Analysis of Flood Physical Vulnerability in Residential Areas

Case Study: Naga City, the Philippines

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by

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Abstract

Vulnerability assessment is a crucial input to comprehend the degree of loss that the built environment suffers as a result of the occurrence of a natural disaster. Very few researchers have conducted flood vulnerability assessments in developing countries. This research examines the flood physical vulnerability and people's coping mechanisms in flood-prone residential areas in Naga City, the Philippines. From literature review, the physical vulnerability is considered to include the following elements at risk: the structural types of building, building contents and outside properties. The study in Naga City was conducted through an inventory of 245 buildings, using mobile geographic information system (GIS) equipments and a digital camera to record detailed attributes of each building. Subsequently, interviews were done with 68 households to gain data on flood depths, flood occurrences, coping mechanisms to flooding and flood impact to each of the elements at risk. From two major flood occurrences in Naga City, flood Rosing and flood Unding, the flood depths were assessed by interviewing the local population. The information from interviews was interpolated using a triangulated irregular network (TIN) of flood depth data. The results show similarity with flood modelling from research done by Bin Abd Rahman in Naga City (2006). Six structural types of buildings were found in the study area. Vulnerability curves were made for these six structural types, by plotting the relationships between flood depth and damage for each structural type. The results indicate that the structural type with plywood walls and wooden floors is the most vulnerable buildings to flooding, while the structural type with hollow block walls and concrete floors is the least vulnerable. Vulnerability of building contents is mainly determined by the number of floors. Households with a two-floor house are the least vulnerable and households with one floor house are the most vulnerable. The damage to outside properties was rarely found because people could cope by transferring them when a flood occurs. This research can be helpful for the small municipality to conduct a cost-effective flood vulnerability assessment and to design an appropriate approach or policy for reducing the flood disaster risk. This research concludes that flood awareness and coping mechanisms play a large role in reducing damage to the structural type of building, building contents and outside properties.

Keywords: physical vulnerability, flood impact, coping mechanism, Philippines, field survey, mobile GIS

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1. Introduction

This chapter explores the introduction to the study, research problem, research objective and research design. It describes in brief the benefits of this research, time schedule and the outline of the thesis.

1.1. Urban Area and Floods

Urban areas are more frequently exposed to natural hazards, in particular to flooding. Surprisingly, floods might be considered as one of the hazards making most impact on human beings (Ward 1978; UNDOR 1978, cited by Blaikie et al., 1994). Smith (2001) also stated that floods claim over 20,000 lives and adversely affect around 75 million people worldwide annually. This statement in fact has not yet included material loss during the flood events. Thus, the magnitude of problems due to flood disasters is even bigger than the records in the mentioned studies indicated. Flood also has been a dominant natural hazard in terms of events for recent years in South East Asian countries (figure 1-1). Notwithstanding the fact that floods seldom cause big fatalities for human beings, it contributes to the biggest disruption among all hazards since it occurs very often.

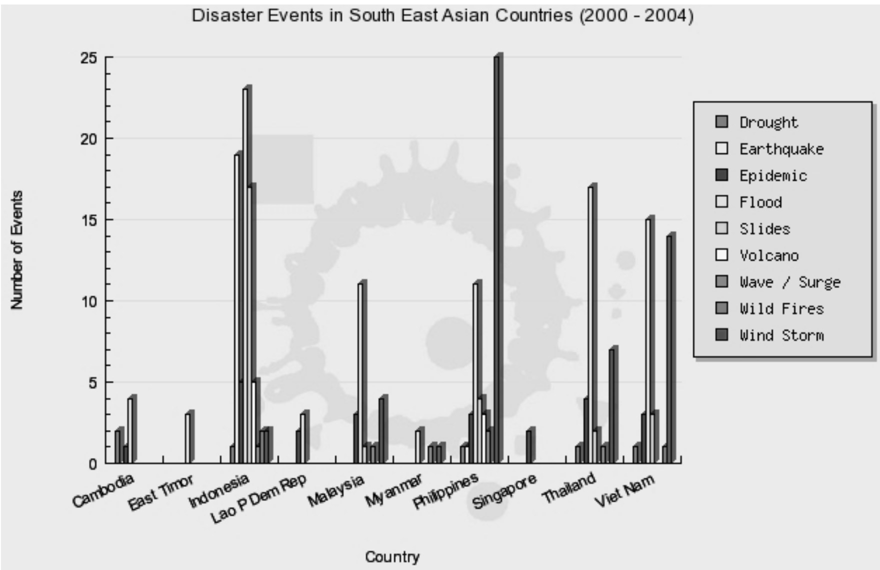


Figure 1-1 Disaster Events in South East Asian Countries (2000-2004)
Source: (CRED, 2005)

The trend of urban development, especially in developing countries, is continuing to grow. It leads to the need for more land to expand. Cities in South East Asian countries, for example: Bangkok, Jakarta and Manila, have been growing rapidly in terms of population. Consequently, they need more space for people to live and work in the city. This can be noticed by the urban expansion in the fringe area or also in hazardous areas.

In developing countries, people living in flood plain areas often are poor people. As they cannot afford to buy legal land, they occupy vacant land along the riverside. Nevertheless, it does not always happen like that. Many planned settlements are also built on landfills in lowland areas. This indicates the scarcity of suitable land in the urban area. However, when flooding occurs, not only people who live in the floodplain area, but also neighbouring areas may experience flooding since the flood plain area has been expanded.

Many ways have been introduced to deal with flood, which in general can be classified into: structural and non-structural measures (Correia et al., 1999). Structural measures comprise a set of works and structures for modifying floods through the reduction of one or several hydraulic parameters that characterise a flood event, such as the volume of runoff, peak discharge, time of rise and duration, depth, velocity or extent of the flooded area. The structural approach typically has been a major tool all over the world, until the rise of criticisms in terms of the significance of its environmental impacts.

The non-structural measures involve a wide range of prevention or adjusting measures to reduce flood risk through modification of human activities that are vulnerable to flood in the flood plains. Thus, the non-structural approach focuses on doing certain things to reduce the possibility of human activities to be influenced by flood. This approach includes flood forecasting and early warning systems, flood proofing and flood insurances, disaster preparedness and emergency plans, and land-use regulations for development control. The non-structural measures modify the susceptibility of damage and disruption of individuals and the community. The non-structural approach for flood adjustment was campaigned primarily after the 1960's (White, 1964, cited by Correia et al., 1999).

Both approaches, structural and non-structural, are still relevant to flood mitigation. It depends on the characteristics of the area, as well as on the capacity of a local authority to choose one of the approaches. Nonetheless, the assessment of material loss or in other words, vulnerability and risk assessment cannot be eliminated from the picture. Dutta et al., (2003) state that a quick estimate of economic loss after a disaster can be very useful in allocating resources for recovery and reconstruction. It is also important for long-term flood control planning, emergency management, as well as useful for land use planning and management (Burby, 1998; NAP, 1999; Mileti 1999, cited by Dutta et al., 2003). Hall et al., (2003) argue that risk assessment and analysis is important in order to provide the basis for identification and analysis for the policy responses to future risks, in particular for policy responses whose implementation may take several decades.

Most of the countries around the world, especially Asian countries, do not have any methodology of estimation of loss due to a natural disaster (Dutta and Tingsanchali, 2003). In addition, loss functions for different land cover features are rarely available. The information about loss estimation caused by floods of different magnitudes and the loss return period are crucial to develop policies for a rational flood alleviation, based on cost effective measures (Penning-Rowsell and Chatterton, 1977; Smith and Ward, 1998). Having data of loss estimation, the local, provincial or national authority can design such policies to tackle or to reduce the damage if flooding occurs. In the context of urban planning and management, loss functions can also be used as an input for a scenario, based on the different land uses or activities in urban areas. For example, having the information about possible losses of such an area when flooding occurs, the municipality can prepare actions to lessen the effects, if not to escape from the disaster events.

1.2. Research Problem

Naga City and a large portion of its nearby municipalities, together known as Metro Naga, are situated in the floodplains of the Bicol river basin. Naga City frequently faces problems due to flooding and typhoons. Therefore, Naga City has been selected as one location for the SLARIM (Strengthening Local Authorities in Risk Management) research project in International Institute for Geo Information Science and Earth Observation (ITC).

Recently there have been two great concerns of flood risk in Naga City: First, there is a significant increase in the vulnerability of the land due to the nearly uncontrolled growth of the city. The second concern is the increase of flood hazards, which can be attributed to the sedimentation within the embanked riverbed (Adolfo, 2003 cited by Alkema et al., 2004). Moreover, the wind (typhoon) effects in the areas are also quite severe. It causes damage to roofs and walls of residence, flying objects and building collapse, as what has happened on November 2004 (Typhoon2000.com, 2004). It has more severe effects to people when the flood comes at the same time as the typhoon, as flooding can also be caused or made worse by the strong wind from the coastal area (ADPC, 2001).

There have been many studies conducted in Naga City and its broader areas in order to deal with the flood and typhoon problems (see Naga City Disaster Mitigation Plan on ADPC 2001). The latest research, which focuses on the flood problem, is the research under the Strengthening Local Authority in Risk Management (SLARIM) project of the cooperation between the International Institute for Geo-Information Science and Earth Observation (ITC) and Naga Municipality. It has produced studies on flood modelling using 2D – two dimensional models (Tennakoon, 2004), analysis on the community coping mechanism (Reganit, 2005) and flood vulnerability assessment in term of its structural, social and economic aspects (Monrroy Prado, 2005).

However, losses due to floods have not yet been addressed properly. This knowledge is actually valuable as input for making appropriate policies and actions for reducing the damage (Deyle et al., 1998; Dutta and Tingsanchali, 2003; Penning-Rowsell and Chatterton, 1977). Therefore, this research aims to contribute to the analysis of the physical impact and losses (damage) due to floods, particularly in residential areas. The physical impact and losses due to wind are not explored in this research, because it is assumed that this type of damage can be explored separately. Of course, the effects can be much worse if both flooding and typhoon occur at the same time. Nevertheless, typhoon impacts are also briefly discussed (see section 3.3.4).

1.3. Research Objectives

The main objective of this study is to develop a rapid assessment for flood physical vulnerability and to apply it in a case study in residential areas in Naga City, the Philippines

The specific objectives are:

1. To identify the elements at risk relevant for flood vulnerability assessment in the residential area
2. To assess the damage of structural types of building, building contents, and outside properties as well as to conduct vulnerability assessments for those objects
3. To identify how people mitigate the impact of the vulnerable objects due to flood

1.4. Research Questions

Regarding to sub-objective one, the research questions are as follows:

1. What are the basic data collection methods to do the flood physical vulnerability assessment?
2. What elements of risk are relevant to be analysed in the physical vulnerability assessment in Naga City?

Regarding to sub-objective two, the research questions are as follows:

1. How are the relationships between flood-depth with vulnerability to buildings, building contents, and outside properties?
2. How is the spatial distribution of vulnerability for structural type of buildings, building contents and outside properties?
3. What type of structural type of building, of building content and outside properties is categorized as the most vulnerable?

Regarding to sub-objective three, the research questions are as follows:

1. What kind of actions people introduce to mitigate the impact of flood?
2. What are the advantages of the actions to reduce the impact of flood?

1.5. Research Design

This research consists of three main parts (figure 1.2). The first step is the identification of the elements at risk, the second step is vulnerability assessment and vulnerability functions and the last one is people's actions (so-called people's coping mechanisms) to reduce the impact of flood. First step done was developing the database of elements at risk. The database was classified based on literature review and fieldwork findings. In general, three elements at risk were identified: structural type of building, building contents and outside properties (Dutta and Tingsanchali, 2003). Each element at risk is elaborated into detailed classes. Structural types of buildings are classified into several categories in terms of the combination of materials of wall and floor. Building contents and outside properties are examined in terms of its value. The detailed research framework and the analysis framework are discussed in chapter 3.

The fundamental assumption of this research comes from the hypothesis that there is a significant relationship between depth and duration of the flood and the damage to buildings, as discussed intensely by many researchers (White 1967 in Smith and Ward; Penning-Rowsell 1997; Dutta et al 2003). However this assumption is only applicable for slow-rise, rather than flood with high-velocity (Kelman, 2002). This section is discussed in more detailed later in the literature review (chapter 2). Having the classification of the elements at risk, the depth-damage and damage were established and plotted to elaborate the relationships of depth-damage for each element at risk.

The data for this research come from the fieldwork done in two barangays[1] in Naga City, the Philippines. The two barangays, Sabang and Igualdad, lie on the junction of the two main rivers in Naga City: Naga River and Bicol River (see figure 3-2 in chapter 3). One reason of selecting these barangays are because the two barangays are amongst the most severely affected areas in Naga City when flood hits (Naga Disaster Mitigation Plan 2001).

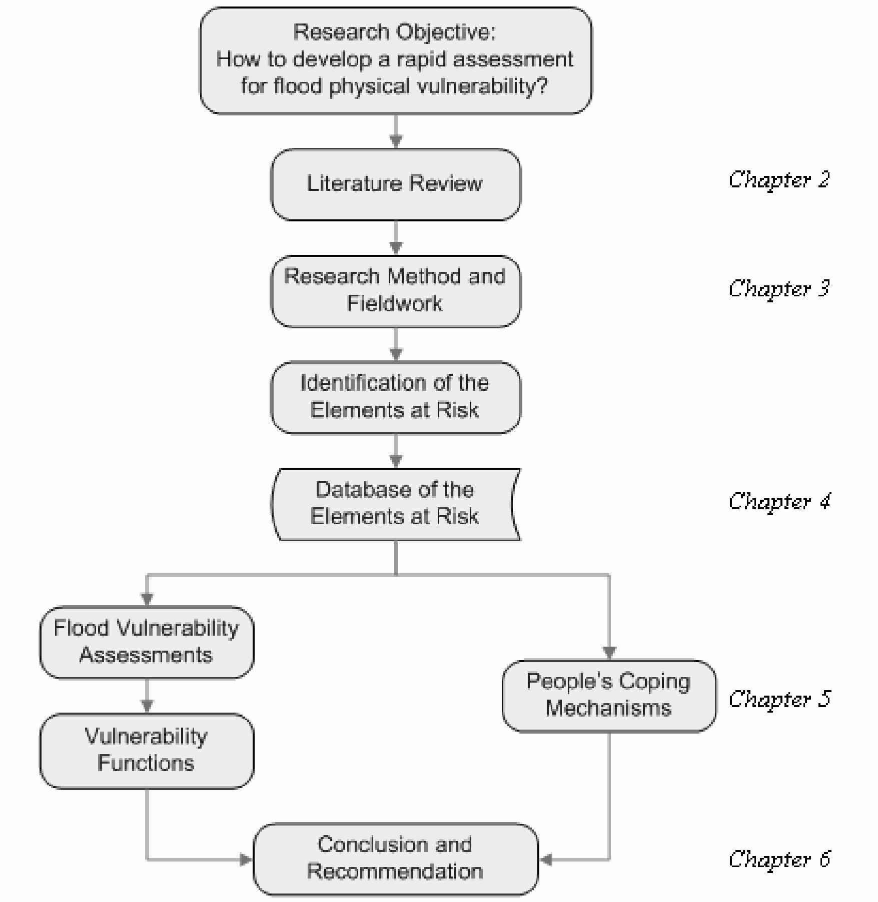


Figure 1-2 Research Framework

Prior to the fieldwork, the research sub-objectives were matched with several methods in order to come up with a schematic way in conducting the research (Table 1-1). The pre-action before the fieldwork was done through a literature review on physical flood vulnerability as well as previous research at Naga City. Then, the methods to carry out the fieldwork were prepared based on the appropriate tools. In the absence of an accurate building footprint and detailed aerial or satellite imagery of Naga City, the data collection for the elements at risk was mainly done through building inventory using mobile GIS equipments.

Sub-Objectives	Research Questions	Methods / Literature
1.	1. What are the basic data collection methods to do the flood physical vulnerability assessment?	▪ Field survey (Close Sensing) with digital camera for each building ▪ Mobile GIS (PDA and GPS) to map buildings
	2. What elements of risk are relevant to be analysed in the physical vulnerability assessment in Naga City?	▪ Classification based on data from previous step ▪ Field survey in the study area
2.	1. How is the relationship between flood depth with damage for buildings, building contents, and outside properties?	▪ Interviews of flood depths with questionnaire to respondents ▪ Collect data of flood depths to get the flood extent ▪ Classify the elements at risk ▪ Data analysis from household interview with depth-damage relationship for each element at risk (structural types of building, building contents and outside properties)
	2. How is the distribution of vulnerable objects based on building, building contents and outside properties?	▪ Plot the result from previous step to map ▪ Link the result spatially
	3. What type of buildings and where are the most vulnerable buildings located?	▪ Comparison of result from each element at risk from the step 2.a ▪ Plot the data spatially
3.	1. What kind of actions people introduce to lessen the impact of flood?	▪ Data analysis from the interviews
	2. What are the advantages of the actions that people use to reduce the impact of flood?	▪ Relationship of 2.1 with 3.1

Table 1-1 Research Question and Proposed Methods

1.6. Study Benefit

This study has benefits for several stakeholders, in particular those who have an interest in flood disaster management in urban area, as follows:

- It performs the process of data collection for the elements at risk and its classification for flood physical vulnerability assessment in residential areas
- It provides the methods for flood physical vulnerability assessment in residential areas, specifically for cities with characteristics similar to Naga

[1] A barangay is the smallest local government unit in the Philippines.

– It is useful for Naga Municipality in order to develop policies in reducing the flood impacts in residential areas.

1.7. Research Schedule

The research was done from May 2005 until February 2006 (table 1-2). From May until – July, the research carried out intense literature review on flood vulnerability assessment. Subsequently, the fieldwork was conducted from August 19 – September 24, 2005.

Tasks	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Writing Proposal										
Literature Review										
Checking Data Availability										
Preparation for Field work										
Field Work										
Data Analysis										
Writing Report										
Finalising Report										

Table 1-2 Research Schedule

1.8. Outline of the thesis

The research comprises theory, methodology and analysis, which correspond to the three major sections of the thesis. Chapter 2 offers the theoretical framework for analysis. Chapter 3 deals with research method, study area and proposed data analysis. As the core of this research, chapters 4 to 5 present findings and analysis from the field.

Chapter 1 provides a general overview of the research. This includes its relevance, the questions that are addressed, its research objectives and its methodology.

Chapter 2 provides the theoretical discussions that are relevant to this research. The theoretical section is dominated by the definitions of vulnerability and physical vulnerability. The methods of flood depth-damage are elaborated in this discussion. Next, selected method for this research is stated.

Chapter 3 introduces the study area, selection criteria for study area and how the area suffers from floods. It follows with discussion of data collection on fieldwork, data preparation and methodology analysis.

Chapter 4 presents the analysis of the relevant elements at risk for flood physical vulnerability. Initially, it classifies the elements at risk (structural types of building, building contents and outside properties) based on the literature. Subsequently, it provides more detailed classes based on findings from the field.

Chapter 5 analyzes the flood physical vulnerability for structural types of building, building contents and outside properties. It continues with the discussion on people's coping mechanism related to flood physical vulnerability.

Chapter 6 provides the conclusions with reference to the research objectives set out above and offers discussion and suggestions for further research.

1.9. Limitation of the Research

The study of vulnerability assessments depends very much on the quality of input data for the analysis. The detailed data of building is very important in this research. However, due to the absence of detailed satellite imagery of Naga City in this research, no classifications of building could be made before going to the field.

Data of value of damage to structural type of building could not be obtained because the respondents could not remember the value. It could have been obtained if more fieldwork time was available. Therefore, the data of value of damage for structural type of building is relatively coarse, because it used the classification made by the author to deal with the problem in data collection.

As there is no input and feedback from the beneficiaries and end users of this research, there has been no attempt to refine the quality of this research. The scope of this study does not deal with this aspect of receiving feedback from the beneficiaries and end users.

In the case of flood damage assessments in developed countries, for instance in UK, the height of electricity installation inside the house is considered. However, this was not considered in this research. According to the discussions with some respondents, the electricity is turned down in order to reduce the damage to electricity installation.

The results of this thesis must be taken very carefully. However, the techniques and procedures are completely valid and applicable in similar studies.

2. Review of Related Literature

This chapter discusses the key definitions of vulnerability and the term physical vulnerability used in this research. Then some case studies on flood physical vulnerability, assessment and methods for computation of the flood physical vulnerability are discussed. It continues with an explanation of the selected methods that are used in this research. In addition, several theories on people's coping mechanisms relevant to physical vulnerability are discussed. Finally, it examines the integration of flood physical vulnerability with people's coping mechanism.

2.1. Definitions of Physical Vulnerability

The definition of vulnerability to natural hazards is very broad, depending which points of view one wants to adopt. Thus, different definitions of vulnerability from many disciplines (civil engineering, geography, social science) exist. Initially, the concept of vulnerability was used by engineers in estimating construction designs related to the level of resistance to physical forces exerted by ground motion, wind and water (ISDR, 2002). Recently this concept has been used by many other disciplines and brought new ideas or even mixed concepts of vulnerability. The following discussion refers to some definitions of vulnerability and later puts it into the context of physical vulnerability.

Launching the International Decade for Natural Disaster Reduction in 1990s, the United Nation Disaster Relief Coordinator (UNDRO, 1991) developed the basic concepts of mitigation below.

Natural hazard is the probability of occurrence, within a specific period in a given area, of a potentially damaging natural phenomenon.

Vulnerability means the degree of loss of a given element at risk or a set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss)."

Elements at risk include the population, buildings and civil engineering works, economic activities, public services, utilities and infrastructure, etc., which are at risk in a given area. Natural hazards

Risk is the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently, the product of specific risk and elements at risk.

Blaikie et al. (1994) define vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. In addition, it involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete and identifiable event in nature or in society.

Pelling (2003) states definition of physical vulnerability by saying that it denotes the exposure to risk and inability to avoid or absorb potential harm in the built environment. Built environments include human settlements, infrastructures and people's belongings.

Vulnerability is also seen as the extent to which a person, group or socio-economic structure is likely to be affected by a hazard (Twigg, 2004). He moreover insists that the observable part of vulnerability is the emphasis on physical / material aspects.

ISDR (2004) proposes that vulnerability is a state or condition that is determined by one or more factors that increase the susceptibility of a community to the impact of hazards. These factors include physical, social, economic and environmental conditions. Accordingly, physical vulnerability can be determined by aspects such as population density levels, remoteness of a settlement, the site, design and materials used for critical infrastructure and for housing.

The definitions of physical vulnerability above are line and supporting each other. Emphasis is put on how elements at risk or built environments are adversely affected by occurrence of natural hazards. Nevertheless, because the purpose of this research is to assess the physical vulnerability, definition stated by UNDRO is selected, as it is quantitative and measurable. The concept of elements at risk is also used to define the objects of interest in this research.

