distributions

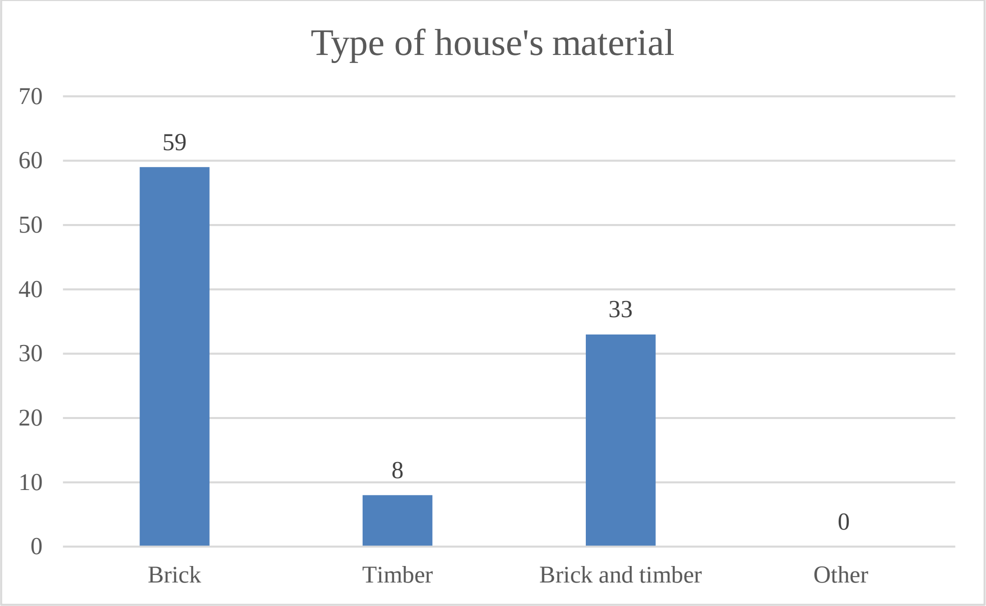

Figure 4.6 Type of house's materials distributions

There are different types of houses which are terrace, semi-detached, bungalow and others type of houses. Most of the houses that in others type category are village house, lot and shop house as shown in Figure 4.5 and most of the houses are one-storey house. The most widely observed type of building materials is brick as shown in Figure 4.6, which is 59%. 33% of houses are brick and timber, while house that construct with only timber are only 8%. Figure 4.7 and Figure 4.8 shows the single storey house construct with timber.

Figure 4.7 Single storey house's construct with timber at Sungai Isap

Figure 4.8 Single storey house construct with timber at
Kampung Galing Besar

Table 4.1 Distribution of damage according to number of levels, building types and building materials

Criteria	Number of building	Structural Damage		Content Damage	
		Average damage (RM)	Standard deviation (RM)	Average damage (RM)	Standard deviation (RM)
Number of levels					
One	94	2183	4208	8062	7714
Two	6	917	917	7000	3347
Building types					
Terrace	38	2058	3603	7008	5692
Semi D	12	3825	7089	10248	6503
Bungalow	18	2500	3540	7688	6473
Others	32	1694	3684	9284	10321
Building materials					
Brick	56	2905	4899	8728	6418
Timber	8	750	1134	7150	5814
Brick and Timber	33	1391	2740	7655	9944

The distribution of damage according to number of levels, building types and construction materials are shown in Table 4.1. The average structural damage and content damage are highest for one storey building which are RM 2,183 and RM 8,062 respectively. According to building types, the semi-detached houses have highest average content and structural damage which are RM 10,248 and RM 3,825 respectively. The 56 houses that are construct with brick have bigger average of both content and structural damage than others house that are construct using timber and combination of both brick and timber, RM 8,728 and RM 2,905 respectively.

As conclusion, the results show that average value for content damage and structural damage for one storey house are higher compare to two storey houses. According to four types of building, terrace, semi-detached, bungalow and others, the highest average value for content damage and structural damage is semi-detached house and house construct with brick received highest average value of content damage and structural damage. This result is different compare to the study by Roos et al. (2003). Roos et al. (2003) used structural calculations to investigate the resistance of different types of buildings (wood, brick, concrete) and showed that the most vulnerable are wooden constructions (Pistrika et al., 2010). This are due to the old wooden type house observe was construct higher from ground and receive less content and structural damage.

