Rural Flood Risk Assessment for Nam Chun, Thailand

Saviour Alomatu **March, 2009**

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by

Saviour Alomatu

Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: (fill in the name of the specialisation)

Thesis Assessment Board

Prof. Dr. V. G. Jetten (Chair)
Dr. T. W. J. van Asch (External examiner)
Dr. D. Alkema (First Supervisor)
Drs. N. C. Kingma (Second Supervisor)

Observer :
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INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDE, THE NETHERLANDS

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Abstract

Assessment and identification of risk is crucial in order to provide critical information for risk reduction policy-making and help to prioritise risk reduction investments. Therefore, appropriate information on disaster losses, hazards, vulnerabilities and risks at the different spatial levels is fundamental. Flash floods have damaged both life and properties in Nam Chun, which is common during the rainy season from May to October. It is important to identify the degree of loss that the built environment suffers as a result of the occurrence of flooding. The aim of this study is to assess flood risk taking into account the social aspects. To achieve this, the following questions were set for the study: 1. What are the water flow distribution and the flood characteristics in the downstream area for 2, 10 and 20 years return period floods? 2. How do physical structures (such as bridges and culverts) affect the flow of floodwaters? 3. What is the rural public perception of the risk of flood hazard and does it differ with location? and 4. What is the risk in floods of 2, 10 and 20 years return periods? To answer questions 1 and 2, a combined one-dimensional and two-dimensional hydrodynamic modelling was done using Sobek to simulate the flood propagation including bridges and culverts, then excluding them in the analysis. This resulted in zonation of flood hazard areas with the influence of flood characteristics as velocity, impulse, depth and warning time on flooding in study area. The total inundated area is 149.40, 6500.80 and 8327.90 (ha) for 2, 10 and 20yrs return period flood respectively. The maximum velocity increased as 0.6, 2.7 and 4.1 m/s for 2, 10 and 20yrs return periods respectively. The other parameters had the same trend. The presence of structures caused an increase in depth and impulse. Sensitivity analysis on the structure types show that abutment bridges increase the flood depth whereas for the culvert, circular shaped culverts increased the velocity and impulse. To answer question 3, interviews with community's people made clear that they perceive flood as risk because their economic level is affected negatively. The economic level varies with location within the catchment. Question 4 was tackled by combining the results of the Sobek modelling with the people's perception and the losses were assessed for crops, people and building structures for all scenarios. The results indicate an increase in total area in hectares of crop affected with return period. The loss of rice was 17310, 445729 and 897979 Baht/ha for 2, 10 and 20 years return period flood respectively. In case of people, the area in hectares that pose risk to pedestrians also had same trend. For buildings, none was affected by the 2yr flood, 8 were affected by 10yr flood and 15 by 20yr flood. The procedure of flood risk assessment followed in this study is useful for risk reduction policy-making. However, other experts like structural engineers should be involved.

Key words: Flood risk, risk perception, vulnerability, hydrodynamic modelling, bridge and culvert.

Acknowledgements

I express my appreciation to the Netherlands Fellowship Programme for funding this MSc. I express my heartfelt gratitude to my first and second supervisors, Dr. Dinand Alkema and Drs. N. C. Kingma respectively for their valuable suggestions that have made this thesis a reality.

I am also grateful to Mrs. Fasai Weir of Thailand for her immense support during fieldwork. Mr. Ekapol Sealao of Daung-ta restaurant (alias Area specialist) for his contributions to this work. I extend my appreciation to Mr. Govert Verhoeven of Delft Hydraulics, Delft and to Dr. Graciela G. Peters of ITC. To all who in diverse ways supported throughout this programme whose names are not mentioned here, you are highly appreciated.

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1. Introduction

This chapter give a the general overview of this research which consists of the background, research problem, research objectives, research hypothesis, research question, limitations and thesis structure.

1.1. Background

Flood is any high stream flow, which overtops the natural or artificial banks of a stream. It is a natural and recurring event for a river or stream. There are different flood types namely river flood, flash flood, dam break flood and coastal flood. The main causes of floods are high rainfall amount, lower topography, environmental degradation and natural or man-made blocking of waterway. Flooding at a place where it is not wanted can become a disaster. In recent times, flood has become the most recurring, widespread, disastrous and frequent natural hazard globally causing loss of life and property.

Flash floods are the most dangerous weather-related natural disasters in the world (Ethan and Korine, 2007). It is a major threat to both human and animal life and infrastructure with more damage than the other flood types. Flash floods are distinguished from the other types by the short time scales over which flood producing rainfall occurs over small spatial scales (O'Donnell, 2002).