Physical vulnerability itself cannot be seen as one unit as many factors are involved and shaping the vulnerability, for instance one cannot asses the vulnerability of a building but neglecting the other. ISDR (2004) proposes a chart showing the relationship of physical, economic, social and ecological factors shaping the vulnerability (figure 2-1). However, this is actually related to the underlying factors like economic condition and level of education of the house owner. Therefore, though by scope this research focuses on the physical aspect, it also briefly considers other factors like economic and social aspect to be involved in the discussion part. As a result, people's adaptation or people's coping mechanism should also be taken into account (ISDR, 2004).

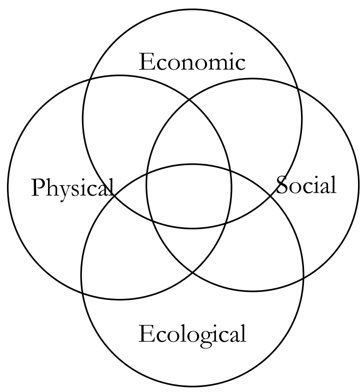


Figure 2-1 Interaction of Vulnerability Factors
Source: ISDR (2004)

2.2. Flood Physical Vulnerability Assessment

Flood physical vulnerability deals with the level of damage or loss that elements at risk or built environments suffer from the occurrence of flooding. Some studies emphasize the measure of the damage effect due to flooding instead of vulnerability. Nevertheless, those studies are relevant to support in identifying vulnerability. Following sections discuss damage effect of flooding in some countries, how the methods are relevant in this research and selected methods used for this study.

2.2.1. Methods to Determine Flood Physical Vulnerability

Three main methods exist in computing the direct economic losses from floods (Aglan et al., 2004; Penning-Rowsell and Chatterton, 1977; Smith and Ward, 1998). The first method is done by conducting an experiment to measure the flood damage when building and its contents are exposed to floodwater. Aglan et al (2004) conducted an experiment by inundating some buildings to assess the damages that would happen to building structure and its contents for before and after flood (figure 2-2). The case study was done in Tennessee, United States. The effects of floodwater to wall, floor, doors and windows for different flood durations were assessed. Subsequently, the vulnerability curves of the relationships between duration and damage were created. This type of research costs a lot of money and time in order to provide similar environment with the real condition of flooding. It also needs knowledge in civil engineering to understand the performance of building before and after flooding.

Figure 2-2 Experiment of Flood Damage, before and after Flooding
Source: Aglan et al (2004)

The second method is based on assessing the potential losses as the expected result from the flood events on a specific severity based on generalised relationship between certain flood characteristics and physical damage (Smith and Ward, 1998). The disadvantage is, however, that results tend to be synthetic rather than actual. It is important to realize that unmodified synthetic losses can be higher than actual recorded losses simply because the assessments ignore the damage reducing actions that the floodplain residents take in a flood event.

The third method is based on the collection of actual flood damage information which is reported after the event (Dutta and Tingsanchali, 2003; Penning-Rowsell and Chatterton, 1977; Smith and Ward, 1998). This method was applied by White (1967) and Penning-Rowsell (1977) in the cases of

Tennessee, the United States and the United Kingdom, respectively. The advantage of this method is that it deals with real event. It is based on field interviews and questionnaires on damages to properties and level of injury to people due to flood. The results very much depend on the responses of the respondents. However, it has disadvantages, as there might be exaggerated data from the respondents.

The latter method is more appropriate for this study since it is achievable and applicable in a relatively short time. The other reason is that this research deals with respondents who experience flood annually. Accordingly, the respondents are assumed sufficient as the source of information for the damage assessment. The following section continues highlighting on the applications of the third method in flood vulnerability assessment in several case studies.

2.2.2. Flood Physical Vulnerability Assessment based on Actual Event

The literature of the flood damage effect highlights more in the cases of developed countries, for instances: cases in UK, US and Germany (Kreibich et al., 2005; Penning-Rowsell and Chatterton, 1977; Smith and Ward, 1998). Rarely have been any discussions on flood physical vulnerability in the case of developing countries, particularly in South East Asian countries (Dutta et al., 2003). In this review, discussions use several examples of flood depth – damage relationships from developed countries as well as from developing countries.

White (1964) was believed to be the first to create the flood depth – damage graph to represent the relationship between damage and flood depth (Smith and Ward, 1998). The case study was taken in a floodplain at Tennessee, USA. He used several occurrences of flood to establish flood records and the damage that happened. Based on several flood depth and damage data, he established some curves representing relationships between flood depths and damage (figure 2-3). Flood depths were measure in cm and flood damages were transferred into currency (US $). The damage curves were established to each type of house with the assumption that each type of house has different damage. Flood depths were measured from three occurrences of flood: 1950 flood, regional flood and maximum probable flood.

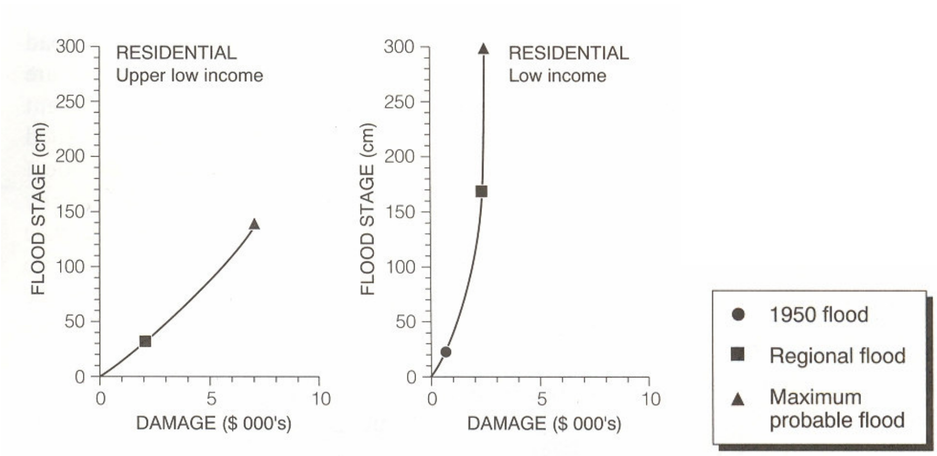


Figure 2-3 Examples of Representative Properties on the Floodplain at Tennessee, USA
Source: White (cited from Smith and Ward 1998)

Likewise, Penning-Rowsell and Chatterton (1977) established the relationship of depth and damage due to floods in the United Kingdom (figure 2-4). Their methods, later known as Blue Manual, were collected and used as the basis for determining the flood damage in UK. They divided the elements at risk into several detailed elements at risk, i.e.: classification of house is divided in detached, semi-detached, industry, commercial shop, etc. For each element at risk, they developed questionnaires and asked the households (respondents) to record the flood damage.

The relationship of depth-damage that happened to particular elements at risk was calculated to create some flood depth – damage curves (figure 2-4). They tested the concepts on two cases study in Bristol Flood and Ashton Vale flood to get the data on flood damage in the two areas. The intention was to assist the residents who did not have flood insurance and the municipalities in both areas so that they could estimate how much damage they suffered. Another purpose was to help municipalities in calculating the possible damage in the future, if flood would happen and therefore they could determine which approach would be selected based on Benefit-Cost Analysis.

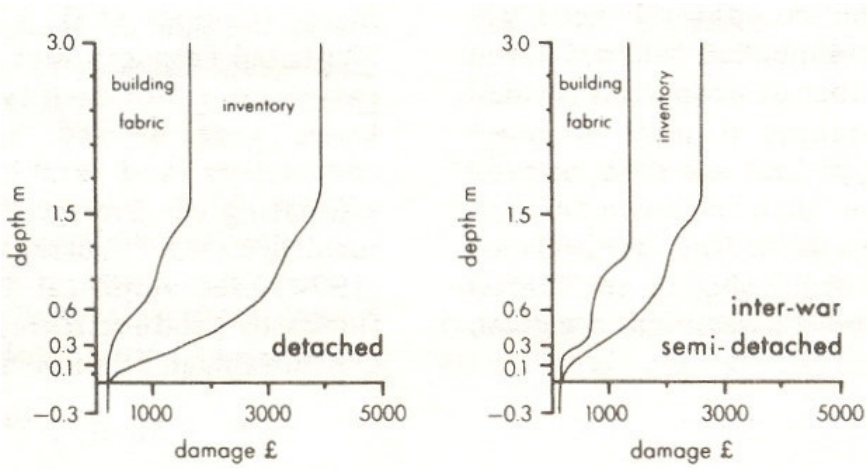


Figure 2-4 Examples of Standard Flood Depth-Duration-Damage Curves for the UK
Source: Penning-Rowsell and Chatterton (1977)

Flood damage assessment method developed by White (1967) and Penning-Rowsel and Chatterton (1977) consists of the following procedure:

1. Determine by levelling the elevation of the first floor for each type of building or establishment.
2. Select from stream profiles or flood histories for floods of three critical stages (flood depth) the elevation each flood would reach in the building.
3. Identify the stage at which damage would begin. Below this level, zero damage is assumed.
4. Estimate the amount of damage (in financial term) that would result from flooding at each of the selected stages and graph smooth curve.
5. Secondary flood characteristics: duration, velocity are used to modify the curves, for instance: stage damage curve could have short, medium, and long duration variant.
6. In addition, particularly Penning-Rowsell and Chatterton proposed to test the synthetic damage estimates so derived by comparing them with actual damage assessments as these become available.

Data collection plays an important role in order to estimate the loss accurately. Penning-Rowsell and Chatterton (1977) suggested that one who wants to collect data should consider the sub-category land use and depth - damage data. Therefore, the questionnaire (guideline) must include recording in full. During the more comprehensive field surveys the type and age of dwellings and determining the social class of the occupants, which has a significant effect on potential damage. More details of this typical data collection are shown in table 2-2.

	Field Survey	Depth / damage data	Other data
A	None; Land use from maps / plan	All: sector averages (including industrial)	Mean ground floor
B	Selected field checks; Land use survey from maps / plan	Residential: type or type and age averages Retail: type averages Industrial: site survey or average data	Ground floor heights from maps/plan
C	Full field land use survey	Residential: type, age and social class (census or questionnaire) Retail etc: category or sub-category Industrial: full site survey	Ground floor heights levelled (or from aerial photographs)
D	Full field land use survey	All: full site survey methods	Levelled ground floor heights

Table 2-1 Data Collection for Flood Damage Assessments
Source: Penning – Rowsell and Chatterton (1977)

One recent research of flood risk assessment with a case study in Bangkok, Thailand, South-east Asia was done by Dutta and Tingsanchali (2003). In principle, they conducted similar methods as those of White (1967) and Penning-Rowsell and Chatterton (1977). Dutta and Tingsanchali did the research with the case study at two districts in Bangkok. The methodology was based on questionnaire surveys to gather data and information for development of loss functions. Recorded damages are particularly on structural type of buildings[2], building contents and outside properties. For the establishment of loss functions, they found two main construction materials: wooden and non-wooden (concrete). Therefore, the data were divided into two main data sets based on the building construction material. The loss curves (flood depth and damage) were established through the relationship of floodwater depth (in m) and the damage (in Baht). Likewise, the loss curves were also established for building contents and outside properties.

Dutta and Tingsanchali (2003) propose an approach to classify urban land use into two classes: residential building and non-residential building. This approach does not include urban infrastructure in the classification. For each class, the assessment considers damage of structural type of building, building contents and outside properties. The flood depth damage relationships are developed with

[2] In this case, Dutta and Tingsanchali refer to the structural type of building as the main construction material of the building.

data of flood depth and damage obtained through interviews. With the data below, the model can get basis data of elements at risk for several flood damage and flood loss estimation (table 2-3).

No.	Land use classification	Input data Required
1.	Residential building	Total floor area
		Type of structures
		Value of any structure per unit floor area
		Building Height
		Household distribution
		Content and outside property value per household
2.	Non Residential Building	Total floor area
		Type of non-residential buildings
		Number of non-residential buildings per type
		Property, stock and outside property values of non-residential building per worker per type
		Property, stock and outside property values of non-residential building per worker per type
		Total workers of non-residential building per type

Table 2-2 Input Spatial Parameters for Flood Loss Estimation
Source: Dutta and Tingsanchali (2003)

On the contrary, Kelman (2002) argues that the flood depth – damage approach cannot be established to generate the vulnerability or damage that elements at risk suffer. Subsequently he mentioned that flood-depth damage should also consider the effect of flood velocity because flood as such is not the only factor that creates severe damage. He paid attention to the impact of flood on residences in coastal areas, eastern England, Canvey Island on the Thames Estuary and Kingston upon Hull on the Humber Estuary. The study emphasises the characteristics of the physical vulnerability of the residences to floods on coastal area. It relatively introduces new form of vulnerability profiling in comparison with that of White (1964) and Penning-Rowsell and Chatterton (1977).

First, it establishes the damage scale used to fill the table on the vulnerability matrices (table 2-1). Second, it continues including two dimensional vulnerability matrices with flood depth differential along one axis, flood velocity along the other axis, and the matrix cells displaying a damage outcome (appendix 2). The value of vulnerability is defined and filled in to the vulnerability matrix.

V_{max}	F diff $_{max}$					
	0.0 m	0.5 m	1.0 m	1.5 m	2.0 m	[…]
0.0 m/s						
0.5 m/s						
1.0 m/s						
1.5 m/s						
2.0 m/s						
[…]						

Table 2-3 Vulnerability Matrix for First-Order Vulnerability Profile
Source: Kelman (2002)

Kelman's hypothesis is valid when velocity of flood is taken into account or velocity is high enough to create destruction to building or built environment[3]. However when the flood velocity is not high enough, it is still valid to establish the relationship between flood depth and damage. To establish the concept in determining flood damage, it is important to post a question: "What will fail first when flood water contacts a house or different types of houses?". Kelman and Spence (2003) proposes a diagram to understand flood failure (figure 2-4).

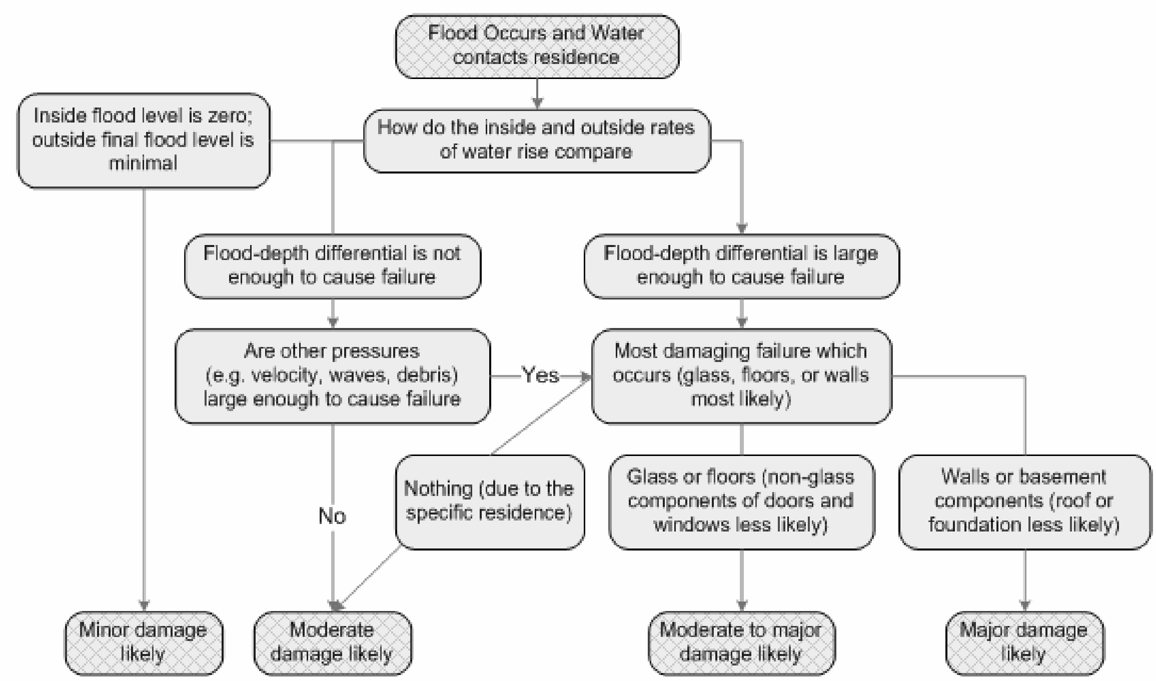


Figure 2-5 Flood Failure Flowchart
Source: Kelman and Spence (2003)

In addition, there was research related to flood vulnerability conducted in Naga City the Philippines. Monrroy-Prado (2005) conducted flood vulnerability assessments with considerations to three aspects of vulnerability: structural, social and economic vulnerability. She emphasized identifying structural

[3] After several discussions with Ilan Kelman by emails (2005), the author could conclude that for a case study in which flood velocity was not speedy enough to cause destruction; the effect of velocity can be assumed less relevant.

(buildings), social and economic 'pre-hazard' conditions of two communities in order to determine their vulnerability to floods by applying participatory methodologies combined with GIS. Participatory methodologies were employed by interviewing and conducting workshops at two flood affected communities. One of the conclusions she made was that structural vulnerability are very much related with the levels of pre-hazard safety conditions of the society.

2.2.3. Selected Physical Vulnerability Methods for This Research

Based on the discussion in the previous sections, this part selects the most appropriate method to be used in the analysis. As it is assumed that flood occurrence in Naga City is a slow-rise flood, therefore the flood depth-damage methods that were introduced by White (1964), Penning-Rowsell and Chatterton (1977) and Dutta and Tingsanchali (2003) are appropriate. Main classification of the elements at risk for this research follows those of Dutta and Tingsanchali (2003), who classify the objects into structural type of building, building contents, outside properties. Therefore, the further analyses in chapter 4 and chapter 5 include the three components: structural type of building, building contents and outside properties.

Method for data collection of depth-damage follows the method of data collection as those of White (1967), Penning-Rowsell and Chatterton (1977) and Dutta and Tingsanchali (2003). Accordingly, in this research, a questionnaire was prepared and used to gain information of the elements at risk. The questionnaire consists of questions on structural type of building, building contents and outside properties), flood occurrence, flood damage and loss and flood mitigation (appendix 1).

Initially, damage in this research was going to be analyzed in term of cost, in the local currency, the Philippine Peso (PhP). Since during the interviews, respondents could not recall properly the value of damage in terms of money for structural type of building, value in money is not used in this research. However, the respondents were asked to describe the damage in terms of its percentage of the value of entire building (see chapter 5.2 for detailed discussion). For the building contents and outside properties, the respondents were able to estimate the values of damage in terms of money.

Several reasons why the respondents found it difficult to describe the value of damage of the building are as follow:

- Some respondents do not repair the damage. Others repaired the damage after the building structures (wall, floor) are completely broken.
- They receive relief from the Naga Municipality, Barangay office and other charity agencies in the means of construction material of which they do not know the value.
- They replaced the damaged structure with other scrap materials or lower quality material, for instance: some respondents mentioned that they replaced the wall with plastics for temporary.

2.3. People's Coping Mechanisms on Flood

Coping mechanisms are the manner in which people react within existing resources and ranges of expectations in a situation, to achieve various ends (Blaikie et al., 1994). In addition, coping can change the physical and social structures of the city and interrupt the progression of the vulnerability

(Pelling, 2003). Therefore, additional analysis on coping mechanism is also very important to support the analysis on physical vulnerability.

Reganit (2005) conducted research of coping mechanisms with the case study Naga City, the Philippines. The coping mechanisms with flooding have significant contributions to reduce flood disaster risk in local communities. She found that economic and social coping mechanisms are employed by the households focus on the preparedness, response and recovery measure in dealing with floods. In addition, she added that coping mechanisms should be included for more realistic policies and programs in disaster management. Findings of coping mechanisms from Reganit (2005) are combined with related findings in this thesis in chapter 5.

In dealing with damage on structural type of buildings, building contents and outside properties, the emphasis should be more on how coping mechanism can reduce the physical vulnerability. Pelling (2002) mentions two examples of a coping mechanism due to the environmental stress (for example: flood, earthquake), such as: build house on raised ground and retrofit buildings to withstand hurricane or earthquake stress.

In the lesson learned from the Elbe Flood on 2002, Kreibich et al (2005) observed the following building precautionary measures may mitigate losses in flood prone areas (see figure 2-6):

- Elevated configuration
- Shielding with water barriers
- Waterproof sealing
- Fortification
- Flood adapted use
- Flood adapted interior fitting
- Safeguarding of hazardous substance

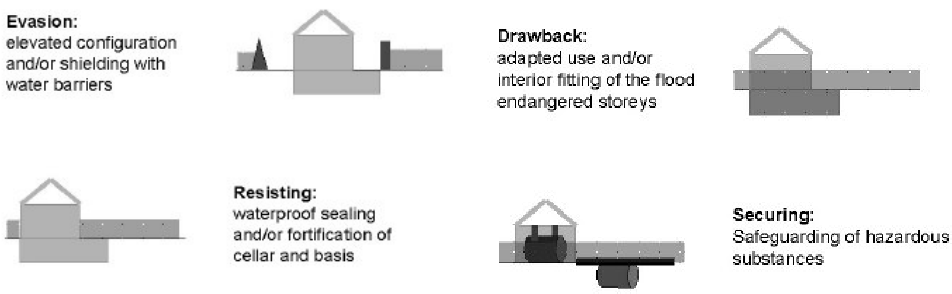


Figure 2-6 Overview of Different Building Precautionary Strategies and Measures
Source: Kreibich et al (2005)

It was found that building precautionary measures have a significant potential to reduce flood damage of residential buildings and contents. Although these measures are mainly effective during small floods, they even led to significant mean damage reductions of up to 53% for buildings and contents during the extreme flood events in 2002.

Building precautionary measure can be applied by implementing certain building codes to minimize the flood damages by ensuring that beneficial uses of buildings are located above the design flood elevation (ISDR, 2002). Buildings can be raised above the design flood level by placement of fill; stilts or piles used to elevate the structure; and building utilities can be located above the flood level (figure 2-7). Preparing suitable designs for occupants in the flood plain area can be very useful guidelines as not all people are aware of the risk of natural hazards.

Figure 2-7 Illustration Design of Building Code
Source: ISDR (2002)

Besides building code, land use planning can play a role to reduce the impact of flooding (Burby, 1998; Randolph, 2004). This approach is often used by municipalities in United States. Land use that is carefully designed and rigorously implemented is the most useful approach to managing urban or population growth and managing associated risks (ISDR, 2004). Land use planning needs the significant role of state to develop a plan for natural hazard mitigation (Berke et al., 1996). Figures 2-7 provides how information of flood levels is taken into account in making land use plan in flood plain area. Houses should be built by considering the possible flood level in the flood plain area.