4.2 Regression analysis

. regress contentdamagerm business numberoflevel

Source	SS	df	MS
Model	700110401	2	350055201
Residual	5.0636e+09	96	52745314.6
Total	5.7637e+09	98	58812863.3

Number of obs =	99
F(2, 96) =	6.64
Prob > F =	0.0020
R-squared =	0.1215
Adj R-squared =	0.1032
Root MSE =	7262.6

contentdama~m	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
business	6536.814	1994.064	3.28	0.001	2578.629	10495
numberoflevel	3736.276	1939.342	1.93	0.057	-113.2885	7585.84
_cons	3036.598	2292.685	1.32	0.188	-1514.346	7587.542

Figure 4.9 Content damage regression analysis

reg structuraldamagerm brick business

Source	SS	df	MS
Model	232928547	2	116464273
Residual	1.4762e+09	97	15218892.3
Total	1.7092e+09	99	17264253.5

Number of obs	=	100
F(2, 97)	=	7.65
Prob > F	=	0.0008
R-squared	=	0.1363
Adj R-squared	=	0.1185
Root MSE	=	3901.1

structural~m	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
brick	1703.545	793.4196	2.15	0.034	128.8272	3278.264
business	3535.83	1064.44	3.32	0.001	1423.211	5648.449
_cons	662.1753	635.7827	1.04	0.300	-599.6773	1924.028

Figure 4.10 Structural damage regression analysis

A single regression analysis was done to investigate the relationship between flood damage and socio-economic characteristic or property variable. The result of the regression analysis for both content damage and structural damage are shown in Figure 4.9 and Figure 4.10. From Figure 4.9, the regression analysis show that the content damage is influence by type of occupation and number of levels while in Figure 4.10, the regression analysis show that the structural damage is influence by also two variable which are type of building materials and type of occupations.

Based on the result in Figure 4.9 and Figure 4.10, the damage function for both type of damage was generated manually as shown in equation (4.1) and equation (4.2):

$$\text{Content damage} = 6536.814\mathbf{A} + 3736.276\mathbf{B} + 3036 \quad (4.1)$$

$$\text{Structural damage} = 3535.83\mathbf{A} + 1703.545\mathbf{C} + 662.175 \quad (4.2)$$

Where:

A represents type of occupation

B represents number of house’s storey

C represents type of construction materials

R^2 get for both content damage and structural damage is weak (R^2=0.12) and (R^2=0.14) to explain that type of occupation, number of house's storey and type of construction materials as influence to content damage and structural damage. The content damage is influence by the variables type of occupations and number of house's level while structural damage is influence by type of building materials and type of occupation.

4.3 Flood Depth-Damage Curves

The flood depth-damage curve is the curve of flood depth versus flood damage. The data of water depth in metres was collected during the interview survey while the flood damage percentage is calculate using the equations (3.1) and (3.2). Then the graph is plot flood depth (m) versus flood damage (%).