Risk refers to the expected losses from a given hazard to a given element at risk over specified future period of time. Flood risk assessment is a holistic approach, which considers all kinds of flood types and flood events for a study area. It combines the hydrologic knowledge about the frequency of different flood types and flood events and the hydraulic modelling information about inundation behaviour of floodwater in flood plains. According to the way in which the element at risk is defined, the risk may be measured in terms of expected economic losses, or in terms of number of lives lost or the extent of physical damage to property (Coburn et al., 1994). Risk assessment can be done at various scales such as rural, urban and regional. Urban risk assessment involves more elements at risk than rural risk assessment.

Important factors that play a major role in flood risk assessment include background conditions i.e. flood history, flood type, flood prediction, flood protection, environmental (e.g. climate change), social (e.g. awareness) and economic.

In the history of Thailand, floods such as flash flood have damaged both life and properties. Flash flood is common during the rainy season from June to October. An increases in runoff volume generated had subsequent effects on the flood magnitude in the lowland (Prachansri, 2007).

Improving the analysis and identification of risk is crucial in order to provide critical information for risk reduction policy-making and help to prioritise risk reduction investments. Indeed, accurate, comparable and appropriately scaled information on disaster losses, hazards, vulnerabilities and risks at the different spatial levels is fundamental for designing and implementing effective policies and programs that reduce disaster risk (Provention, 2005). In order to accomplish this it is important to carry out a semi-quantitative flood risk assessment for the area.

1.2. Research Problem

Human activities in the past decades have extensively deforested the North central part of Thailand. Local farmers have exploited the mountainous areas, which were originally covered by dense tropical forest. Improper land use practice has resulted in severe land degradation in the watershed and the floodplain to which the watershed contributes may experience an increase in flooding. On 11th August 2001, heavy rains after typhoon Usagi swept through the watershed of Nam Chun and caused landslides in highlands and flooding in lowlands. At least 120 people died and over a 1,000 people were made homeless (Conachy and Divjak, 2001; World Vision).

Increase in runoff volumes and changes in timing of flows have increase severe flooding in the lowlands, which implies poor catchment management practices results in increased rates of surface runoff and flood extent (Prachansri, 2007).

Previous work in Nam Chun was done on flood hazard assessment (Prachansri, 2007). This study adds to that work by assessing the risk taking into account the social aspects. The impacts of floods depend on the elements at risk, such as population, buildings, agricultural land and so on and their associated vulnerability to damage. This study focuses on agricultural land, population and buildings as elements at risk.

In order to know the flood characteristics and hazard prone areas, hydrodynamic modelling makes it possible to predict hydrologic processes. The vulnerability and elements at risk is analysed to reduce impact and risk of floods.

1.3. Research Objectives

The main objective is to develop a methodology for semi-quantitative flood risk assessment for a rural area. The specific objectives are the following:

- To assess flood hazard for Nam Chun area, by using a hydrodynamic model to simulate flood scenarios and consider physical structures;
- To gain a better understanding of the flood risk perception of the local people;
- To integrate the flood risk perception of the community and hydrodynamic modelling into a semi-quantitative flood risk assessment methodology.

1.4. Research Hypothesis

- Hydrodynamic modelling is a suitable technique to identify and quantify flood characteristics;
- Physical structures (such as bridges and culverts) affect the flow of floodwaters and thus hazard;
- Flood risk perceptions differ with location within the catchment;
- Floods of 2, 10 and 20 years return periods have varying levels of risk.

1.5. Research Questions

- What are the water flow distribution and the flood characteristics in the downstream area?
- How do physical structures (such as bridges and culverts) affect the flow of floodwaters?
- What is the rural public perception of the risk of flood hazard and does it differ with location?
- What is the risk in floods of 2, 10 and 20 years return periods?

1.6. Limitations

Flood risk perception of the people was obtained through group interviews organised at five locations. It was envisaged in addition to the group interview, to carry out household (individual) interview but this was not done due to lack of an interpreter. The author got an interpreter in the last week of field work (four days) hence organised only group interviews. Due to that effect, damage to buildings information was not collected to evaluate vulnerability to people and buildings. Individual building vulnerability data was collected by visual inspection of the existing buildings during the field work since there was no interpreter for detailed information about the 2001 flood damage. Secondary data requested for were not obtained during fieldwork.

1.7. Thesis structure

This research consists of nine chapters:

Chapter 1 - Introduction

This chapter contains the background of this research, followed by the research problem, research objectives, research hypothesis, research questions and limitations of this study.

Chapter 2 - Literature Review

This chapter provides theoretical background from selected literature on the topics related to this study.

Chapter 3 - Research Methodology

The research procedure is in three stages, pre-field work, field and post-field work. Each stage provides detailed description.

Chapter 4 - Study Area

This section gives a description of the study area such location, climate, geology and land use.

Chapter 5 - Flood Modelling

This chapter deals with simulating flood scenarios and behaviour in the area. Simulating physical structures such as bridges and culverts and how the different bridge types influence flood behaviour.