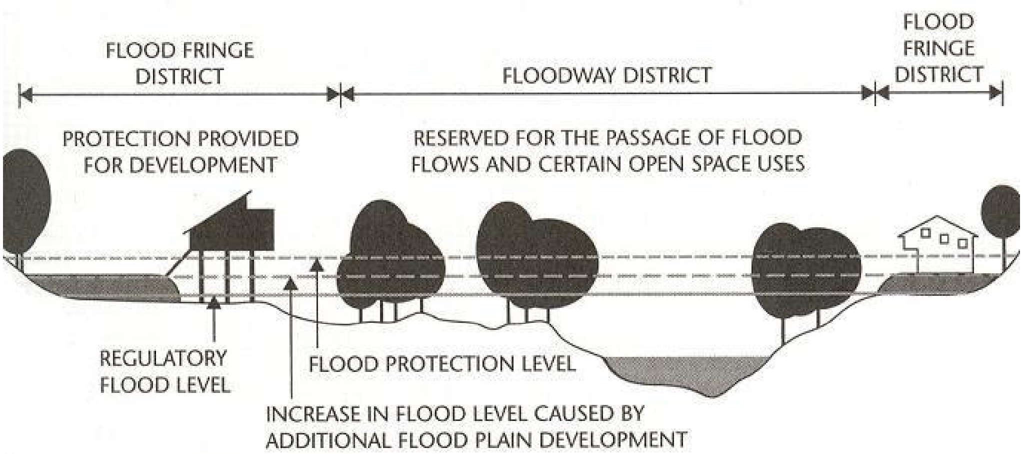


Figure 2-8 Floodplain Zoning Using Floodway and Floodway Fringe Districts
Source: Randolph (2004)

2.4. Conclusion

This chapter supplies significant definitions of physical vulnerability that are the important basis used in this research. Discussions on several case studies in flood damage assessment and flood physical vulnerability methods provide clear ways to conduct flood physical vulnerability. The benefit from people's coping mechanism against flood is important to be considered in the analysis. Hence, it is significantly important to integrate the analysis of the physical vulnerability with the analysis of people's coping mechanism that is related to certain vulnerability.

3. Research Methods

This chapter describes the process of this research. It starts discussing the research approach and data requirements and data availability. Then, the study area is described briefly. It follows examining the fieldwork data collection. Finally, it explains the analysis used in this research. The process of this research has been grouped into three phases that is the pre-field, fieldwork, and post fieldwork (figure 3-1).

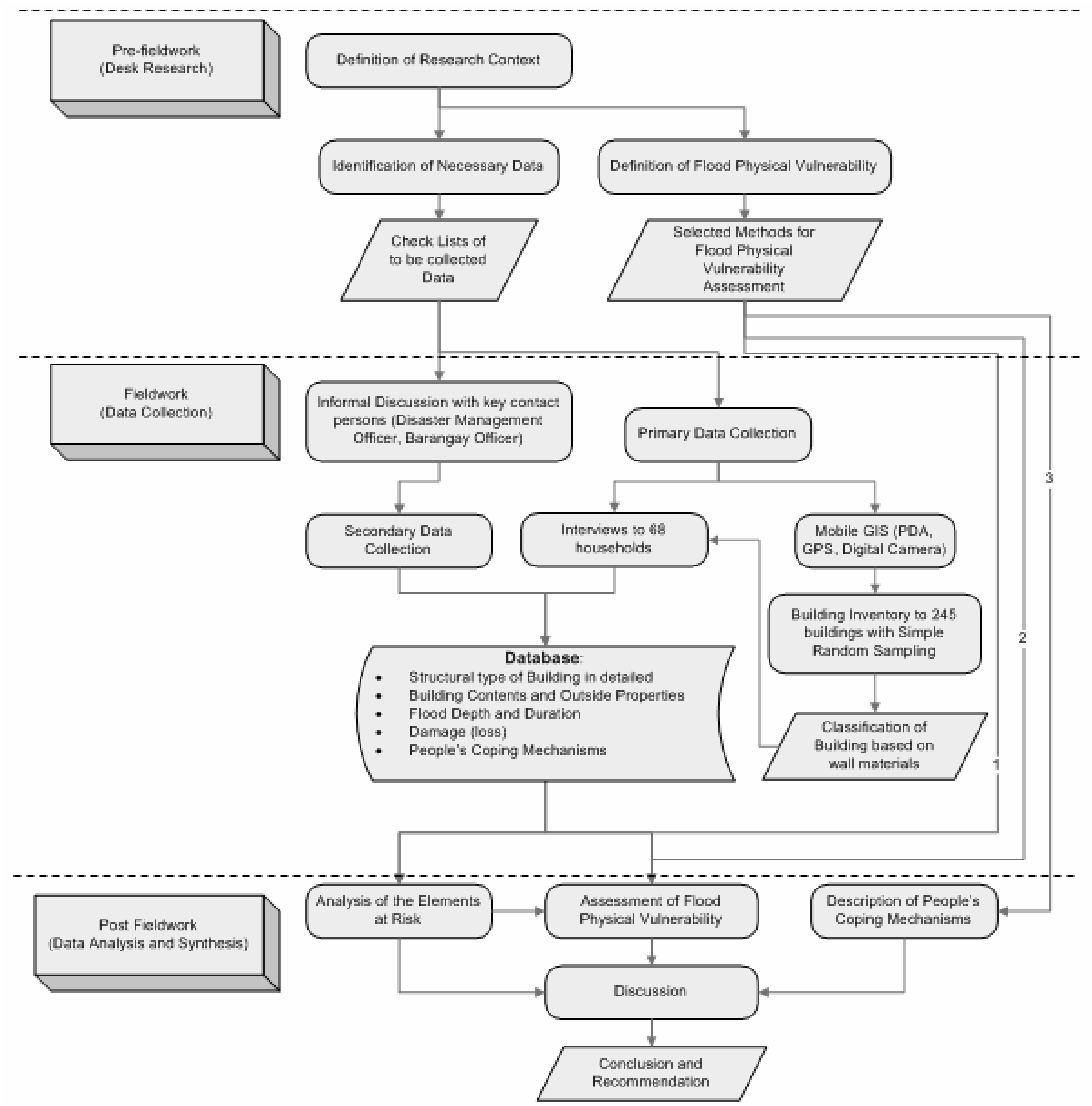


Figure 3-1 Outline of the Research Process

3.1. Research Approach

This research commences from reviewing the need for more understanding of flood physical vulnerability in South East Asian context. As discussed in chapter 2, only a few research studies was done on flood vulnerability assessments in a South East Asian context (Dutta and Tingsanchali, 2003). The flood damage assessment on physical aspect in an urban area can be done on many elements at risk on the basis of land use or functions of buildings (Dutta et al., 2003; Penning-Rowsell and Chatterton, 1977; Smith and Ward, 1998). However, the time available during data collection in the field only allowed for data collection in the residential area.

This research conducted a case study in two flood-affected communities in Barangay Sabang and Barangay Igualdad, Naga City, the Philippines. The choice of the communities was based on several factors: the experiences of flood in the study area, the location is in South East Asian context, the related previous research and the willingness of the local municipality to accommodate (as part of the ITC-SLARIM research project).

During the pre-field phase, an intensive literature review was done based on relevant literature studies to develop a concise research basis. This phase provided identification of the research context and the proposed necessary data and methods for data collection and analysis. In the fieldwork, primary data collection was done through building inventory using Mobile GIS devices (GPS, PDA with digital map and Digital Camera) and interviews with flood-affected communities in two Barangays. In the final phase, the research carried out analysis of the elements at risk, analysis of flood physical vulnerability and identification of related people's coping mechanisms in flood physical vulnerability.

3.2. Data Requirement and Data Availability

The data requirements for this research were identified from methods developed by White (1967), Penning-Rowsell and Chatterton (1977) and Dutta and Tingsanchali (table 3-1). Some data were available from previous research prepared from Tennakoon (2004), Monrroy-Prado (2005) and Reganit (2005). However, most of the data for the analysis of flood physical vulnerability needed to be collected from fieldwork because those were not available.

Before coming to fieldwork, it had been assumed that the digital data of the building footprint were accurate. However, when it was compared with ground check, the building footprint data were not accurate, for instance, the buildings were hard to be identified and there were missing buildings. The digital road map data were correct and could be used. Therefore, these were used as reference during the fieldwork. The land use map of the study area from previous research was not valid because some changes had taken place.

Analysis	Data Requirements	Availability
Spatial Analysis	▪ Digital Road Map ▪ Digital Building Footprint ▪ Digital Land use	Available from previous studies
Analysis of the Elements at Risk	▪ Structural type of building including building materials, building construction ▪ Building Contents and the values ▪ Outside Properties and the values	Fieldwork
Flood maps of the study area	Flood depths of the study area	Fieldwork
Flood damage assessment	Flood damage of Structural type of building, Building Contents and Outside Properties	Fieldwork
Flood Physical Vulnerability Assessment	Flood depths – damage relationship	From analysis of elements at risk and flood damage assessment

Table 3-1 Data Requirement and Data Availability

3.3. Case Study Area

Naga City is located on 377 km to the south of Manila, the Capital of the Philippines and located between 130 36' 40" – 130 38' 40" North Latitude and between 1230 12' 30" East Longitude. Administratively, Naga City belongs to Bicol Region, in province of Camarines Sur. The Philippines is passed by an average of 20 tropical cyclones of various strengths in every year. The Bicol Region including Naga City does suffer from by an average of 5 typhoons annually (ADPC, 2001).

The city itself has a form like a ship with its bowing facing east towards Mount Isarog, and its stern sitting west just about the junction of the Bicol and Naga rivers (figure 3-2). At the western part of Naga the urban centre is located, the most populated part of the City. The urban centre comprises of 17 barangays and lies between 1.00 – 5.00 meters above mean sea level. Rapid changes in atmospheric and meteorological condition by typhoon may worsen the condition of the city during high tide and storm surge (ADPC, 2001).

The total population in Naga in 2002 was 137.810 inhabitants with an average growth rate of 1.65% per year ((Naga-City, 2005)). As the city is situated in the "heart" of the Bicol Region, the population of the city is increasing every year. Many people from the surrounding municipalities come to city to gain the opportunity to earn livelihoods. Those who come without sufficient assets then live in vacant land or along the riverbanks as squatters.

Originally there was only one Central Business District (CBD) in Naga City, which is now famous as CBD I. However, as the City grew in terms of economics, the Naga municipality decided to expand the growth to on other part of the city by creating CBD II. However, the expansion to CBD II may also cause problems towards flood. The topography of the area in CBD II is located in low area where normally the water inundates after the storm surges.

Figure 3-2 Location of Naga City in the Philippines

3.3.1. Natural Disaster Problem

The common natural disasters in Naga City are floods and typhoons. Typhoon are normally brings rain and heavy wind together. Typhoons occur through out the 12 months of a year[4]. They occur more often and severe from September to December when the rainy season hits the region. To make people aware and remember typhoon occurrences, each typhoon is named in Tagalog (Philippine national language) by PAGASA (Philippines Atmospheric, Geophysical & Astronomical Services Administration). According to the study conducted by team from ADPC and Naga City office (ADPC, 2001), there were at least four major typhoon occurrences recorded in Naga City in the last two decades (Table 3-2).

Observed Typhoon	Max One Day Rainfall (mm)	Equivalent Return Period (Year)
1987 Typhoon Sisang	132	1.8
1988 Typhoon Yoning	185	3.5
1993 Typhoon Monang	292	10
1995 Typhoon Rosing	292	20

Table 3-2 Major Typhoon Occurrences in Naga City
Source: ADPC (2001)

[4] The information was obtained from discussion during the interviews with local communities in Barangay Sabang and Igualdad, Naga City.

The most recent severe typhoon before the fieldwork data collection was Typhoon Unding that hit the city in December 2004. It caused high damage to many facilities, such as gasoline station, electricity facilities, disrupted road, destroyed houses, etc. Figured 3-3 illustrates the severity of the typhoon in December 2004.

Figure 3-3 Destructions due to Typhoon Unding in December 2004
Source: Typhoon2000 (2005)

Figure 3-4 Flood Occurrences in Naga City
Source: ADPC (2001)

Besides typhoons, floods are also major natural hazard in Naga City (figure 3-4). The occurrence of flood is always associated with the occurrence of typhoons (ADPC, 2001). Lowland areas in Naga City are affected by several types of flood. They sometimes happen in combination: a). riverine floods from the Bicol, the main river in the area, b). flash-floods from the torrent Naga that originates on the slopes of the nearby volcano and c) storm surges coming from the Bay of San Miguel (Pacific Ocean) (Alkema et al., 2004).

The major typhoons in Naga were associated with flood occurrences in low-lying area of Naga City (table 3-1). Each typhoon was related with rainfall intensity and equivalent flood return-period. This was confirmed later on during the fieldwork interviews. The local communities mentioned that the typhoon as well as flood occurred simultaneously.

3.3.2. Case Study Area: Barangay Sabang and Barangay Igualdad

Two Barangay in Naga City were selected as the case study area for fieldwork data collection. Barangay Sabang and Barangay Igualdad are located at the junction of two rivers: Naga River and Bicol River (figure 3-5). Naga River is a tributary of Bicol River. Being located on the low site of Naga City, the two barangays are almost annually inundated by floodwater from Bicol and Naga River. Those barangays are located very close to the Naga City's central market and can be reached within walking distance. Many inhabitants in these barangays work in Naga City's central market.

Figure 3-5 Study Area
Source: Peters-Guarin (2005)

3.4. Fieldwork Data Collection

The fieldwork activities aimed to collect data of elements at risk (building, building contents and outside properties), flood depth and duration, damage due to floods and people's coping mechanisms. The fieldwork activities consist of two major activities: *first*, building inventory and *second*, interviews with households. Beside the two activities, some discussion with staffs from Naga City Office and staffs from Barangay Sabang and Igualdad were also helpful to provide insights about disaster management in Naga City and particularly in Barangay Sabang and Barangay Igualdad.

Fieldwork was carried out from August 19 – September 24, 2005. There was a delay from September 12 -16 when citizens of Naga went to a Penafrancia Festival, a local festivity. During this five days period, interviews could not be done because people were not at home.

3.4.1. Mobile GIS

Mobile GIS Mobile GIS devices used in this research consist of GPS (Global Positioning System) and PDA (Personal Digital Assistance). Digital maps obtained from previous research under SLARIM project (Monrroy Prado, 2005; Reganit, 2005; Tennakoon, 2004) were used as the reference in conducting the building inventory with Mobile GIS (figure 3-6). In an addition, a digital camera was used to make photograph of each building visited during the building inventory. ArcPad 6.0.3 software was used in the PDA to display, store and retrieve the digital maps. In the process of building inventory, a shape file of building should be prepared first. This shape file contains several attributes to be collected.

As the purpose of this research is to have detailed information of buildings in the study area, it needs to create an accurate positional reference using Mobile GIS. During the use of Mobile GIS in the field, the level of accuracy showed an estimated positional error (Garmin, EPE) in between 5 – 11 m. The geo-reference on the PDA and GPS was set to the Philippines Transverse Mercartor (PTM). The building is represented by point. During the building inventory with Mobile GIS, each building was digitized as a point.

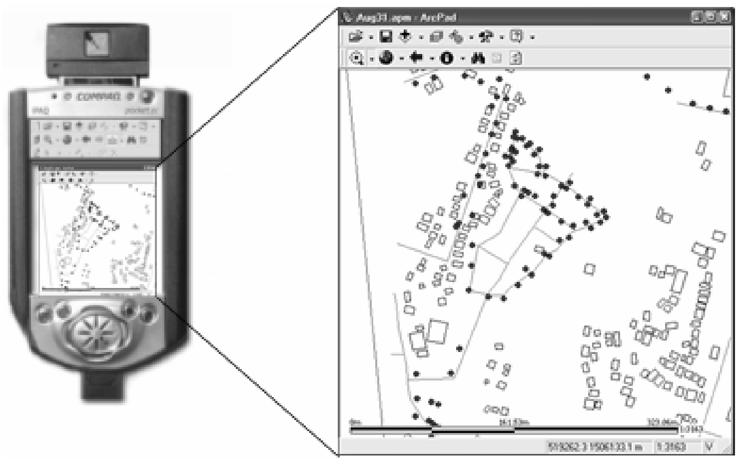


Figure 3-6 PDA with Built-in GPS and the Display in ArcPad

To check the level of accuracy, the PDA and PDS were carried along the road with the GPS tracking mode on. The GPS tracks were displayed on the screen of PDA correctly along the roads. Therefore, it is worthwhile to use the mobile GIS as the source to pinpoint the location of buildings. However, when the mobile GIS devices were carried to narrow roads or areas with high buildings, the level of accuracy was substantially reduced. Since very few tall buildings exist in Barangay Sabang and Barangay Igualdad, the accuracy positions from GPS were accurate. Mobile GIS devices were used during both the building inventory as well as the interviews. In the building inventory, before went to the field, some attributes had been made in digital format.

3.4.2. Building Inventory

In total 245 buildings were recorded during the building inventory. Building inventory is the process to collect information to be used for identifying the elements at risk. Building inventory or sometimes called as close sensing, is doing observations / measurements made from nearby (Hofstee et al., 2005). Building inventory was done by visiting the buildings in the study area with simple random sampling (figure 3-7). Simple random sampling aims to obtain data, whereby each element is given an equal and independent chance of selection. This is the most commonly used method of selecting a probability sample (Kumar, 1996). The selection of buildings in the fieldwork was done through choosing one building out of three to five buildings from the study area.

Figure 3-7 Building Inventory with Mobile GIS
Source: Hofstee (2005)

To get an equal sample distribution, Mobile GIS devices (Personal Digital Assistance, GPS and Digital Camera) were employed to verify the location of each building and to give the spatial reference on the Earth. Given the digital data of the road map, the building footprint and the river in Naga City from the previous research, the data were used with Mobile GIS to pin the point where the location of the observer was. Therefore, during the fieldwork, it was tried to check how accurate the previous data were shown in PDA In addition to that, printed map of the study area with information of road map, building footprint and river was also brought.

Building inventory process collected information on: *Building_ID, first floor height from surface, first floor height from street, number of floors, wall material, roof material, existence of pillars* and *size*. It recorded the picture of each building with a digital camera and the position of each building with the GPS device. The internal clock of digital camera and the GPS device was set for the same arrangement so that picture of each building could be distinguished later on.

The result of the building inventory was processed rapidly during the fieldwork in order to get classifications of structural types for stratified random sampling for the interview process. Further discussion of the building inventory is presented in section 4.2. The building inventory took two weeks (12 working days).

3.4.3. Interviews

Interview in this research is the process to collect in-depth data of elements at risk, structural types of buildings in detail, building contents, outside properties, flood damage detailed information from households (respondents). Interviews were done based on stratified random sampling with 68 households in the study area. Stratified random sampling was selected as the way to acquire information of the loss data. In stratified random sampling the researcher attempts to stratify the population in such a way that the population within a stratum is homogenous with respect to the characteristic on the basis of which is being stratified (Kumar, 1996).

Montoya (2002) used stratified random sampling as a way to capture representative data for each type of object that needs to be classified. Trochim (2001), cited by Montoya (2002), affirms several advantages of stratified random sampling as follows:

- It ensures that one will be able to represent not only the overall population (in this case structural types), but also the key subgroups of the population, especially small minority groups.
- It generally has more statistical precision than simple random sampling. If the strata of the groups are homogeneous, the variability within the strata is lower than the variability for the building stock as a whole.

Figure 3-8 shows how the stratified random sampling is described. A sample is taken to represent each class that has been identified.

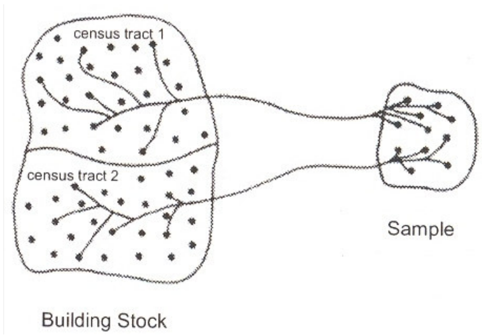


Figure 3-8 Scheme of Stratified Random Sampling
Source: Montoya (2002)

Having identified the classification of structural types from the building inventory, there are four types of building material found (see chapter 4.1 for detailed discussion of the four types of building material). These four types of building material were used to select the households to be interviewed. In total 68 households were interviewed. The interviews used questionnaires (see appendix 1 for the list of questions) and Mobile GIS devices as the tools. The author was accompanied with a local translator who assisted to translate the questions during the interviews. Fortunately, the local translator, a journalist for an English weekly newspaper, comes from the case study area. In this sense, she could confirm the trustworthiness of responses given by the respondents or she could give some inputs when the answers did not make sense. It took two and half weeks to finish the interviews to 68 households. The interviews were recorded with questionnaires and the results were analyzed in chapter 4 and chapter 5.

One important thing from the interview was that the respondents were asked to indicate the flood depths. Some respondents needed to recall their memory about the floods. Therefore, the questions were started with the last flood that hit Naga City in November 2004, which corresponded with the occurrence of typhoon Unding. Almost all of the respondents mentioned that the maximum flood depth happened in 1995 when Typhoon Rosing hit the city. To ensure that the respondents provided accurate information of flood depths, they were asked to indicate the depths with reference to their house (figure 3-9).

Figure 3-9 Respondents point the Flood Depths

3.4.4. Secondary Data

Secondary data in hardcopy information of the study area was collected from the Urban Poor Office of Naga City. This office was responsible in assigning relocation for some households in the study area. This information is useful to help the researcher to understand the history of households living in the study area. Hardcopies of two maps of two locations in the study area were also obtained, which are useful as input to make correction to the previous digital map obtained from previous research conducted in Naga.

3.4.5. Flood during Fieldwork

Surprisingly, during the fieldwork, rainfall hit Naga City heavily. Three days rain without stop from September 14 – 16 caused many Barangays, including Barangay Sabang and Barangay Igualdad (case study area) were inundated of floodwater (figure 3-10). The flood happened during the interviews with the households in the study area.

The inundation of floodwater during this flood could confirm what people had mentioned about the flood depth in the study area. In general, in the maximum level the flood depths on the top of walkway were in range 42 – 72 cm. Many houses lying along the Bicol River bank toward Naga River were inundated with floodwater inside. It was observed that water was submerging from Bicol River to the surrounding area, including at the residential areas of Barangay Sabang and Barangay Igualdad. The source of floodwater was not only from storm surges in Naga City, but also from an increasing volume of water of Bicol River from up-stream area.

Figure 3-10 Flood During the Fieldwork in September 2005

3.5. Method for Data Preparation and Data Analysis

Two main datasets were obtained from the field: *first*, data from building inventory and *second*, data from interviews. Given the data from building inventory was collected digitally with Mobile GIS, the data were ready to be used for analysis. The data of building inventory were stored in points with attributes of information collected during the building inventory. The data could be used directly using Geographic Information System (GIS) software. In this research, ArcGIS 9.0 is used to conduct the spatial analysis. The data from interviews needed to be transferred from paper format into digital data to get it ready for analysis.