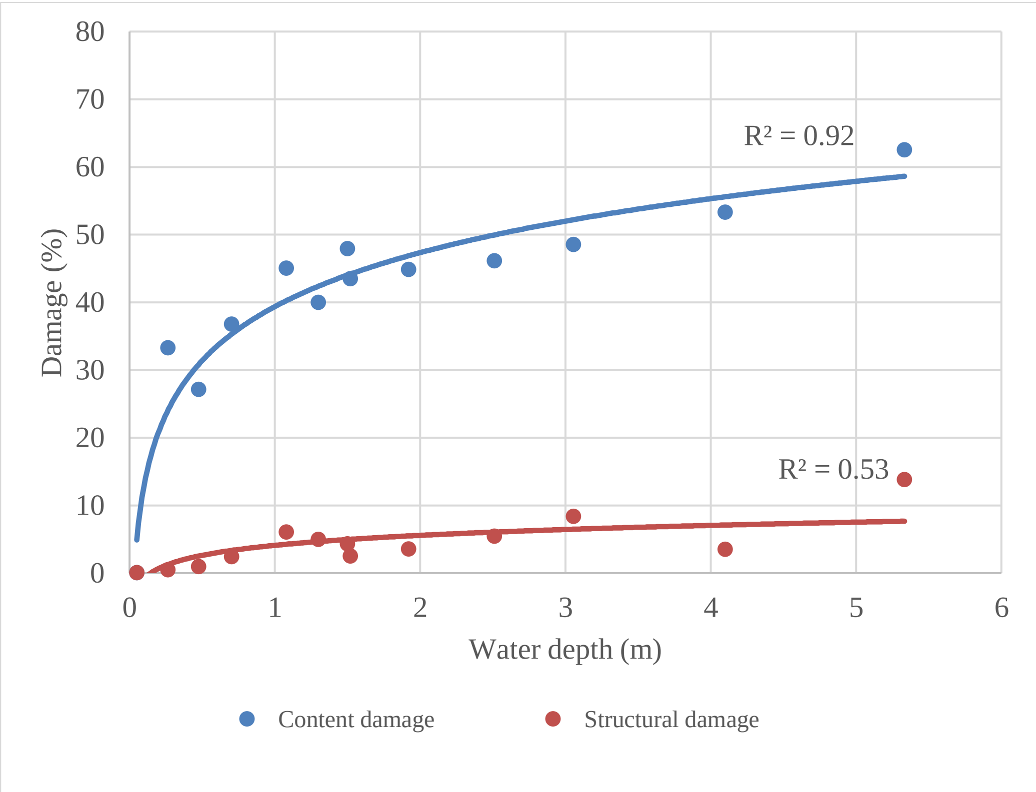

Figure 4.11 Residential flood depth-damage curve for Kuantan

Figure 4.11 show the flood depth-damage curve for Kuantan. The R^2 is 0.92 for content damage and for structural damage the R^2 is just 0.53. The R^2 for content damage is good since it is near 1.0 which mean 92%. The R^2 for structural damage is poor due to the data collected is not accurate. The curve for content damage is higher than the curve of structural damage. This due to the cost of household loss combine is higher than the structural repaired cost. According to the data collected, some of houses is not damage by flood. The flood damage also increases when the flood level increase. This result is similar to previous study by another researcher.

CHAPTER 5

CONCLUSION

5.1 Introduction

In this study, flood damage assessment was performed for residential category for Kuantan, Pahang that were affected by flood during 2013. Flood damage was assessed using direct assessment and the flood depth-damage curve was developed for Kuantan using the data collected from interview survey. The variable that influenced the flood damage was identified by regression analysis using STATA software.

5.2 Conclusion

The result of this research according to the objectives are as follows,

i. The distribution of flood damage according to the number of levels, building types, and building materials show that the average damage is highest for single-storey houses, semi-detached houses, and brick. The average content damage is RM 8,200 for every respondent's house and the average structural damage is RM 2,200 for every house. Most of the houses are terrace house and was constructed using brick.

ii. Regression analysis show that content damage is influenced by type of occupation and number of storeys while structural damage is influenced by type of occupation and type of building material.

iii. The flood depth-damage curve obtained is reasonable for content damage as the R-squared is 0.92 but not reasonable for structural damage since the R-squared is 0.53.

Finally, these finding can be very useful for future application of flood damage estimation works in support for flood disaster risk reduction efforts in Malaysia.

5.3 Recommendation

Some of recommendations for reducing flood damage in Kuantan area.

i. Improve the questionnaire design to attract respondent's attention which will also improve the data collection.

ii. This type of study should be extended for more respondents to improve for better result and consider additional direct damage to public facilities.

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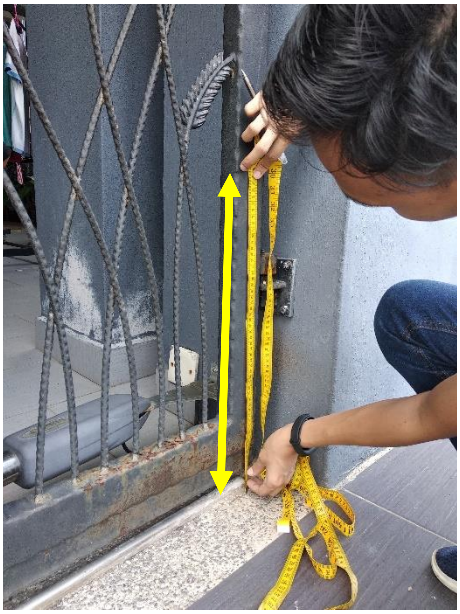
APPENDIX

Measuring flood depth

Location: Permatang Badak Baru
Flood depth: 0.8 m



Location: Permatang Badak Baru
Flood depth: 0.6 m

Location: Bukit Setongkol
Flood depth: 2.4 m

Location: Bukit Setongkol
Flood depth: 0.78 m

Photo during interview session

Location: Permatang Badak Baru

Location: Bukit Setongkol

Location: Bukit Setongkol