Chapter 6 - Flood Risk Perceptions

This chapter looks at the peoples' information about flood and their perceptions of flood risk.

Chapter 7 - Vulnerability

Analyse physical vulnerability based on building structure, coping mechanism and impact minimizing strategies.

Chapter 8 - Flood risk assessment scenarios

This chapter deals with risk assessment for 2, 10 and 20years return period floods integrating flood modelling, vulnerability and risk perceptions.

Chapter 9 - Conclusions and Recommendations

This chapter provides conclusions on the results of this study and recommendations.

2. Literature review

This chapter reviews related literatures used to support for this study. It discusses hydrodynamic modelling, risk assessment, flood risk perception and vulnerability.

2.1. Hydrodynamic modelling

Flood hazard assessment involves the development of flood inundation maps for specified return periods. Over the past decades, hydrodynamic modelling has become a frequently used tool for studies in hydraulic and environmental science. Most widely used mathematical models are one dimensional (1D) and two dimensional (2D) models, which are used for the simulation of the behaviour of hydrodynamic systems. Some 1D models are HEC-RAS, Mile 11 etc which model flow of water in a channel or along predefined flow paths. 2D flood models solve the non-steady state flow in shallow water environments. Examples of 2D models are LISFLOOD, FLS, Telemac-2D, Mike-21 and Sobek.

Sobek was built by WL|Delft hydraulics, an independent consulting and research institute located in the Netherlands founded in 1927. Sobek is a fully dynamic 2D hydraulic model specifically for floodplain flood modelling. The computation used for the 2D floodplain modelling is based on the finite difference method (Hesselink et al., 2003; WL|Delft hydraulics). The Sobek software package integrates 1D with 2D hydrodynamic prediction package known as Sobek 1D2D, which has the advantage of bringing the model behaviour closer to real physical behaviour. The 2D model in Sobek is designed to simulate overland flow on the initially dry land and through complex topography (Alkema and Middelkoop, 2005).

Previous work (Abdul, 2006; Alkema et al., 2007; Hesselink et al., 2003; Rugai, 2008) have indicated that Sobek gives outputs close to reality. The model output parameters are the flood depth and velocity at hourly time-steps and the corresponding maxima. In this study, Sobek software package is used to simulate the inundation process in Nam Chun floodplain.

Model sensitivity analysis is carried out. This helps in identifying which parameters have the most effect on the model prediction when altered by a certain magnitude. This would provide vital information for future studies in the area as to which of the parameters should be given importance and measured as accurately as possible in the field to improve the quality of the model output.

2.2. Risk Assessment

The term risk refers to the expected losses from a given hazard to a given element at risk, over a specified future time period. According to the way in which the element at risk is defined, the risk may be measured in terms of expected economic loss, or in terms of number of lives lost or the extent of physical damage to property (Coburn et al., 1994). Risk is the probability that negative consequences may arise when hazards interact with vulnerable areas, people, property and environment (Abarquez and Murshed, 2004). Risk assessment is the first step designed to find what problems are. It involves evaluating the significance of a risk, either quantitatively or qualitatively (Smith, 2001).

Defined as the expected losses (e.g., casualties, injuries, property damage, and disruption of economic activities) due to hazardous events in a given area during a specific reference period, risk can be estimated as the product of hazard, vulnerability and cost of the elements at risk (UNDRO, 1991). Crichton (1999) defines risk as the probability of a loss, and depends on the three elements, hazard, vulnerability and exposure. If any of these three elements increases or decreases then risk will increase or decrease respectively (Kelman, 2003). Risk is less if some area is hazardous but no vulnerability or if there are vulnerable people but no hazard event (Blaikie, 1994). Pelling defines risk “To be threatened by harm. To be at risk is to be under threat of harm ” (Pelling, 2003).

Risk assessment answers the fundamental question that fuels the natural hazard mitigation planning process: “what would happen if a natural hazard event occurred in your community or state?” risk assessment is the process of measuring the potential loss of life, personal injury, economic injury and property damage resulting from natural hazards by assessing the vulnerability of people, buildings and infrastructure to natural hazards. The risk assessment process focuses your attention on areas most in need by evaluating which populations and facilities are most vulnerable to natural hazards and to what extent injuries and damages may occur (FEMA, 2001).

According to Asian Disaster Preparedness center (ADPC, 2005) risk may be simply stated as the probability that negative consequences will occur. Risk consists of the interaction of three elements:
Hazard: probability of occurrence and severity of the event.
Exposure: characteristics of values at risk, i.e. inventory, that will be analysed under hazard conditions.
Vulnerability: expresses the potential loss of life, damage or estimated costs caused by the impact of potential hazard events on the exposure inventory.