Figure 3-11 illustrates the steps in data preparation and data analysis. Data preparation includes correction and digitization of digital map of buildings, roads and land use. Data from interviews in the paper formats were inputted into tabular data in statistical software (SPSS).

Statistical and spatial analyses were used as the methods for data analysis. Statistical analysis used in this research includes descriptive statistics, cross tabulation analysis and regression analysis. The descriptive statistic was used to describe the all data in general. The cross tabulation analysis was used to seek the relationships between more than one variable, for instance the relationships between data number of floors and the structural types. The regression analysis was used to generate vulnerability functions between the flood depths and damage for each of the elements at risk.

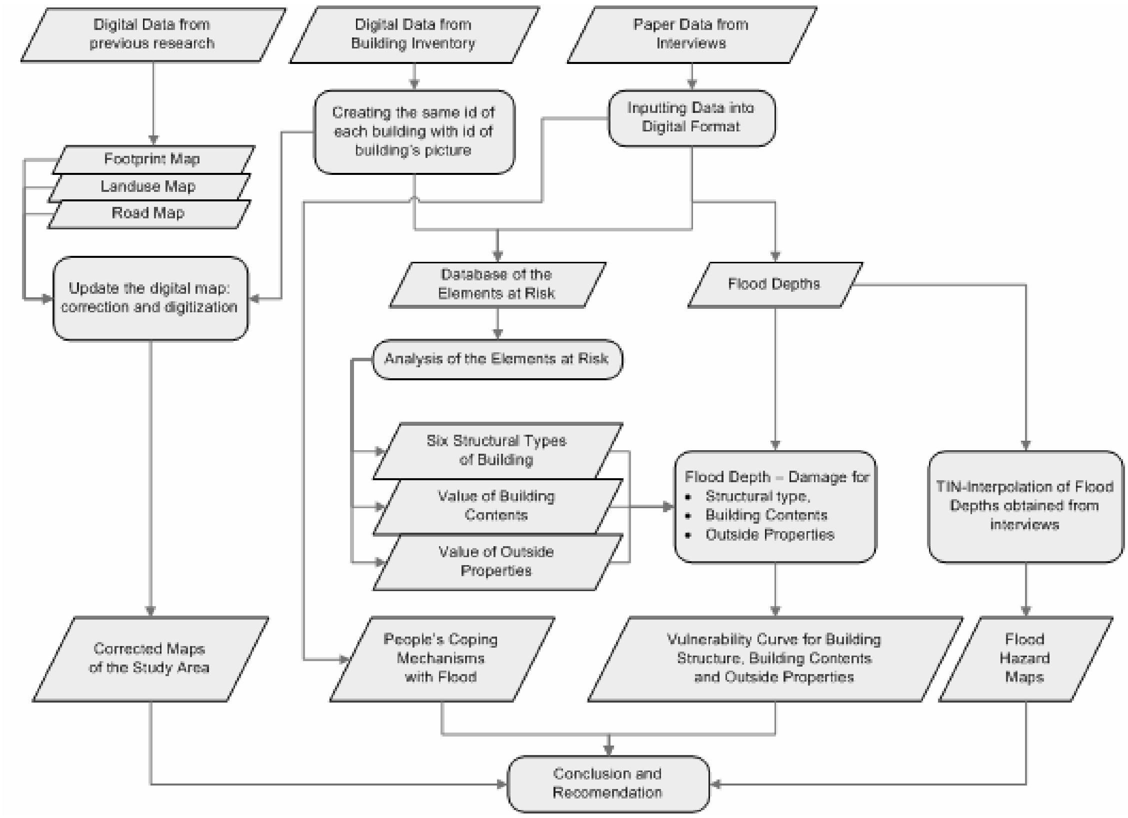


Figure 3-11 Summary of Data Analysis Procedure

Spatial analysis was used to visualize the results from statistical analysis. In addition, the flood depths were interpolated to produce two maps of flood depths using the Triangulated Irregular Network (TIN) function in ArcGIS 9.0.

3.6. Conclusion

This chapter has discussed the data and methods used in the fieldwork data collection, data preparation and data analysis. The use of Mobile GIS was very useful during the building inventory. One important advantage of using Mobile GIS is the data are provided in digital format. It alleviated the time that the researcher needed to input the data from the building inventory. The data collected from the fieldwork will be examined in the next chapter.

4. Analysis of the Elements at Risk for Physical Vulnerability

This chapter discusses the characteristics of the elements at risk for flood physical vulnerability. The database of the elements at risk is from data collected from two sources: building inventory in 245 buildings and interviews to 68 households in Barangay Sabang and Barangay Igualdad, Naga City. The building inventory was carried to provide general information of the structural types in the study area. The detailed information of the elements at risk consisting structural types of building, building contents and outside properties were collected through interviews. Figure 4-1 illustrates the spatial distribution of the building inventory (green symbols) and the household interviews (red symbols) in the study areas in Barangay Sabang and Igualdad. In the last part, the discussion of the elements at risk is presented.

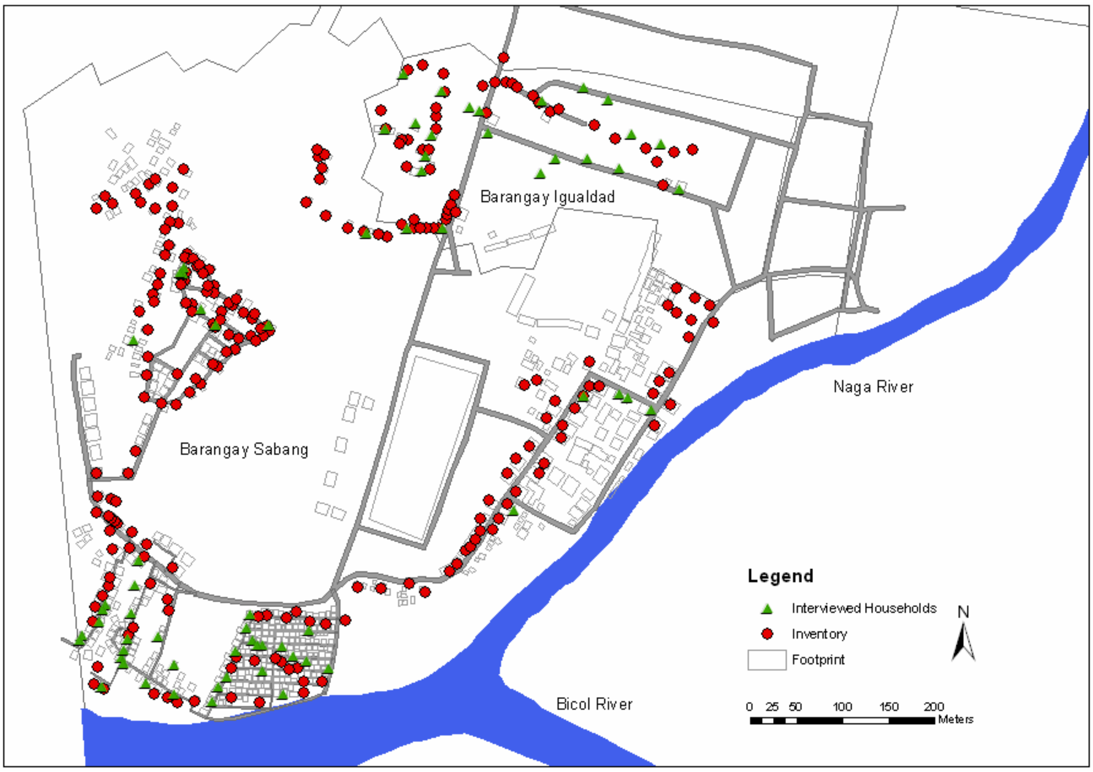


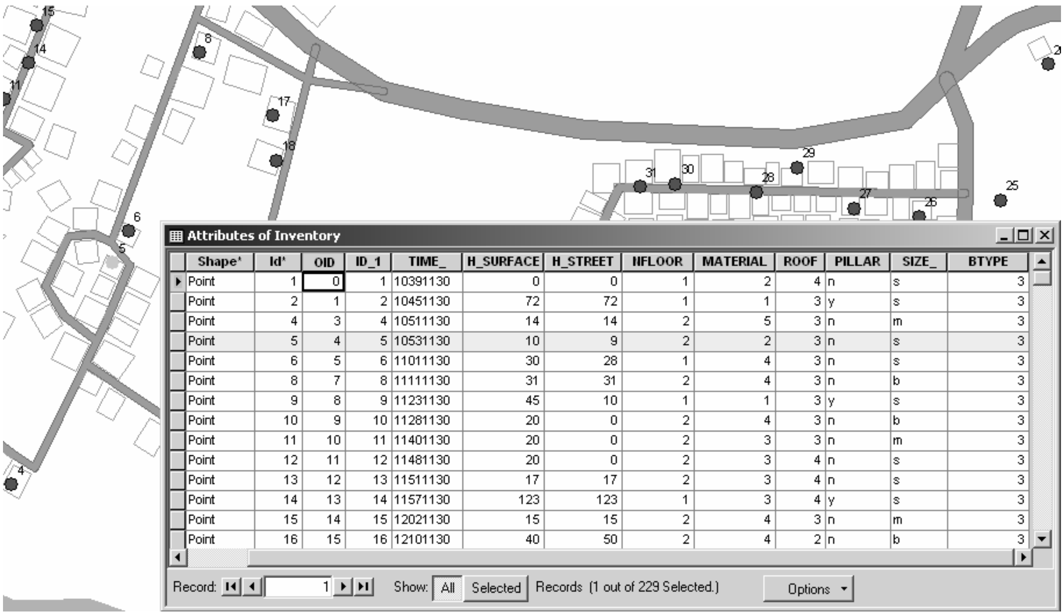
Figure 4-1 Spatial Distribution of Building Inventory and Interviewed Households

4.1. Information of Structural type of building

Database of structural type of building information is from the building inventory and household interviews in the two barangays. The building inventory covered 245 buildings based on simple random sampling. The interviews were carried out in 68 households based on stratified random sampling.

4.1.1. Building Description from Building Inventory

Data from the building inventory includes information of eight attributes: *Building_ID, first floor height from surface, first floor height from street, number of floor, wall material, roof material, existence of pillar* and *size*. All these attributes were collected in a mobile GIS in order to have the spatial reference of each building (georeference). Buildings were stored in an ArcPad shape file as points. Each point has eight attributes in tabular data (figure 4-2). The attributes were collected by measurements and observations in the field. For instance, the floor height of each building above the surface and from street was collected using metric tape. This information was then stored as a value in an appropriate attribute in ArcPad The information on the number of floors, wall material, roof material, existence of pillars was collected by observation. All of this information was recorded in the PDA with the ArcPad software. For instance, figure 4-2 shows the selected point in with the attributes shown in the table. All 245 points representing the buildings in the study area are recorded with the eight attributes. This makes it easier when one wants to retrieve as well as to display certain data of a particular building.



Shape*	Id*	OID	ID_1	TIME_	H_SURFACE	H_STREET	NFLOOR	MATERIAL	ROOF	PILLAR	SIZE_	BTYPE
Point	1	0	1	10391130	0	0	1	2	4	n	s	3
Point	2	1	2	10451130	72	72	1	1	3	y	s	3
Point	4	3	4	10511130	14	14	2	5	3	n	m	3
Point	5	4	5	10531130	10	9	2	2	3	n	s	3
Point	6	5	6	11011130	30	28	1	4	3	n	s	3
Point	8	7	8	11111130	31	31	2	4	3	n	b	3
Point	9	8	9	11231130	45	10	1	1	3	y	s	3
Point	10	9	10	11281130	20	0	2	4	3	n	b	3
Point	11	10	11	11401130	20	0	2	3	3	n	m	3
Point	12	11	12	11481130	20	0	2	3	4	n	s	3
Point	13	12	13	11511130	17	17	2	3	4	n	s	3
Point	14	13	14	11571130	123	123	1	3	4	y	s	3
Point	15	14	15	12021130	15	15	2	4	3	n	m	3
Point	16	15	16	12101130	40	50	2	4	2	n	b	3

Figure 4-2 Illustration of Point with Attributes Collected from Building Inventory

During the building inventory, a photograph was taken of each building to provide better information. The distribution of some buildings in the study area and some points of interests with their reference and pictures is presented in the figure 4-3.

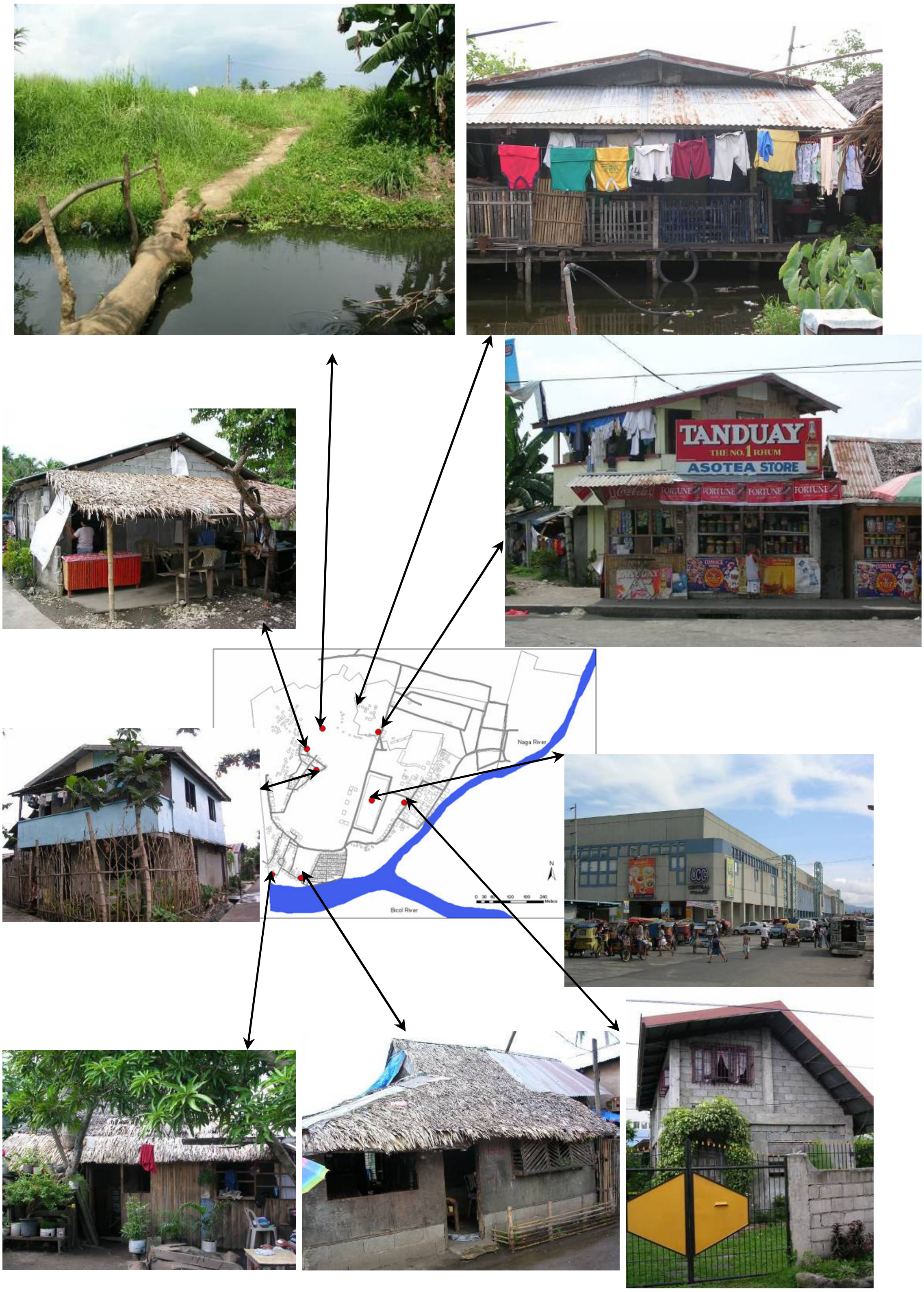


Figure 4-3 General Overview of the Location of the Study Area

a. Wall Material

The wall material was selected as the way to make building classes for the stratified random sampling. Four types of wall material were found during the building inventory in the study area: plywood, wood, bamboo and hollow block (Table 4-1). Mixed wall material means that the building has more than one floor and the wall material of the first and second floor is different. Later on, in the interviews four types of wall material were used as the basis to determine which households to select based on stratified random sampling.

Wall Material	Number of Building	%
Plywood	59	24
Wood	29	12
Bamboo	18	7
Hollow-Block	95	39
Mix	42	17
Zinc	2	1
Total	245	100

Table 4-1 Wall Material based on the Building Inventory
Source: Fieldwork Data (2005)

b. Height of First Floor

The height of the first floor was measured to people‘s awareness to flooding, whether any private measurements have been taken or not. The height of the first floor of a building to the ground surface or street varies from one building to another. The height of the first floor from the surface is defined as the height difference between the surrounding surface with first floor, while the height of the first floor from the street is measured from the distance between the street and the first floor (figure 4-4). In average, floor’s height from surface is 29.5 cm and floor’s height from street is 24.8 cm (detailed data in appendix 3).

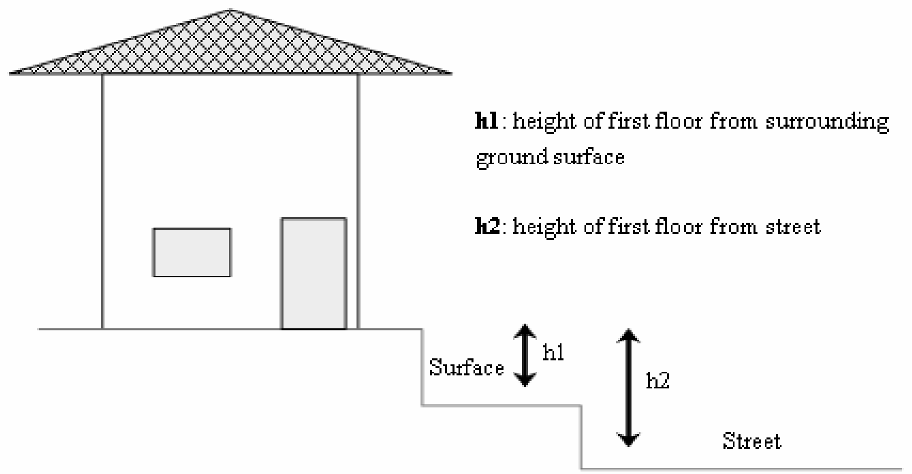


Figure 4-4 Height of First Floor from Surface and Street

Some buildings are constructed more than 50 cm above the ground surface and streets. Those constructions indicate that the house owners have tried to construct their building so that it can mitigate flooding (figure 4-5). According to the interview with a counsellor (assistant) of Barangay Sabang (Edgar de la Cruz, 2005), people have constructed their house (building) in their own way to reduce the possibility of getting flooded. The reason is that people have experienced so many occurrences of floods. Households in these barangays have recognized how high the flood-depth is. The height of floor's construction varies depending upon the house owner's capacity in term of income, assets, etc.

Figure 4-5 House with lifted Height of First Floor Compared to Street

c. Number of Floors

Based on the building inventory, 145 buildings are constructed with one floor, 99 buildings with two-floors and one building with three floors (table 4-2). There is a relationship between wall materials with the number of floor. Most of the walls for houses with second floor are made of hollow-blocks; while most of houses with plywood wall material, (53 out of 56 buildings) have only one floor. The spatial distribution of buildings based on the number of floor is presented in map in figure 4-7.

	Number of Floor			Total
Material	**One-floor**	**Two-Floor**	**Three Floor**	
Plywood	53	6	0	59
Wood	19	10	0	29
Bamboo	13	5	0	18
Hollow-Block	42	52	1	95
Mix	17	25	0	42
Zinc	1	1	0	2
Total	145	99	1	245

Table 4-2 Cross-tabulation of Number of Floor with Wall Material

There is no such significant spatial pattern of the number of floors in the study area, except the buildings located in the center and the center-right of the study area. Buildings located in the center-right of the study area are dominated by two-floors. This makes sense because houses built in this area belong to a relatively high-income group[5]. Buildings located at the middle-top at the study area are mainly inhabited with one-floor buildings.

[5] Personal discussion with Barangay Sabang's counselor, Edgar de la Cruz (September 2005)

d. Existence of Pillars

Another way for people to deal with flooding is by constructing the house on pillars (figure 4-9). This approach is normally found for building with light material, i.e.: plywood, bamboo and wood material. Of the 245 buildings surveyed in the study area, around 20% or 49 buildings are constructed with pillars, in particular for buildings located along the Bicol River. There is a relationship between pillars and light construction materials. Pillar only belongs to house with light material. In average, floor's height of house with pillar is 62 cm from surface and 49 cm from street. Though constructions with pillars are quite cheap[6], still very few people have applied it in the study area. The interviews indicate that it is common for people to help each other in constructing their house. This is called "bayanihan", an approach in the Philippines where people share the labour power from their close relatives to construct someone's house.

Wall Material	Pillar		Total
	No	Yes	
Plywood	33	26	59
Wood	17	12	29
Bamboo	9	9	18
Hollow-Block	95	0	95
Mix	41	1	42
Zinc	1	1	2
Total	196	49	245

Table 4-3 Cross-tabulation of Wall Material and Existence of Pillar from Building Inventory

Figure 4-6 House with Pillars

In order to detect the existence (or not) of a spatial pattern of houses with pillars, the map of houses with pillar is overlaid with the flood depth maximum in study area (figure 4-8). The map of flood depth maximum is obtained from data interpolation of flood depth obtained from interviews (discussion in detail is presented in section 5-1). Only in the swampy area or houses over the water surface people construct their house with pillars. It is a surprising conclusion that construction with pillars is not a dominant approach in the study area.

[6] According to the interview, one house with light materials (plywood, wood, bamboo) and pillars can cost around PhP 10.000 – 20.000 or € 143 - 286

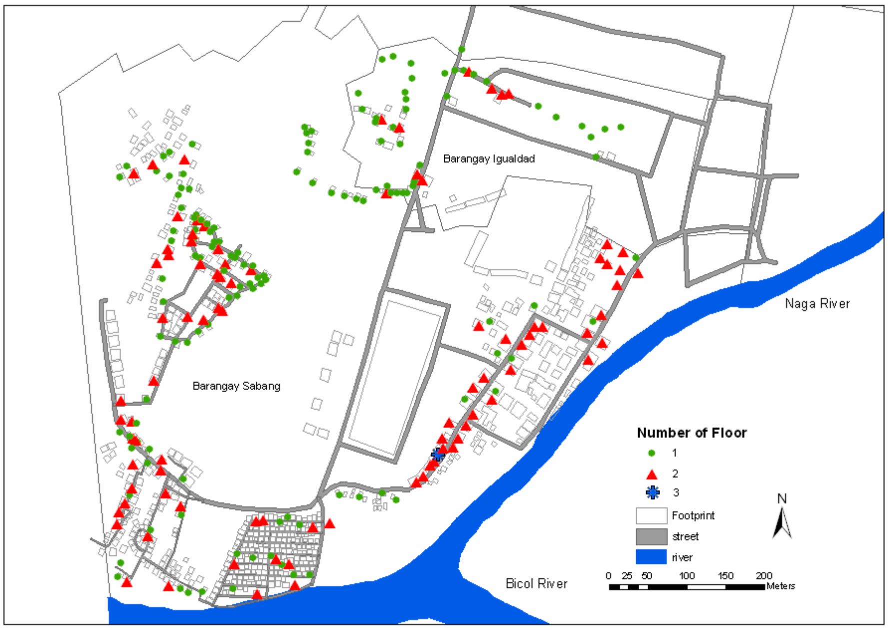


Figure 4-7 Map of Number of Floor in the study area

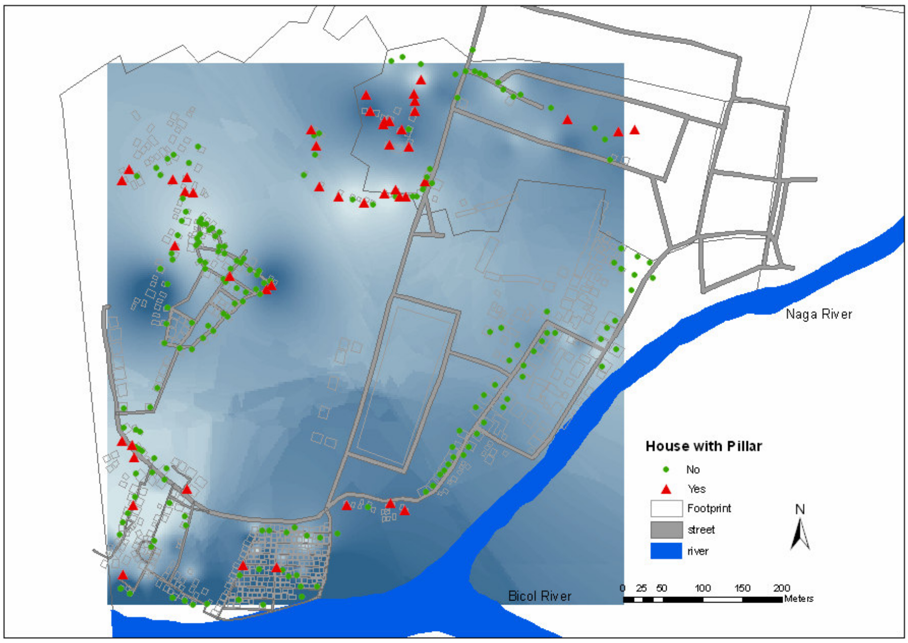


Figure 4-8 Spatial Distribution of House with Pillar in the Study Area

4.1.2. Building Description from Interview

The interviews were held with 68 households from the two Barangays in the study area. This section discusses more detailed information than that of the building inventory. Investigation of building could be done in more detailed because being inside of the house, the elements of the inside the house were seen, for instance: floor material and design inside the house.

a. Combination of Wall-Floor Material of Building

Type of building material determines building's structural vulnerability to flooding. The flood risk assessment research in Bangkok Thailand classified the type of house into three: wood, concrete and mix (Dutta and Tingsanchali, 2003). However, this research uses a more detailed classification of structural type of building as more building materials were encountered in the study area. In this research, to derive a meaningful classification for the vulnerability assessment, a cross-tabulation of wall and floor material is made. Hence, this research uses detailed classifications of structural type of building by including the combination of not only wall but also floor material (table 4-4).

Wall Material	Floor material					Total
	Concrete	Soil	Wood	Bamboo	Plywood	
Ply wood	9	1	8	2	4	24
Wood	7	0	7	0	0	14
Bamboo	3	0	2	5	0	10
Hollow Block	16	1	0	1	0	18
Nipah	0	0	0	1	0	1
Flat Sheet	1	0	0	0	0	1
Total	36	2	17	9	4	68

Table 4-4 Cross-tabulation of Wall-Floor Material

Based on the cross-tabulation of wall and floor material, there are apparently six types of building mainly found in the study area. All combinations of the six common structural types and their pictures are presented in table 4-4. These combinations of structural types will be used as input of the elements at risk for the analysis in chapter 5. The least frequent occurrence of structural type is for structural type 3, bamboo wall – bamboo floor material with only five households that have that structural type. The highest frequency of occurrence is for structural type 6, hollow-block – concrete floor material, with 16 households. In addition, the spatial distribution of structural type of building is presented (figure 4-9).

a. Structural Type 1 **Plywood wall – wooden floor**	**b. Structural Type 2** **Plywood wall – concrete floor**
	
c. Structural Type 3 **Bamboo wall – bamboo floor**	**d. Structural Type 4** **Wooden wall – Wooden Floor**
	
e. Structural Type 5 **Wooden wall – Concrete Floor**	**f. Structural Type 6** **Hollow Block wall – Concrete Floor**
	

Table 4-5 Six Common Structural Types of Building in the Study Area

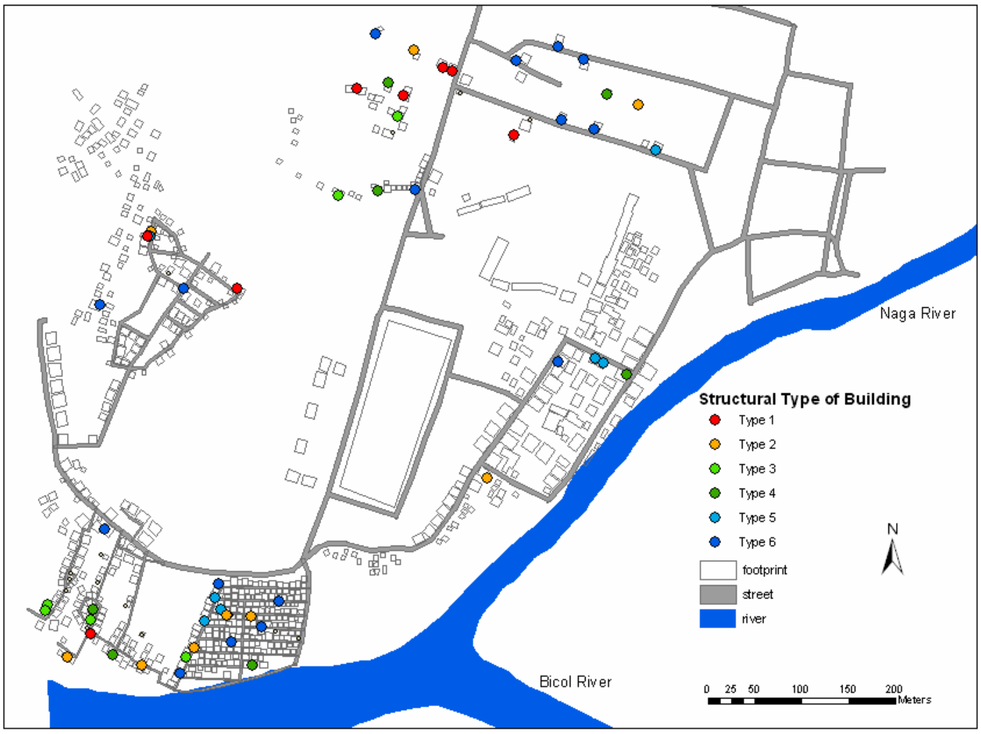


Figure 4-9 Spatial Distribution of Structural Type of Building in the Study Area

b. Different Floor Levels inside the house

Another phenomenon is the different floor levels inside the house. This action is applied because household experienced floods coming inside the house. The construction is based on the level of importance of the room so that rooms that are more important will not be flooded. For example, figure 4-10 illustrates the case of bedroom as the most important place as it is the highest floor of all rooms in the house. The height of construction varies from one house to another.

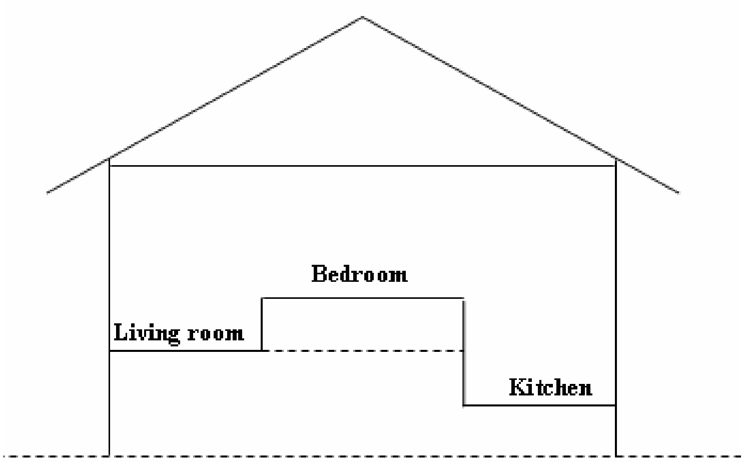


Figure 4-10 Sketch of Different Level of Floor inside House

4.2. Building Contents and Outside Properties

To examine the vulnerability of building contents and outside properties, it is important to analyze value of the assets that people have (Blaikie et al., 1994; Dutta and Tingsanchali, 2003; Pelling, 2003; Smith, 2001). In this research, the value of assets is analyzed separately between building contents and outside properties (appendix 1). The building contents and outside properties are analyzed separately for the purpose of vulnerability analysis in chapter 6.

Building contents are all household's belongings that are located inside the house. Building contents include appliances, furniture and other tools that people have inside the house (see questionnaire in section 2.2 building contents). Information of building contents and their values was obtained from interviews to 68 households. Fortunately, during the fieldwork data collection, the author was accompanied by a local translator who lives in the study area. Therefore, during discussions the author could get verification of the value of assets for the interviewed households. For instance, it was sometimes difficult to ask the respondents from a household to estimate the value of their belongings. Nevertheless, all the estimation then could be done with the assistance of the fieldwork translator.

In this research, there is a distinction made between building contents and outside properties. Each of the two is calculated differently to get their values. The value of all building contents was summed up to get the total value of building contents of each household. The total values of building contents for all households indicate a very high range, with a minimum value PhP 1,000 and a maximum value PhP 142,400. However, most total values of building contents are less than PhP 20,000 or € 286 (figure 4-11).

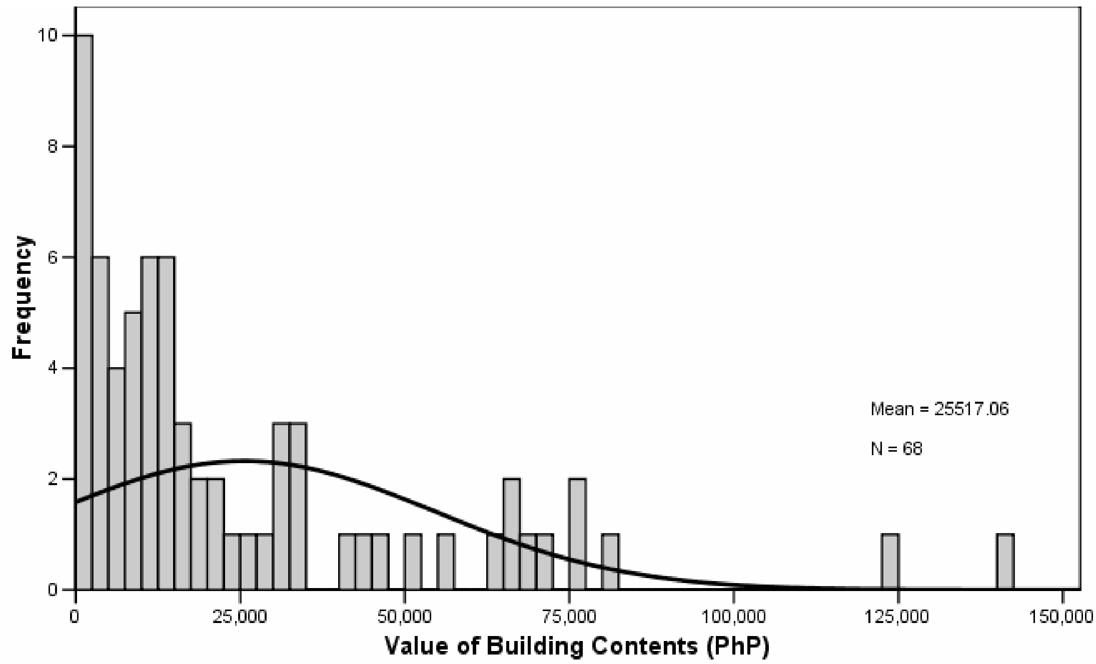


Figure 4-11 Values of Household's Building Contents

Outside properties are all people's belongings that are normally placed outside the house or in a garage or storehouse (figure 4-12). These include animal, car, pedicap, and bicycle (appendix 1). The values range of outside properties is PhP 0 – 290,000. Most values of outside properties have a value less than PhP 2,500 or € 36 (figure 4-13). Some people do not have any outside properties at all, while others have valuable properties used to support their work (figure 4-12).

The values of building contents and outside properties (is called as total asset) were calculated in order to understand thoroughly of household's possessions (appendix 4). The value shows that commonly people own total asset less than PhP 110,000. In order to find the pattern of the income in the study area, four classes of households based on the frequency of household's assets (see in appendix 4) are made as follows:

- Households with assets PhP 1,000 – 15,000 is low income.
- Households with assets PhP 15,000 – 55,000 is medium-low income.
- Households with assets PhP 55,000 – 110,000 is medium-high income
- Households with assets > PhP 110,000 is high income

Figure 4-12 Household's outside Properties

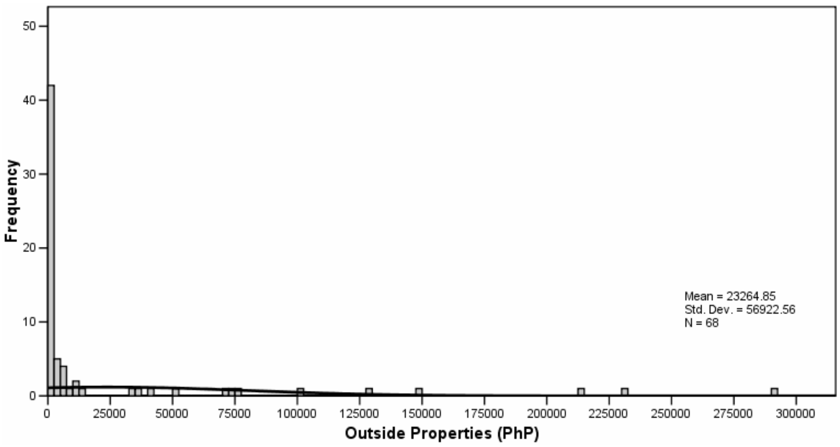


Figure 4-13 Value of Household's Outside Properties

4.3. Social Economic Information of Households

Information about economic conditions needs to be included in a vulnerability assessment as people's capacities (income, number of family members, etc) determine their ability to cope with disaster (Blaikie et al., 1994; Pelling, 2003; Reganit, 2005). In this part, the factors, daily income, daily expense, and number of family members from 68 households in the study area are explored. The information of daily income and expense is important for the consideration to explore household's capacity to save some money besides their daily expenses. Daily expense includes cost in basic things: food, transportation, clean water and electricity. It is assumed that the more money that people can save; the more is their capacity to deal with disaster.

According to the interviews to households in the study area, the common source of income is from daily livelihoods, for instance: pedicap driver, tricycle driver, labour and private store. Previous studies conducted by Monrroy Prado (2005) and Reganit (2005) found that people who live in Naga City along the Naga and Bicol River earn income from daily livelihood (Monrroy Prado, 2005; Reganit, 2005). Their sources of livelihoods are very dependent to the central Market of Naga City. That is why people choose living in Barangay Sabang, Igualdad, Tabuco, Triangulo and Mabolo that are close the central market.

The average daily income of each household in the case study areas is PhP 319[7] while many households earn within the range between PhP 100 – 450 (figure 4-14). The official minimum daily income of a single worker in Bicol Region, where Naga City is located, is PhP 209.00 (NWPC, 2005). Hence, the households who live in Barangays Sabang and Igualdad approximately earn in average as much as the official minimum daily income stated for a single worker in the Bicol Region. As detailed information is lacking, it is assumed here that the minimum daily income of a single worker is considered adequate for the needs of a household.

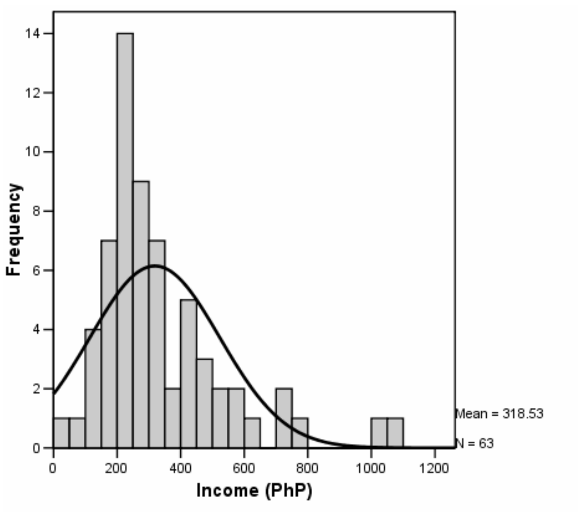


Figure 4-14 Daily Income of Households

[7] During the fieldwork (September 2005), € 1 = PhP 70. Therefore, the average income of the household is approximately € 4.6

However, 13 out of 68 households or around 20 % population in Barangay Sabang and Barangay Igualdad earn less than PhP. 200 (figure 4-14). This income is lower than that of the official standard in Naga City. Therefore, in term of money, these people can be assumed not to able to save adequate money to deal with disaster risks. Although this statement should be supported with detailed information on the daily expenses of households, it may indicate a group of people who most likely do not have sufficient capabilities to deal with disaster risks.

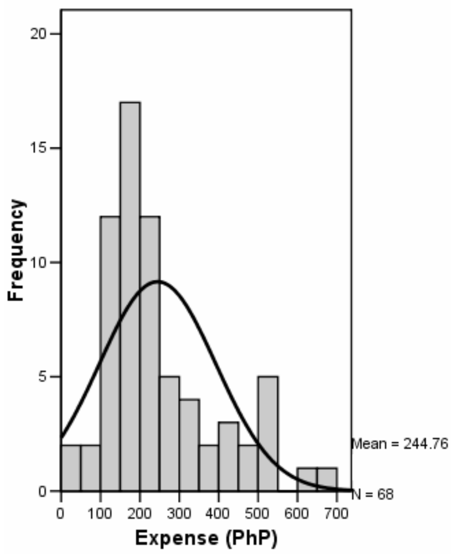


Figure 4-15 Daily Expense of Households

Furthermore, average expense for each household is PhP 245 (figure 4-15). If this value is subtracted from the average income, the average amount of money left is around PhP 74 (more or less € 1,-) for each household. This amount of money is assumed as spare money that each household can use for their extra expenditure, for instance in case disaster strikes.

During the observation, it was found that each household prepares some amount of money to deal with disaster, for instance stocking food, buying plastics, buying medicine and other extra expenses. No accurate data were obtained during fieldwork regarding this issue. Reganit (2005) moreover mentions that there are three phases where people spend money more than those of ordinary day. The three phases are before disaster, during disaster and after disaster. Additionally, the problem can exist more if the household has a large number of family members. The average number of family members in each household is 5-9 persons. Accordingly, the dependency ratio remains high in this city. In 2000, the dependency ratio was 82, meaning that there were about 82 dependents for every 100 persons aged 15 to 64 years (Philippines Census, 2002).

4.4. Discussion

The elements at risk from households in the study area have been discussed in this chapter. From the building inventory, four common wall materials were found. Later that information was used for stratified random sampling in selecting households for interviews. In a more detailed combination with wall-floor materials, there are six classes of building found (table 4-4). These six classes will be used for the detailed classification of the elements at risk for the vulnerability assessment of structural type of building in chapter 5.

Three types of construction relevant to deal with flooding were found, namely: increased height of first floor, variation of number of floor and construction with of pillars. This implies that naturally households (people) have developed their own ways to deal with flooding depending upon their own capacities (income and assets).

There is a relationship between number of floor and building material (table 4-2). Buildings constructed with light wall material (plywood, bamboo and wood) have a tendency to have one-floor. Buildings constructed with hollow-block and mix material exist on both one-floor and two-floors. Relationship does exist between wall material and construction with pillars (table 4-3). Buildings constructed with hollow-block and mix materials tend not to have pillar materials. On the other hand, buildings constructed with light material exist for both constructions with and without pillars.

After interviews, classifications of material types of building were made. Six material types were introduced based on cross-tabulation of wall and floor materials. These six material types are used as inputs of elements at risk for flood physical vulnerability in chapter six. Different levels of flood heights were found which are indicating that people have built the flood mitigation inside their house.

Based on the analysis of the values of the building contents, it was found that most households have total values of building contents less than PhP 20,000 or € 286 (figure 4-11). This value indicates the value of building contents that could be threatened if flood happens.

It was found that most households have the value of outside properties less than PhP 2,500 or € 36 (figure 4-13). This value indicates that not so much value of outside properties that could be threatened by flood.

According to the interviews, the average daily income of people is in the range PhP 100 – 450 (€ 1.5 – 6.5) and the average daily expenses are PhP 245 (€ 3.5). This condition indicates that the households in the study area do not have so much money to spend other than for daily expenses. Having this information, one can assume that the people living in this area do not have enough savings (money) to deal with flooding. In fact according to some respondents during the interviews, flooding actually aggravates the economic condition of people living in this area[8].

It could not be confirmed whether the respondents had given truthful answer or not for the information of income and expense. However, for the building contents and outside properties, it was much truthful since the building contents and outside properties are observable during the interviews. Therefore, the analysis in the following chapter includes the information from the values of building contents and outside properties, instead of the value from income and expense.

[8] During the interview, some households mentioned that flooding causes their living condition becoming worse. This opinion is discussed later in section 6.4 People's Coping Mechanisms

There are reasonable relationships between the structural types of building and the value of the assets. People living in structural type 1, plywood wall – wooden floor, have a tendency to have a small total value of assets. On the other hand, the structural type 6, hollow-block wall and concrete floor, is most likely associated with a medium-high and high total value of assets (table 4-6).

Combination Wall-Floor Materials	**Total Assets**				**Total**
	Low	**Medium-low**	**Medium-high**	**High**	
Structural type 1	3	4	0	1	8
Structural type 2	5	3	0	1	9
Structural type 3	4	2	0	0	6
Structural type 4	2	4	0	1	7
Structural type 5	0	5	1	1	7
Structural type 6	1	4	8	3	16
Other	8	4	1	2	15
Total	23	26	10	9	68

Table 4-6 Cross-tabulation of Wall-Floor Materials with Total Assets

5. Analysis of Flood Physical Vulnerability

This chapter examines the physical vulnerability to flooding for structural type of building, building contents and outside properties based on the relationship between flood-depths and damages. To describe the flood occurrence in the study area, the first part of this chapter discusses the flood occurrence and flood extents based on interviews with the 68 households. Subsequently, the section continues discussing vulnerability to structural type of building, building contents and outside properties based on damage assessment from the interviews. Relevant people's coping mechanisms with flooding are also examined in order to get a better understanding of the whole system in physical vulnerability. Eventually, it examines the relationships of the physical vulnerability with people's coping mechanisms.

5.1. Flood Extent in the Study Area

Data on flood-depths were obtained from each household from interviews with 68 households. The 68 points were used to make an interpolation of the flood-depths. The respondents could recall two major occurrences of flooding[9], namely, Flood Unding in 2004 and Flood Rosing in 1995. Respondents remembered Flood Unding because it happened only a year before the author conducted the interviews. The interviewed households could still remember Flood Rosing because it was the highest flood that had happened in Naga City. It was noticeable that during the Flood Rosing many households from the study area evacuated to an evacuation centre for one – two weeks.

The flood depths during the interviews were measured inside the house with reference to the first floor. To get the real flood depth based on the terrain surface, the flood depth for each point was added with the height of the first floor for each house. The values are separated for two settings of floods: Flood Unding and Flood Rosing. First, the values of flood depth for each flood were transferred into TIN (Triangulated Irregular Network) map to create interpolation of flood depths. Second, TIN maps of flood depths were exported into raster data to create smooth surface of the water depth. Thus, maps of Flood Unding (2004) and Flood Rosing (1995) were created from the raster data of flood depths.

The depths of Flood Unding ranged from 0 – 72 cm (figure 5-1). During this flood, not the whole area of Barangay Sabang and Barangay Igualdad was flooded. Based on the

[9] Flood's name is always given after typhoon's name. Hence, Flood Unding and Flood Rosing were named after the related typhoons: Typhoon Unding and Typhoon Rosing respectively.

interviews, the floodwater during this flood only stayed in less than two days (appendix 5). Therefore, the Flood Unding did not cause so much damage to the interviewed households in the study area. Despite the floodwater was not deep and did not stay for long time, the wind that occurred together with the flood caused much severe damage to Naga City (see pictures in figure 3-3 chapter 3). The flood depths of Flood Unding have similar characteristics with the Flood of 10-year return periods conducted by one research of Flood Modelling in Naga City (Bin Abd Rahman, 2006).

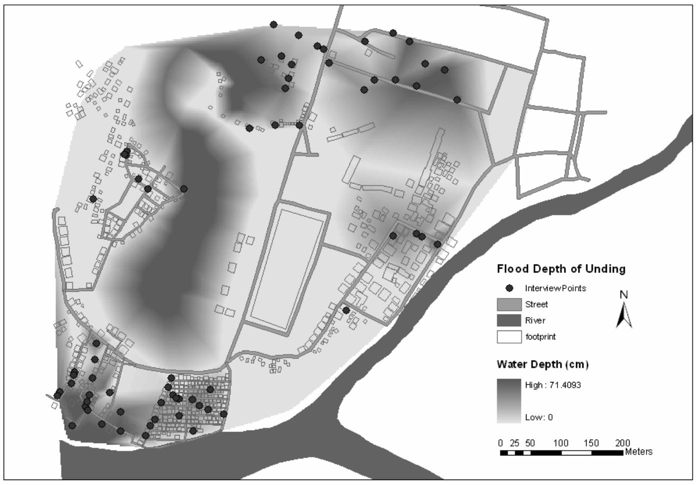


Figure 5-1 Flood Extent during Unding in 2004

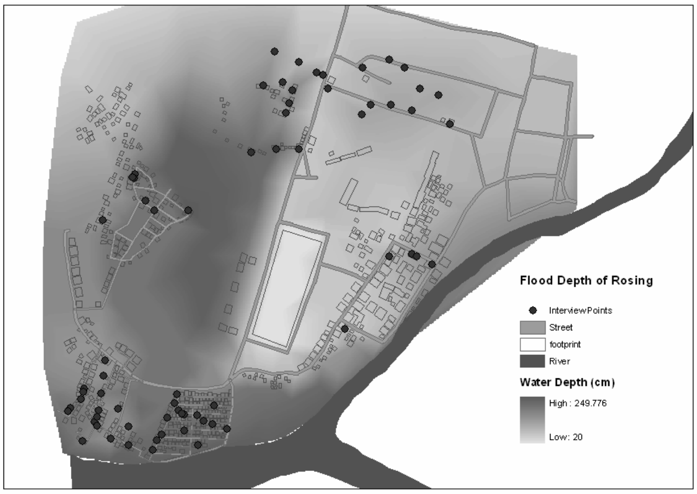


Figure 5-2 Flood Extent during Rosing in 1995

The depths of Flood Rosing were in range of 20 – 250 cm (figure 5-2). According to the households, almost the entire area of Barangay Sabang and Barangay Igualdad was flooded during the Flood Rosing in 1995. In general, people experienced that floodwater remained for seven days (appendix 5). When Flood Rosing happened, the land use of the study area was different with recent land use and many buildings had not been constructed in the study area, for instance: today the LCC building (a supermarket), which did not exist in 1995, is present.

Some buildings still existed along the junction of the Naga River and Bicol River when Flood Rosing happened. However, those buildings were relocated in 2002 and made the households move to other part of the study area. The data of flood depths were linked with the damage that happened to the each of the elements at risk. This link creates flood depth – damage relationships that establish curves of vulnerability for structural types of building, building contents and outside properties (the elements at risk).

5.2. Vulnerability of Structural type of building to Flooding

In this research, the definition of structural type of building refers only to the damage of wall and floor parts of a building, without considering other parts of building, for instance: the structural column, roof and ceiling. Vulnerability to structural type of building only considers the damage to wall and floor materials as those are used as elements at risk (see cross-tabulation of section 5.3). The vulnerability of structural type of building is determined from the percentage of damage for the wall and floor materials from the occurrence of the flood.

Vulnerability means the degree of loss of a given element at risk or a set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).” (UNDRO, 1991). Based on this definition, the value of vulnerability for structural type of building is made on scale between 0 and 1.

Initially, as discussed in the literature review (Dutta and Tingsanchali, 2003; Penning-Rowsell and Chatterton, 1977; Smith and Ward, 1998), all damage was expected to be in financial value (local currency) or the cost that needs to be spent for to repair the damage. Because the respondents could not recall the damage value properly, another approach was used to determine the percentage of damage to the structural type of building. Three values between 0 and 1 (0, 0.5 and 1) were used to generalize the value of vulnerability (table 5-1).

This research attempts to develop a scheme based on the research of Kelman and Spencer (2002): “*What will fail first when floodwater contacts a house or different types of house?”.* In this case, wall and floor materials are used as the basis to determine the damage. During the interview, the following working definition was used and the respondents were asked to define the damage based on the condition of wall and floor after flood occurrence (table 5-1).

If the vulnerability value is 1, it means the total damage occurs only to wall and floor materials and the house owner needs to replace the entire part of the wall or floor. This does not mean that the house is totally collapsed. Yet, other parts of building (for instance ceiling, roof, and columns) remain. Assessing vulnerability values with this concept remains uncertainties due to lack of information and weaknesses in the interpreting the damage. However, this way is still considered the best in the absence of damage data in the local currency.

Vulnerability	Description
0 (no damage)	• If the material does not get damaged due to certain level of flood depth • If the material does not need any replacement due to several occurrences of floods and still can function for several years.
0.5 (half damage)	• If the material does not need any replacement directly after one flood occurrence and if the material needs to be replaced after several occurrences of floods. • If the materials gets damage in a half portion of the entire wall and floor materials for certain level of flood
1 (total damage)	• If the material needs to be replaced after one flood occurrence • If the material needs to be replaced because it is totally damaged after flooded with certain depth

Table 5-1 Working Definition for Vulnerability of Structural type of building

Based on responses from the interviews, the author could conclude that wall, floor and column are parts of structural type of building that can be damaged. However as wall-floor combination have been selected to be the way in defining the elements at risk, in this research, particular attention data collection were much more given to the wall and floor damages. The examples of damage because of flooding to each structural type of buildings are presented in figure 5-3. Figure 5-3 (part a), for instance, describes a house with plywood wall material that has been flooded and floodwater has been absorbed to the plywood wall. This wall is supposed to be replaced though that is not the case because the house owner still makes use of the current plywood. Other example of figure 5-3 (part c) is the house that the wall and pillars have been rotting due to the floodwater.

The relationships of levels of damage and flood depths were plotted into graphics for each of the six structural type of building (appendix 6). Based on the propensity of the plots for each structural type of building, the average vulnerability curve for each structural type of building was created (see the plots of flood depths and damage for each structural type in appendix 6). It should be noted that the flood depths used to construct the relationships between flood depths and damage are measured of depths inside the house.

Figure 5-3 Examples of Damage to Structural type of buildings
The letters a, b, c, d, e show damage to structural type 1, 3, 4, 5, 6 respectively
(There is no picture available for structural type 2)

The vulnerability curves of the six structural types are examined below.

a. Structural Type 1

Houses with structural type 1 are made from the combination of plywood wall – wooden floor material. This structural type is very prone to water because once plywood material is exposed to water, it absorbs the water easily and the plywood gets rotting (see figure 5-3 part a). From the interviews with eight households and the analysis, houses with this structural type start getting damage when they are first exposed to water. Subsequently, as the water increases, it gets half damage in range 16-40 cm. The wall and floor materials for this structural house entirely are collapsed when floodwater reaches 80 cm height or higher (figure 5-4 section a).

b. Structural Type 2

Houses with structural type 2 are made from the combination of plywood wall – concrete floor material. This structural type is also very prone to water because the plywood wall can easily get damaged because of water. However, as the floor is made of concrete, people lift the plywood around 12 cm above the floor. Like the structural type I, as the plywood is exposed to floodwater, it gets damaged easily. Then, when the water increases, it also gets half damage in range 21-45 cm. The wall of this type of house totally collapsed when floodwater reaches from height 90cm and onwards (figure 5-4 section b).

c. Structural Type 3

Houses with structural type 3 are made from the combination of bamboo wall – bamboo floor material. This type of house is normally made on the top of pillars. This structural type is also vulnerable to water. Bamboo floor gets soaked if inundated with water for some days (see figure 5-3 part b). One respondent mentioned that her bamboo floor could no longer be used because it had been exposed to flood water for five days. A bamboo wall is still stronger than a plywood wall. Bamboo gets damage as soon as it is exposed to floodwater. The damage increases as the floodwater increases. Up to 35-63 cm, the bamboo gets half damage. When it reaches 100 cm or higher, the wall and floor materials of this type of building are almost entirely damaged or need to be replaced. The vulnerability curve of this house is presented in figure 5-4 section c.

d. Structural Type 4

Houses with structural type 4 are made from the combination of wooden wall – wooden floor material. This structural type is not so vulnerable to water. It still can maintain to cope with floodwater. According to the flood depth – vulnerability relationship, the wood starts getting damage from flood depth around 40 cm. Subsequently, it gets half damaged when floodwater increases to around 90 cm. The wall and material of this type of building are almost entirely damaged when floodwater reaches to 140 cm or more (figure 5-4 section d).

e. Structural Type 5

Houses with structural type 5 are made from the combination of wooden wall – concrete floor material. This structural type is not so vulnerable to water. Having a strong concrete floor, it is only prone to damage from the wooden wall. According to the flood depth – vulnerability relationship, the wood starts getting damage from flood depth around 45 cm. Later, when floodwater increases, the vulnerability is half for flood depth around 100 cm. The wooden wall is totally damaged when floodwater increases to 170 cm or more (figure 5-4 section e).

f. Structural Type 6

Houses with structural type 6 are made from the combination of hollow-block wall and concrete floor. Having a strong concrete floor and strong hollow-block, this structural type is not vulnerable to water. Although this structural type is strong against floodwater, some people also spent some money to repair the minor damage. For instance, they repair the house after floods by painting the wall or re-enforcing some holes that took place because of floodwater remaining inside the house (figure 5-4 section f).

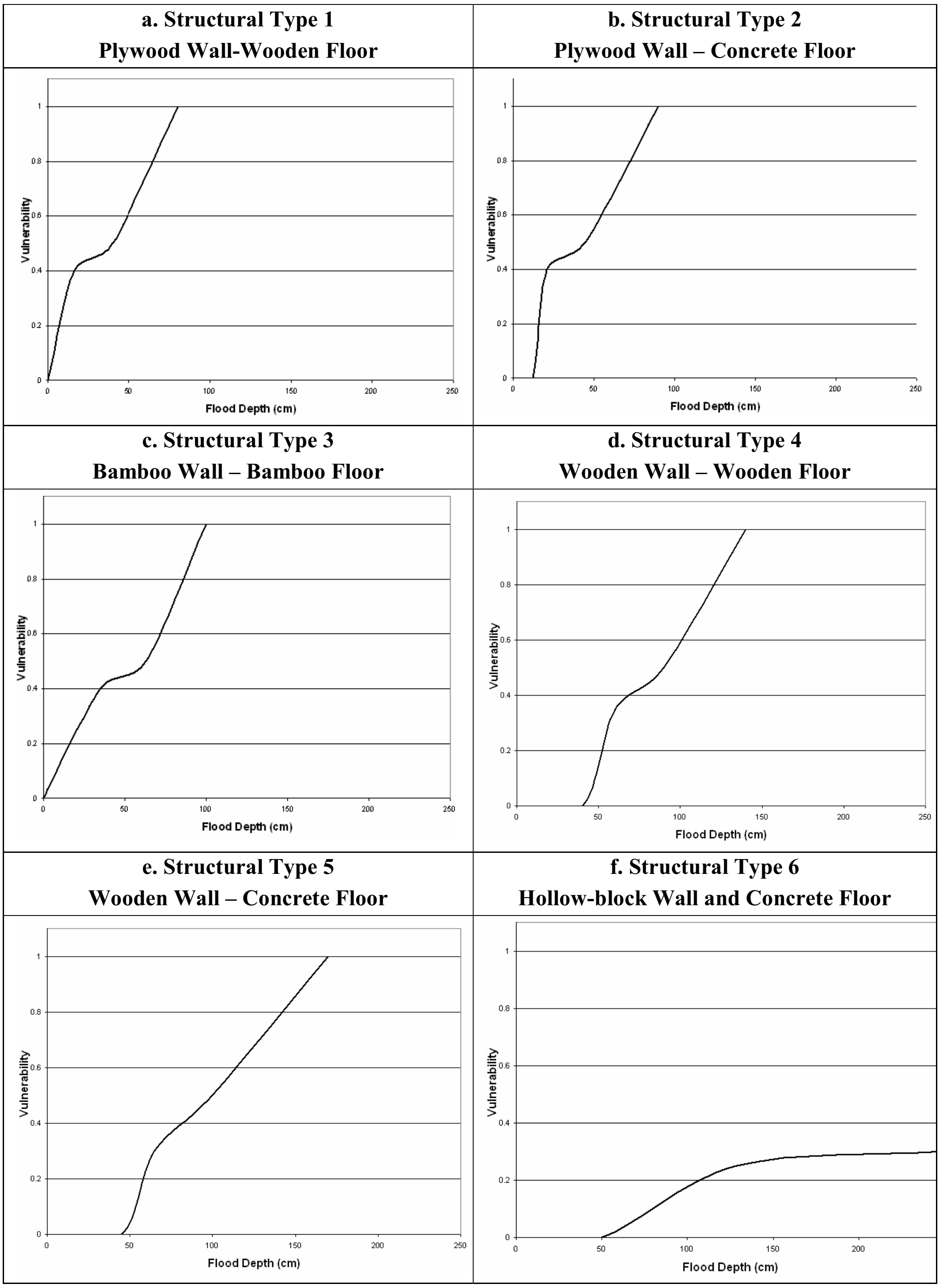


Figure 5-4 Vulnerability Function for Each Structural Type of House
Source: Data Analysis

Comparison of vulnerability functions for the six structural types is presented in figure 5-5. House with structural type 1 is the most vulnerable among all structural types of house in the study area. Additionally, there is similarity of vulnerability function for three types of material: structural type 1, structural type 2 and structural type 3. House with structural type 6 is the least vulnerable among all structural types of house in the study area.

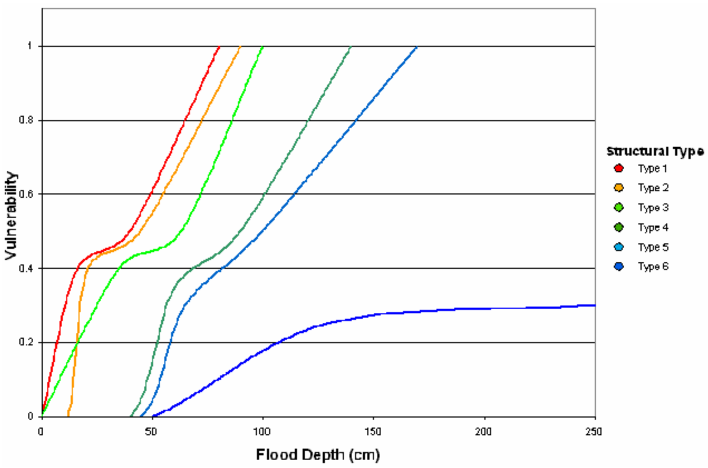


Figure 5-5 Comparison value of Vulnerability Curves for Each Structural Type

It is clearly seen from figure 5-5 that vulnerability curves can be classified into three classes of vulnerability: *high, medium* and *low*. The high vulnerability consists of structural type 1, 2 and 3. The medium vulnerability includes structural type 4 and 5. The low vulnerability comprises structural type 6. These classes of structural vulnerability were inputted into a dBaseIV file so that it could be joined with the shape file of interviewed households originally created with Mobile GIS. A map of structural vulnerability is made using data of classes of structural vulnerability (figure 5-6). The map illustrates buildings from interviews that are categorized as low, medium and high vulnerable to flooding.

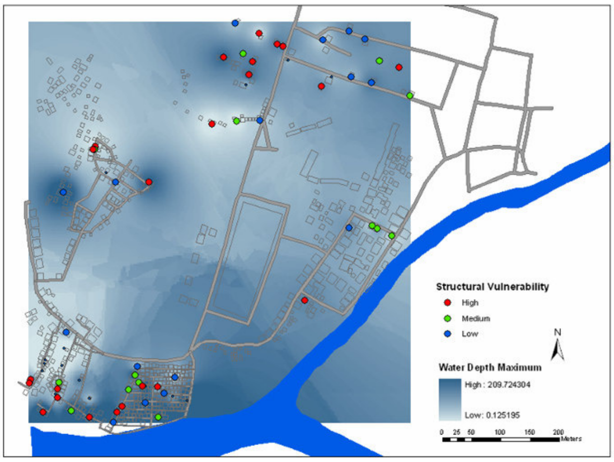


Figure 5-6 Map of Structural Vulnerability
Source: Data Analysis

5.3. Vulnerability of Building Contents and Outside Properties to Flooding

The building contents and outside properties are important elements to be included in the vulnerability assessment. This section discusses the vulnerability for building contents and outside properties in the study area.

5.3.1. Vulnerability of Building Contents

Vulnerability of building content is determined from the value of damaged building contents divided with value of building contents. The value of damaged building contents was recorded from interviews to 68 households. The value of building contents was derived from transferring the value of the building contents into local currency (Philippine Peso). Both data of the damaged building contents and the building contents were derived from questionnaires.

According to the interviews, the common damages happen on wet clothes and loss of small goods. 28% or 19 interviewed households mentioned damage having wet clothes after the flood, 35% or 24 interviewed households mentioned loss of small goods, and about 32% do not suffer any damage to their building contents. During the values, the households were asked to estimate the value of damage. In average, the damage value of building contents is PhP 641 and with range from PhP 0 – 5400. Figure 5-7 illustrates the spatial distribution damage value of building contents. The map does not have any spatial pattern for the distribution of damage value of building contents.

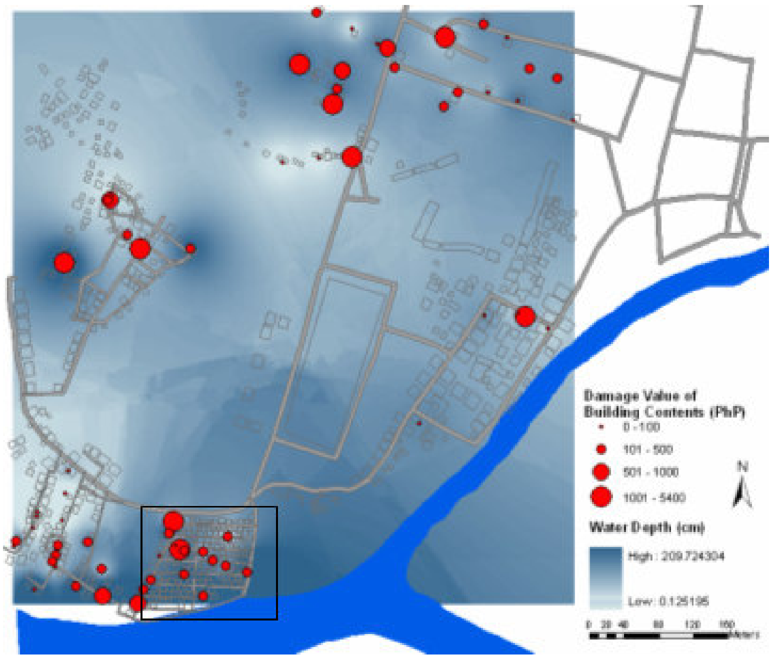


Figure 5-7 Spatial Distribution of Damage Value of Building Contents (PhP)
Source: Data Analysis

However if the data from previous map are compared with the value of building contents, it will give different result. The following map shows the proportion of damage value (from previous map) with the total value (obtained from data in section 4.3).

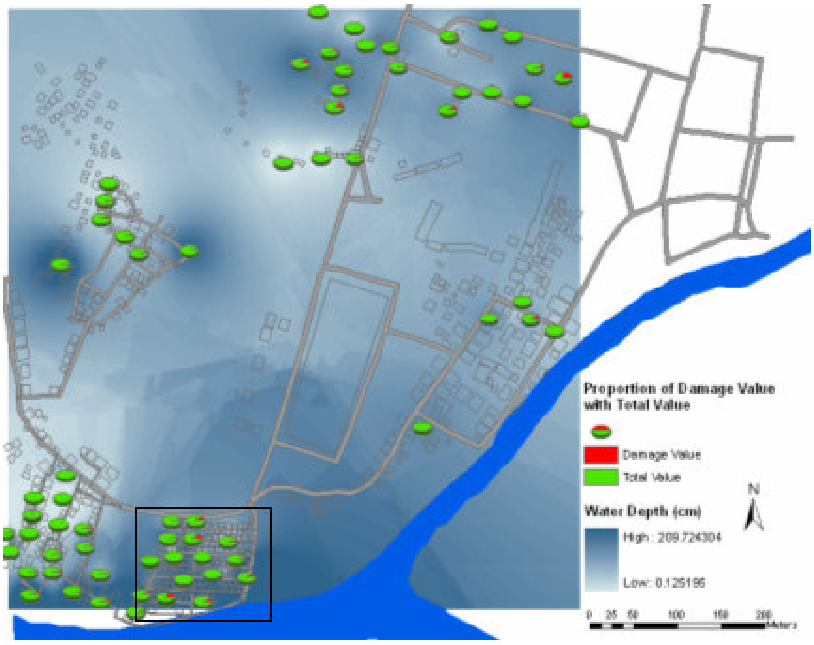


Figure 5-8 Proportion of Damage Value with Total Value of Building Contents
Source: Data Analysis

If figure 5-7 and figure 5-8 are examined carefully, a finding can be generated. The circles within the box in figure 5-7 and the pie charts within the box in figure 5-8 are zoomed in and compared (figure 5-9). In the new comparison in figure 5-9, it seems that many circles in the left side have the same values of damage. However, if those values are compared with the figure in the right side, it can be seen that the proportion of the damage values are different. This condition shows that each household has different capability to deal with damage. Therefore, it is important to introduce concept of vulnerability instead of only flood loss damage in order to get a whole picture of the problem.

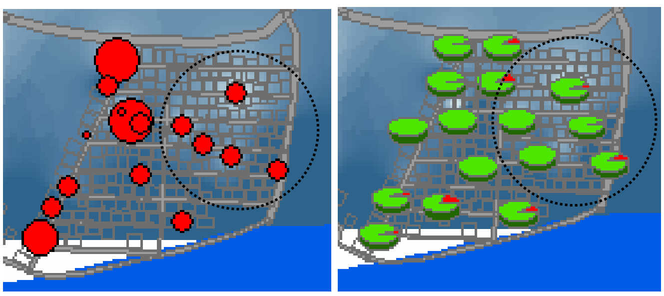


Figure 5-9 Comparison of Damage Value with Proportion of Damage Value with Total Value of Building Contents
Source: Data Analysis

In addition, the vulnerability of building contents in the study area has values in range: 0.00 – 0.26. The frequency of vulnerability of building contents shows that many households lies in low vulnerability or in value 0.00 – 0.01 (figure 5-10). Based on the distribution of vulnerability value of building contents, the vulnerability values are divided into *four classes*. The ranges of the classes are: *class 1* (0 – 0.02), *class 2* (0.0201 – 0.06), *class 3* (0.0601 – 0.12) and *class 4* (0.1201 – 0.26). These classes were used to develop map of vulnerability of building contents in order to identify the vulnerability distribution (figure 5-10). The map composes of overlaid layers from household's location, vulnerability value and flood depth maximum.

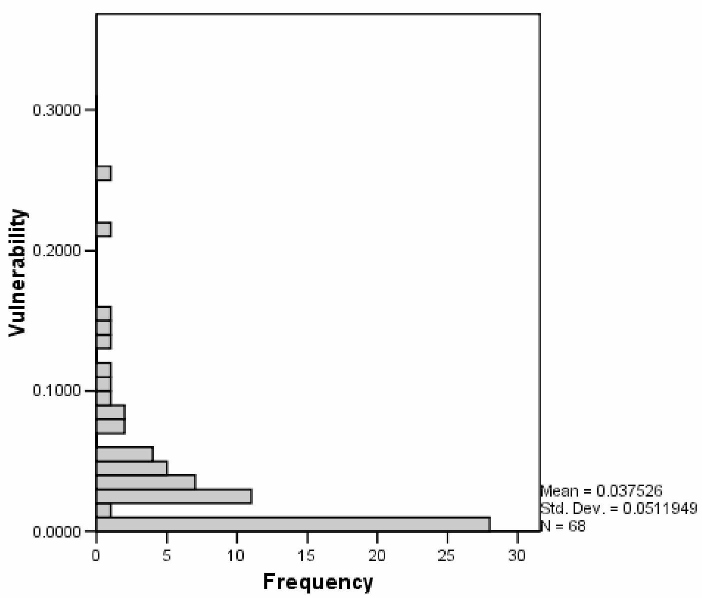


Figure 5-10 Frequency of Vulnerability of Building Contents
Source: Data Analysis

The spatial distribution of building content vulnerability indicates grouping of some data (figure 5-11). The green colour dots in the down-left corner indicate similar level of vulnerability. Likewise, the blue colour dots in the down-left corner show similarity of vulnerability value. In the other area, the green dots in the middle-left show comparable value of vulnerability. These all indicate there is a spatial pattern of the vulnerability of building contents.

As mentioned in section 4.1 (structural type of building), people develop such constructions to counter with flooding with several construction types, such as: number of floor, design inside the house and existence of pillar. However as found during the interviews and observations to households, some houses are constructed with mezzanine. Therefore, house with mezzanine is mentioned as house with 1.5 floors to make it distinct with house without mezzanine, which is one-floor house. Figure 5-12 provides the illustration of spatial distribution of number of floors from interview data.

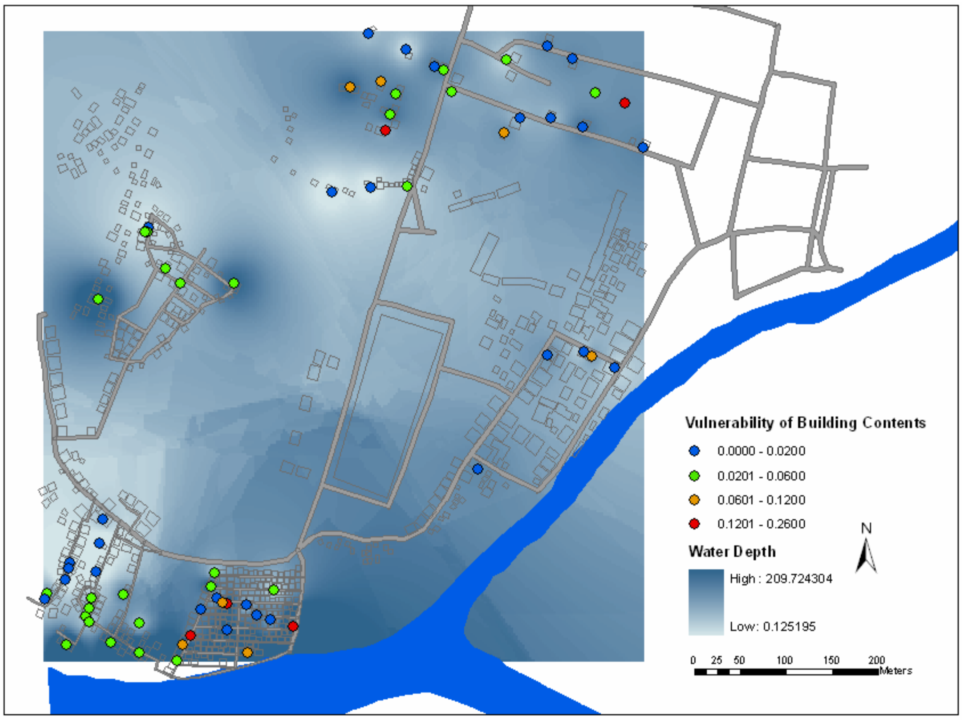


Figure 5-11 Map of Building Content Vulnerability
Source: Data Analysis

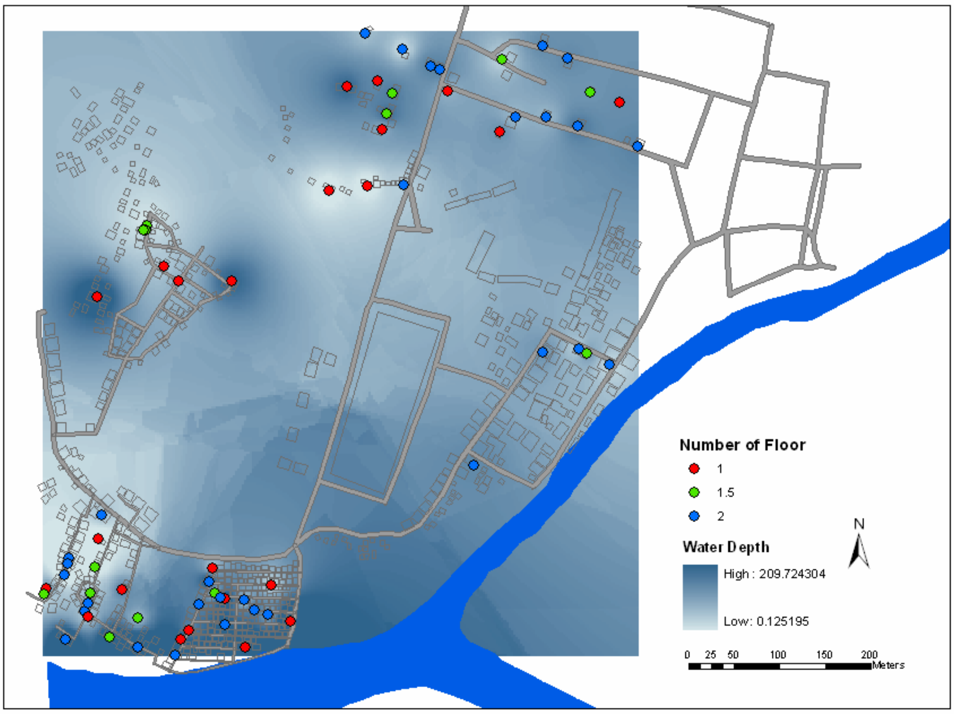


Figure 5-12 Map of Number of Floor from Interview
Source: Data Analysis

In order to seek the relationship between building content vulnerability with the number of floor, both maps of building content vulnerability and number of floor are compared (figure 5-13). Map on the left side and map on the right side of figure 5-13 belong to building content vulnerability and number of floor respectively.

Four spatial relationships between number of floors and the level of vulnerability are distinguished (figure 5-13). In map of number of floor, circle number 1 shows households occupying house with 1-floor, 1.5-floor and 2-floors. In map on the left side, circle number 1 shows that 2-floor buildings (blue colour) have vulnerability values in range 0.00 – 0.02. The buildings with 1-floor could have vulnerability in range 0.06 – 0.12 or 0.12 – 0.26. Likewise, circle number 2 in map of vulnerability of building contents and map of number of floors shows the buildings with two-floors have vulnerability in range 0.00 – 0.02. On the other hand, building with 1.5 floors has vulnerability 0.06 – 0.12. Similar patterns can be seen in circle number 3 and circle 4 as well. Hence, it can be concluded that there exists spatial pattern between vulnerability of building contents and number of floors.

One aim of this research is to develop vulnerability curve based on flood depth – damage relationship. In order to seek for the pattern, the scatter plot of flood depth and vulnerability values is created (figure 5-14). The figure illustrates wide distribution of plots and do not show any pattern. However, when the dots are grouped based on the number of floors, some patterns become clearly visible (figure 5-14). The group with low vulnerability values is the households who have two-floor houses (green dots). The group with relatively medium vulnerability values is the households who have 1.5-floor houses (blue dots). The group with relatively high vulnerability values is the households that have 1-floor houses (red dots).

If the average value of vulnerability for each number of floors is calculated, it obviously shows the different values among buildings with different number of floors (Table 5-2). The households living in floor houses are the most vulnerable among all houses. The households living in the 1-floor and with mezzanine can be able to reduce the vulnerability of building contents. Likewise, the households living in two floor buildings are the least vulnerable for their building contents. Therefore, it can be concluded that households who live in houses with 2-floors and 1.5-floors are more capable to cope with flooding. This makes sense because they can be able to transfer their belongings to the upper floor when flood hits.

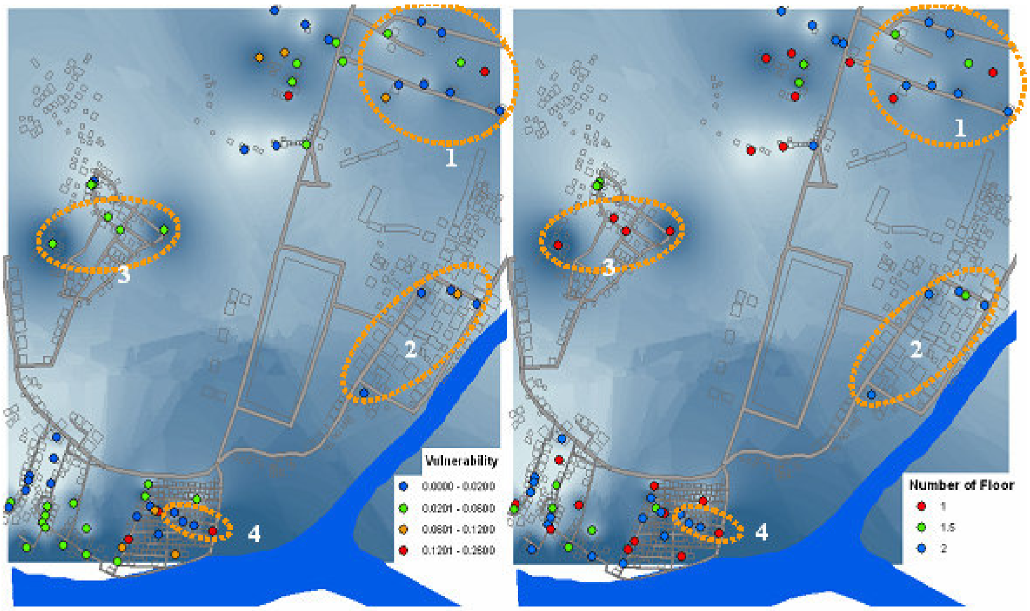


Figure 5-13 Spatial Pattern of Vulnerability of Building Contents and Number of Floors

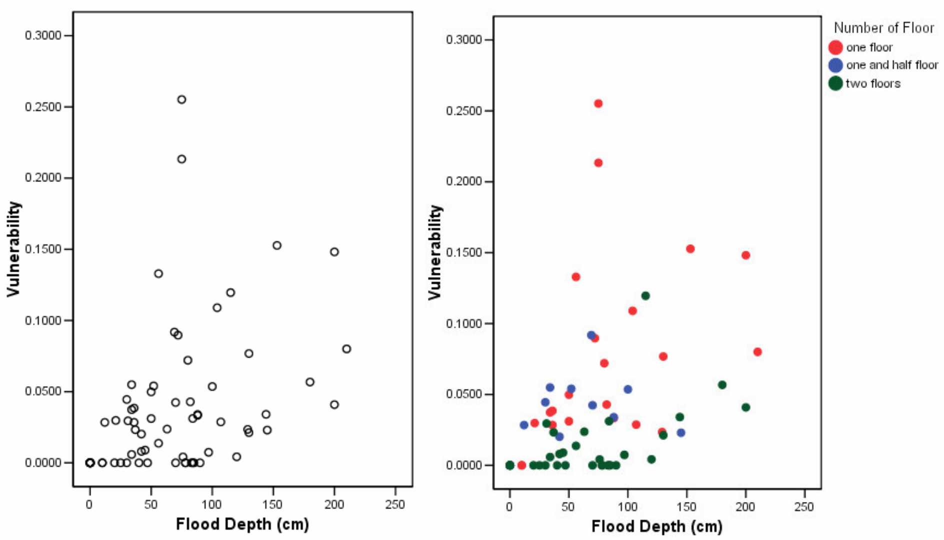


Figure 5-14 Scatter plot of Flood depth and Vulnerability of Building Contents

Number of Floor	N	Mean	Minimum	Maximum
1-floor	23	0.07	0.00	0.26
1.5-floor	14	0.03	0.00	0.09
2-floors	31	0.01	0.00	0.12
Total	68	0.04	0.00	0.26

Table 5-2 Statistical Data of Vulnerability of Building Contents based on the Number of Floor

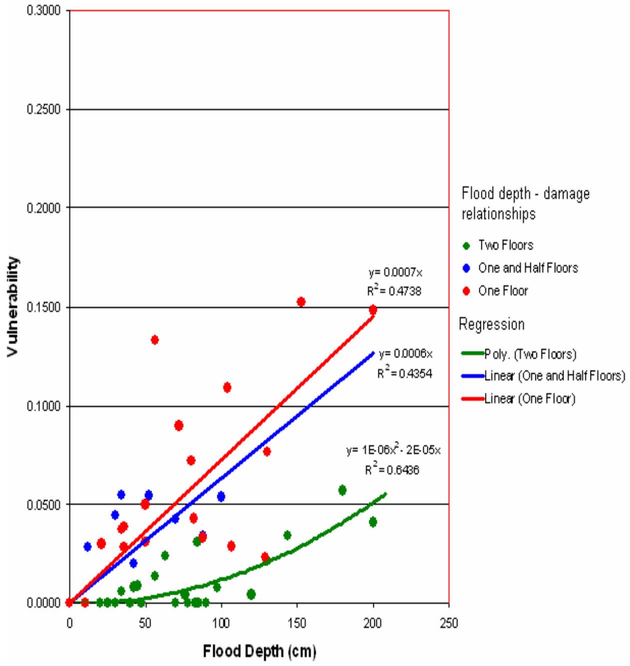


Figure 5-15 Vulnerability Functions of Building Contents

The vulnerability functions are calculated based on the tendency of the plots using regression analysis (figure 5-15). Regression coefficients are calculated for each number of floors. The regression coefficients for buildings with two floors, one and a half floors and one floor are 0.4739, 0.4354 and 0.6436 respectively. The function for each number of floors has been created based on regression between flood depths – vulnerability (figure 5-15). The figure illustrates the tendency of flood depths – vulnerability relationship of building contents for each number of floors. The vulnerability function for 2-floor houses lies in the lowest part of the figure 5-15.

The vulnerability function for 1-floor house is on the top of vulnerability function of 1.5-floor house. However, there is a difference between the two functions. The vulnerability function for 1-floor house is created by widespread data with vulnerability values lie between 0.00 – 0.15. The vulnerability function for 1.5-floor house is created by data that are clustering in the vulnerability value 0.05 (see figure 5-15). This difference indicates that houses with 1.5-floor are less vulnerable than houses with 1-floor. Therefore, it can be concluded that the vulnerability of building contents for houses with 2-floor, 1.5-floor and 1-floor are low, medium and high respectively.

5.3.2. Vulnerability of Outside Properties

Vulnerability of outside properties is measured from the value of outside properties divided with the total value of outside properties. Damage values of building contents and outside properties are data obtained from the interviews to 68 households. According to the interview, only three households out of 68 interviews have reported damage / loss of outside properties. This means 65 households have not suffered significant damage / losses of outside properties. Figure 5-16 shows that almost all data are on the bottom-side or meaning that no damage occurs to 65 households.

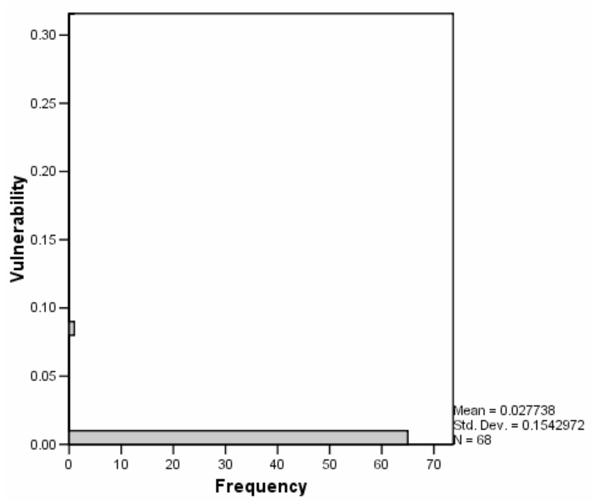


Figure 5-16 Vulnerability of Outside Properties

Based on this information, it is not possible to create a vulnerability function for outside properties since the damage is not significant and does not affect many households in the study area.

5.4. People's Coping Mechanism

People's coping mechanisms to flooding exist in Barangay Sabang and Barangay Igualdad. Based on the interviews and observations, several people's coping mechanisms against natural hazards (floods and typhoons) were found. The following discussions examine coping mechanisms based on the classifications of the elements at risk as used as the framework of this study.

5.4.1. Coping Mechanisms for Structural type of building

Coping mechanisms of structural type of building against floods are all measurements that have been taken in order to reduce the damage to structural type of building. From the observations in the study area, there are two common ways people have conducted to make their structure more resistance against flood. First measurement is through the selection of building material that withstands against water, like hard wood and cement or concrete construction. Nevertheless, the stronger the material, the higher the price will be. Therefore, not every household can afford to have a strong material. Based on the building inventory (table 4-1), only 39% of households do construct their house using hollow-block or concrete material.

The second measurement that people use is increasing the height of first floor. In more specific, two ways are undertaken in this measurement. First way is by increasing the height of first floor through earth-filling land and the second is by constructing house on the top of pillars. In concerns of construction price, building house over the pillars is not expensive. According to the interviews, to build a house with light materials (plywood and bamboo) on pillars may cost around PhP 10,000 – 20,000 or is the same with € 143 – 285.

However, house with pillars is not a common housing type in the study area. Surprisingly, from the building inventory, it was found some houses were built with high pillars more than 80 cm. This is an evident that some households have realized that they live in flood prone area.

Figure 5-17 Houses with High Pillars

It becomes clear from the vulnerability functions of the six structural types of building (figure 5-4) that the first 100 cm of flood depth is the crucial part. Therefore, flood mitigation in household levels should consider the flood depth in this height. This can be creatively solved by constructing house with flood proof material for the first 100 cm. One house was remarkably found with the combination of flood proof material for the first 100 cm (figure 5-

18). The wall of the house consists of 100 cm hollow block wall and afterwards with bamboo wall material. This type of construction can serve to reduce the damage that might happen to building structure. The cost of construction was not part of the attention during the fieldwork. Nevertheless, it can be assumed that the cost of construction of house with mixed hollow-block and bamboo wall should cost less than that of full hollow-block wall.

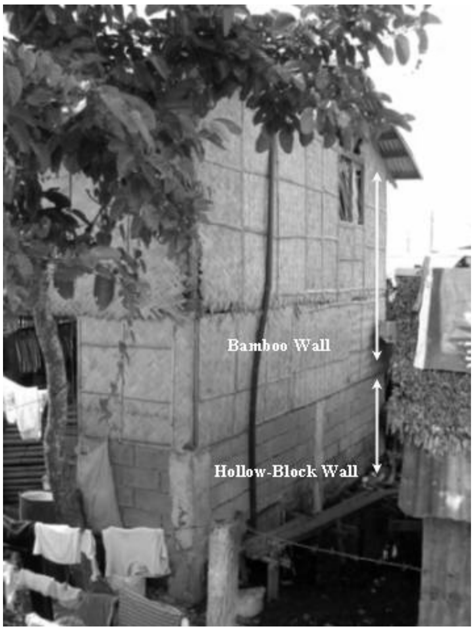


Figure 5-18 House with Hollow Block and Bamboo

In addition to coping with flooding, people also apply coping mechanisms for typhoon. Coping mechanisms against heavy wind during typhoon is applied to the roof to keep the layers of zinc and nipah are not blown away by the wind. People put heavy things like bars and tires to make the roofs withstand against the high-speed wind during the typhoon season (figure 5-18). This coping mechanism is applied only for protection against typhoon.

Figure 5-19 Coping Mechanisms against Heavy Wind

5.4.2. Coping Mechanisms for Building Contents and Outside Properties

Coping mechanisms against flood for building contents and outside properties comprise some ways that people have conducted to reduce the damage of flooding to building contents and outside properties. According to interviews, these coping mechanisms have been applied as natural ways of people to deal with flooding and typhoon because those are common occurrences in Naga City area. Coping mechanism against the damage to building contents, are applied by constructing second floor, plastic bag and mezzanine (figure 5-18). Buying some plastic bags is a habit for households in the rainy and typhoon seasons. Plastic bags are used to put small building contents so that they will not get wet when there are rain and flood (see figure 5-20.

Figure 5-20 Coping Mechanisms for Building Contents

5.5. Discussion

This chapter has explored the flood occurrences in Naga City and the study area, vulnerability of structural type of building, building contents and outside properties. Moreover, it has discussed people's coping mechanisms. The relationships do exist between the vulnerability of structural type of building with the structural types of the building. The six structural types in the study area determine the vulnerability level that exists.

For vulnerability of building contents, damage is strongly linked to the number of floors. Households that have two floors tend to have less damage compared to the households that have one and one-half floor. Having a two-floor house is an effective way to deal with damage to building contents because goods can be transported to the second floor.

Vulnerability of outside properties is very little. Only three households mentioned that they suffered from damage and lost of outside properties due to floods. This makes sense because only a few households who have valuable outside properties (see discussion section 4.2).

The coping mechanisms are found in the study area. The coping mechanisms can be divided into coping to structural types and to building contents. The coping mechanisms vary from one household to another. It is likely that the coping mechanisms are determined by the income, assets, experience of floods and awareness of floods.

6. Conclusions and Recommendations

This chapter provides the concluding part of this thesis. It states the main contributions of this research by relating the findings with the objectives of this research. Finally, this chapter suggests further research recommendations.

6.1. Conclusion

The main objective of this research is to develop a rapid assessment method for flood physical vulnerability and to apply it in a case study in residential areas in Naga City, the Philippines. The following discussions respond to the research questions introduced in the chapter 1 of this thesis.

The first sub-objective of this research is to identify the elements at risk relevant for flood vulnerability assessment in residential area. To respond to this sub-objective, building inventory and interviews have been carried out to identify the detailed classifications of the elements at risk. Initially, this research classified the elements at risk into three major elements: structural type of building, building contents and outside properties. However, given the complexities and findings from the field, it was decided to generate the more detailed classifications of the elements at risk. In conclusion, the structural types of building are classified into six. The building contents are grouped into one element at risk based on the value. However, it is analyzed separately based on the number of floors because different number of floor leads to different level of vulnerability. Subsequently, outside properties are grouped into one element based on its value (sections 4.1 and 4.2).

Mobile GIS devices (GPS, PDA and Camera Digital), as the tools of data collection, have proven useful to provide method for data collection in this research. Given that the prices of these devices are affordable for the small municipalities, like Naga City, these devices will be very helpful to support small municipalities to deal with data collection in disaster management as well as for other purposes. Nevertheless, it should be realized that a trained staff is needed to operate the Mobile GIS.

The second sub-objective is to assess the damage of structural types of building, building contents and outside properties as well as to conduct vulnerability assessment for the elements at risk. It was found from vulnerability assessment that the damage and vulnerability of structural types is mainly determined by the materials of the house. The houses with structural type 1 (plywood wall and wooden floor), structural type 2 (plywood wall – concrete floor) and structural type 3 (bamboo wall and bamboo floor) are the most vulnerable. The houses with structural type 4 (wooden wall and wooden wall) and structural type 5 (wooden wall and concrete floor) are moderate vulnerable houses. The houses with structural type 6 (concrete wall and concrete floor) are the least vulnerable (section 5.2). The information can serve to inform the pattern of vulnerability of structural types in the study area. The vulnerability functions of structural types of building (see figure 5-4) clearly indicates that the first 100 cm is the crucial height. Plywood and bamboo material (structural types 1, 2 and 3) are decaying in this height while wooden material starts to get half damage. In addition, no spatial pattern has been found for the vulnerability of structural types of buildings in the study area.

In general, the vulnerability of building contents varies from value 0 to 0.26. This value implies the percentage of damage of building contents that the households encounter. In order to understand the detailed information, the vulnerability of building contents were analyzed separately based on the number of floors. It was found that vulnerability of building contents for 1-floor houses is the most vulnerable because they do not have enough space to transfer (section 5.3.1). On the other hand, the households who have 1.5-floor is medium vulnerable because still they can transfer their belongings to the mezzanine (the additional construction). The households who have 2-floor house are the least vulnerable because they are able to transfer the building contents to the second floor. Additionally, the spatial patterns of vulnerability of buildings contents follow the spatial distribution of number of floors (see figure 5-13).

The vulnerability of outside properties does not exist since most households in the study are do not have valuable outside properties (section 4.2 and 5.3.2). Therefore, the vulnerability functions for outside properties were not analyzed.

The third sub-objective is to identify how people mitigate the impact of the vulnerable objects due to flood. It was found that people employ a variety of coping mechanisms as also mentioned by previous research (Monrroy Prado, 2005; Reganit, 2005). The approaches employed by the households to reduce the disaster risk from flooding are raising the level of the first floor, building houses on pillars and building two-floor houses. Building houses on pillars is not a common approach by households living in the study area, though it was found that this approach is not costly. Instead, some households have constructed the second floor to deal with flooding. This approach makes sense because more space is available for house with two floors. When the first floor is flooded, the second floor can serve as the place where they can evacuate themselves and their belongings. During the ordinary day, the first floor and second floor can function as usual. There is a common approach where the households do when flood is coming. In each house, the household prepares plastic bag where they can put their belongings.

Some remarkable findings exist in the study area. *First*, some houses are constructed with pillars over 80 cm. This height is clearly above the average height of flood depths (see figure

5-1, Flood Unding has the maximum height 72 cm). Therefore, a question can be posed: "Why did some people construct their house with pillars with that height?". Several answers are possible. However, one basic thing is that the households must have been aware[10] of the average height of flood depth (not the maximum flood depth which is Flood Rosing). In that sense, some households are more able to cope with ordinary floods compared to other households. *Second*, a house with flood proof construction (hollow-block) for the first 100 cm (figure 5-18). Based on the analysis of vulnerability of structural type, the first 100 cm is the crucial depth. Plywood and bamboo get decaying when they are inundated 100 cm (see figure 5-4). The approach that this household applies by constructing the first 100 cm with hollow-block is crucial and important. Why has only this household constructed this type of construction? One possible reason is that this household is aware of flood occurrence[11]. Therefore, it can be concluded that the awareness of flood occurrence is important.

6.2. Contribution of This Research

This research provides contributions as follows:

- Naga Municipality can make use of the data collection methods employed in this research. Since the data collection was done in a low cost method, this method can be adopted by small municipalities to deal with data collection for disaster management.
- Vulnerability assessments of structural type of building, building contents and outside properties in the study area can provide useful information to Naga Municipality to identify the flood physical vulnerability condition in the study area and other similar areas in Naga City or other areas in the other cities.
- The results of this research can be used to conduct flood risk assessments in Naga City.
- The results of this research, in particular from the vulnerability of the structural types can be taken into account in making policies for flood risk reduction, for instance: developing building codes and land use planning (see figure 2-7 and figure 2-8 in literature review).

6.3. Recommendation for Further Research

Recommendations for further research are as follows:

- In order to test the results of this research, further case studies in other part of Naga City need to be done. Consequently, this will bring better understanding of the elements at risk involved and the flood physical vulnerability of the elements at risk.

[10] Two households who have pillars more than 80 cm mentioned that they know the common flood depths.

[11] This is only based on analysis from the photograph of the house. No question was asked to this household of this construction during the fieldwork because this was not realized by the researcher in the beginning. The author realizes that this approach makes sense after having the result from analysis of vulnerability of structural type.

- Coping mechanisms that have been applied by several households should be taken into account. Having information that those coping mechanisms are useful, the next steps to be done are to implement it in wider area and to inform other flood-affected communities.
- Since the occurrences of typhoons have some effects to the households, research on typhoon physical vulnerability should be done. Subsequently, the results can be joined with those of flood physical vulnerability in order to get complete picture of disaster risk in this Naga City.
- As other study about flood modelling with respect to recent development in Naga City has been done by Bin Abd Rahman (2006), it is good to combine the results of this study with the flood modelling done by Bin Abd Rahman. The result can be helpful to develop scenarios of flood disaster management.

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Appendix

Appendix 1 Questionnaire of Flood Physical Vulnerability

Research Title: Assessment of Flood Physical Vulnerability, Naga City, Philippines

Researcher: Saut Sagala — Date: / /
contact: sagala07758@itc.nl — Time
International Institute for Geo-Information Science and Earth Observation (ITC)
Enschede, the Netherlands

This information will only be used for scientific research
We thank you very much for your help and cooperation

1 General Information

1.1 Location

Barangay			
Building_id			
Building Size			
Plot Size			
Block_id			
Building age			
Ownership		own	rent

1.2 Identity

Respondent	
Status	(F),(M),(S),(D)
Job	

1.3 Socio Economic Description

Income	
Family Member	
-Male	
-Female	
-Working	
-Not Working	
-School	
Expenses per day	
-Food	
-Transport	
-Others	

2 Elements at Risk

2.1 Building (Please select)

Type	1). Storage	2). Shop	3). B Hall	4). Residential	
	5).School	6).Workshop	7).Chapel		
Floor material	1).cement	2). Tile / ceramics	3). soi	4).wood	5).
Wall Material	1).Ply Wood	2). Wood	3). Bamboo	4).Brick	
	5).RCC	6). Press Cement	7). Mix	8).Zinc	
Number of floor		pillar	1	2	3
Height of 1st floor			m		
Height from surface			m		
Height from street					
Roof	1).Clay	2).Cement	3).Zinc	4).Nipah	

2.2 Building Contents

2.2.1 Appliances

Item	Q	value
TV		
Stove		
Refrigerator		
Computer		
Air Conditioner		
Radio		
Tape Stereo		
Washing Machine		

2.2.2 Furniture

Item	Q	value
Carpet		
Sofa		
Dinning set		
Book case		
Drawers		
Chair		
Curtain		
Bed		
Double Bed		
Table		

2.3 Outside properties

Item	Q	value	
Animal			
Car			
Motorcycle			
Bicycle			

Item	Q	value

3 Floods

3.1 What is the cause of flooding?

1).Moonson	3). Flash Flooding
2).Typhoon	4)

Which typhoon cause the flood?

typhoon	year

3.1 Flood Occurrence

How high was the depth of water on December 2004?				(m)
	Typhoon Unding			
	Typhoon Yoyong			
How long was the duration?				(h)
	Typhoon Unding			
	Typhoon Yoyong			
Maximum height ever happened?				
When did maximum flood happen?				
Which typhoon cause that?				
How long was the duration?		< 12	> 12	

3.2 History of floods

Typhoon	Year	Depth	Duration

3.3 Flood Protection

-Have you applied any flood protection?	yes	no
-What kind of protection have you done?	-	
	-	

4 Damages and Losses

4.1 Damage to Building Structure

-What is the maximum damage to building structure in last 10 years?

-Depth and Damage

Item	Depth	Damage	Depth	Damage	Depth	Damage	Depth	Damage
Floor								
Wall								
Door								
Window								

Note: C Collapse HC Half Collapse NH Nothing happens

-How much is the cost to repair the damage?

Item	Depth	Cost	Depth	Cost	Depth	Cost	Depth	Cost
Floor								
Wall								
Door								
Window								

Note: in money (pesos)

Damage of Roof

What are the damage of roof and building when typhoon happens?

4.2 Damage to Building Contents

-What kind of building contents have been damaged due to flood in last 10 years?

____

____

____

-Depth and Damage

Appliances	Depth	Damage	Depth	Damage	Depth	Damage	Depth	Damage
Furniture								

-How much is the cost to repair (to restore) the damage?

Appliances	Depth	Damage	Depth	Damage	Depth	Damage	Depth	Damage
Furniture								

Note: in money (pesos)

4.3 Damage to Outside Properties

-What kind of damage has happened to outside properties in last 10 years?

____

-How much is the cost to repair (to restore) the damage?

____

4.4 Clean up cost

What kind of clean up do you do after flood?

____

How much is the clean up cost after the flood events

Depth	Damage	Depth	Damage	Depth	Damage	Depth	Damage

5 <u>Impact of Flooding</u>

Had you experienced flooding problem before you moved to this place (barangay)? yes / no

If yes, where was the former place (barangay)? ____________________

Are you considering to move to other area to getaway from the flooding?

if yes, to which barangay (place) ____________________

Why?

____

What have you learnt from the floods?

____

How do you perceive the flooding in your area?

1). Nuisance
2). Catastrophe
3). Others

What kind of protection for your building would you like to do against the flood?

____

____

In case of flooding, what type of action do you do to reduce the damage of building contents?

____

____

How long do you need to get your things away in case there is flooding? (in hours)

Where do you place your things when flood comes?

Where does your family evacuate to if there is flooding?

Can you continue working when there is flooding? Why?

Appendix 2 Damage Scale for Floods with Dependent Variables

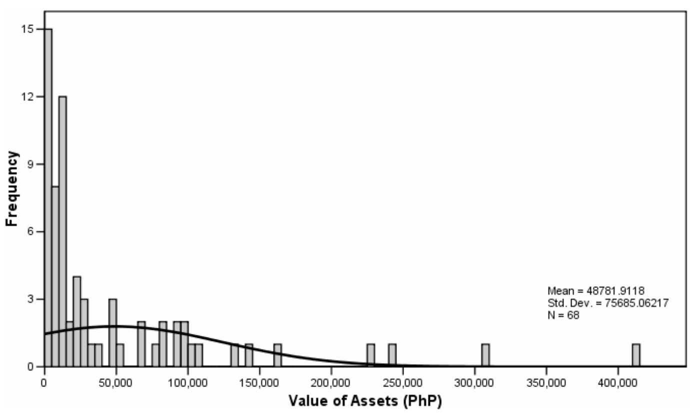
DS	Damage Description	Most Important Residence Characteristics
0	No water contact with structure	-
1	Water contacts outside of structure but does not enter	-
2	Water infiltrates or external features are damaged or removed by water or debris	Flood rise rate
3	Water or debris penetrates through a closed or covered opening (probably by breaking the opening); for example, a window or a door	Glass failure
4	Water or debris penetrates through a route not including an opening (structural integrity is attacked); for example, a wall or roof.	Wall failure
5	Structure is damaged beyond repair; for example, walls collapse, the structure moves, or the foundation is undermined	Wall failure

Source: Kelman (2002)

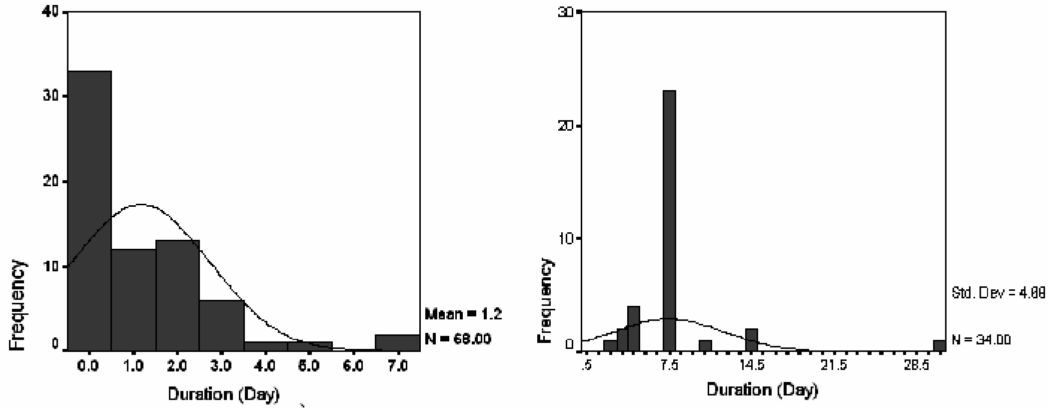
Appendix 3 Height of First Floor from Ground Surface and Street

	Height from Surface (cm)	Height from Street (cm)
N	245	245
Mean	29.5	24.8
Median	20	20
Mode	20	0
Std. Deviation	30.73	34.52
Variance	944.35	1191.63
Minimum	-28	-100
Maximum	165	165

Appendix 4 Total Assets of Households in the Study Area.

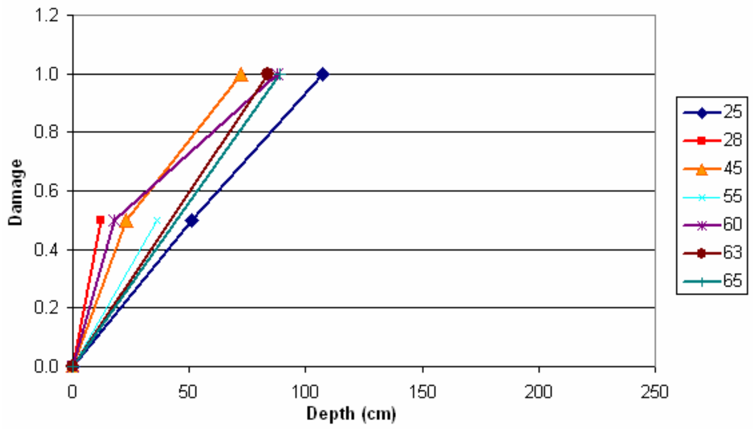


Appendix 5 Flood Duration during the Flood Unding (Left Side) and Flood Rosing (Right Side)

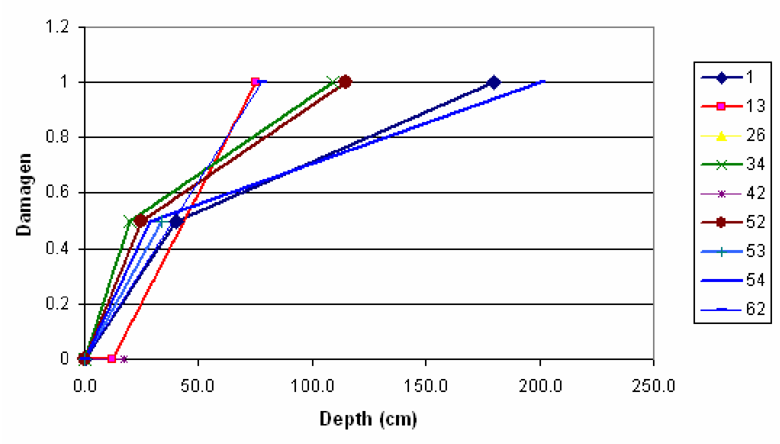


Appendix 6 The plots of Depth – Damage for Six Structural Types of Building

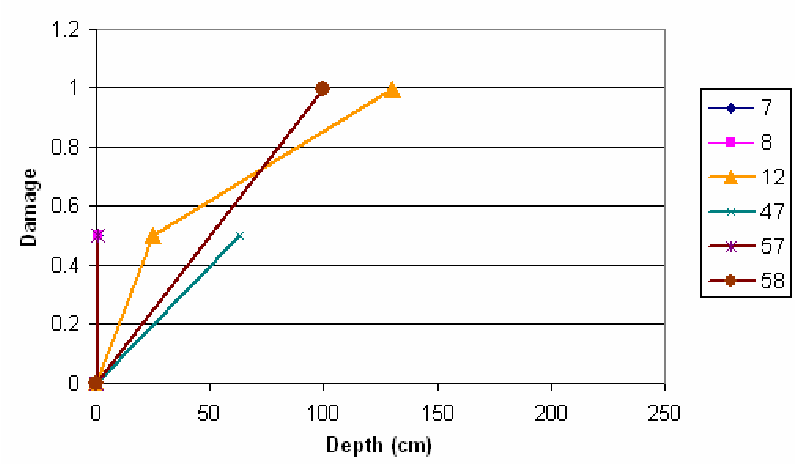
i. Structural Type 1



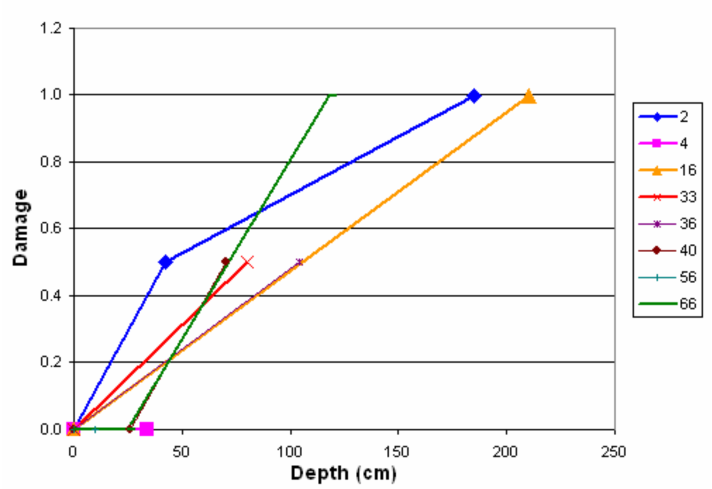
ii. Structural Type 2



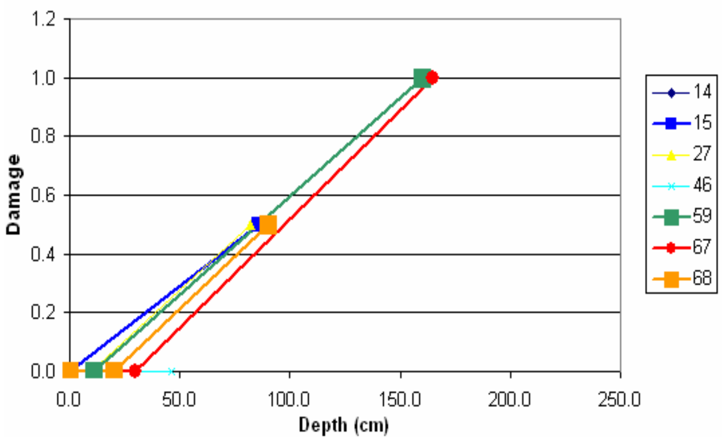
iii. Structural Type 3



iv. Structural Type 4



v. Structural Type 5



vi. Structural Type 6