Disaster events reveal community risks by demonstrating the vulnerability of existing social, environmental and development practices. Risk is created through (ADPC, 2005):

- Changes in the hazard environment (global climate change, sea level rise etc)
- Increase in vulnerability (physical, social, economic, environment).
- Increase in exposure (due to urbanisation, land scarcity, economic pressure etc).
- Decline in capacity to cope (resource constraints for training and capacity building, different political priorities affecting disaster reduction, etc).

A risk assessment determines the likelihood that adverse consequences (risks) will occur as a result of potential hazards, such as floods or earthquakes and the elements that are exposed to those hazards. The risk assessment process facilitates risk reduction decisions by identifying, structuring and presenting the best available risk information for consideration. The risk assessment guides, but does not dictate decisions about risk. The purpose of risk assessment is to define the nature of the risk problem. The risk assessment provides a systematic process to answer questions about the frequency and severity of potential hazards and national and or community vulnerabilities. Asking questions helps establish the scope of the risk assessment. People perceive risk differently, depending on their experiences, exposure and understanding. They often set an arbitrary level of risk that they consider acceptable. This arbitrary level may be based on past experience, convenience, culture or resource availability (ADPC, 2005).

2.3. Flood risk perception

Some risk analysts regard perceptions as invalid because they arise from subjective influences. To the lay person, perceptions are the only relevant view because they incorporate the expert's analysis together with individual judgement based on experience, social context etc. The fact that this view is less 'scientific' does not render it invalid. The benefits of indigenous knowledge within disaster risk reduction are gradually being acknowledged and identified (Mercer et al., 2007).

The public's perception of risk and objective risk assessment are different but complementary and should be harmonized. Developing a better understanding of how local people understand flood risk and account for their flood 'awareness' might make a critical contribution to awareness campaigns. To incorporate this perspective into the field of flood risk research would mean exploring how those identified as living with such risk construct, understand and respond to it (Burningham et al., 2008; Coburn et al., 1994).

Risk perception may be studied in two ways. The *revealed preferences* approach observes how people behave and take this as a reflection of public perception by assuming that through trial and error, society has arrived at an acceptable balance between the risks and benefits associated with any activity. The *expressed preferences* method uses questionnaire surveys to ask a sample of people to express verbally what their preferences are. This method permits the gathering of more specific information but respondents may not always act in the way they suppose when actually faced with hazardous situation. In either method, there are difficulties in sampling opinions in a way that gives a reliable view of the public (Smith, 2001). Previous work (Abarquez and Murshed, 2004; Birkmann, 2007; Marschiavelli, 2008; Peters Guarin, 2003) made use of the expressed preferences approach which gave better results and it is the most commonly used method. Hence, in this study the expressed preferences method is used.

Hazard perceptions are influenced by many interrelated factors including past experiences, present attitudes, personality and values together with future expectations. The dominant influence comes from past experience in that those with direct personal knowledge of previous hazard events have more accurate views regarding the probability of future occurrences (Smith, 2001). Other reasons why lay people perceive hazards differently from technical experts include geographical location and aspects of personality. For example, early work on floods revealed that rural dwellers, such as farmers often reveal hazard perceptions that are closer to objectively derived estimates than urban dwellers. These perceptions may be influences by social or cultural factor. In order to reduce the stress associated with uncertainties hazard perceivers tend to adopt certain recognisable models of risk perception with which they are more comfortable. These can be grouped into three basic types below (Smith, 2001):

Determinate perception

Many lay people find it difficult to accept the random element of hazardous events and therefore seek to view their occurrence in a more ordered fashion. A determinate perspective recognises that hazards exist but seeks to place extreme events in some pattern, perhaps associated with regular intervals or even coming in a repeating cycle.

Dissonant perception

The most negative form of perception is dissonance or threat denial. Like determinate perception, it can take several forms. For example, past events can be viewed as freaks and therefore unlikely to be repeated; or the existence of past events can even be dismissed as not happening. Dissonant perception is often associated with people who have much material wealth and are at risk from a major disaster, such as living adjacent to the San Andreas Fault in California.

Probabilistic perception

This type of perception is the most sophisticated in that it accepts that disasters will occur and also perceives that many events are random. It also deal best with the views of those charged with making resource allocation decisions about risks. But, in some cases, the acceptance of risk is often combined with the need to transfer the responsibility for dealing with the hazard to a higher authority, which may range from the government to God. Indeed the probabilistic view has sometimes led to the fatalistic 'Act of God' syndrome whereby individuals feel no personal responsibility for hazard response and wish to avoid expenditure on risk reduction.

2.4. Vulnerability

The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. It expresses the potential loss of life, damage or estimated costs caused by the impact of potential hazard events on the exposure inventory. Disaster events reveal community risks by demonstrating the vulnerability of existing social, environmental and development practices (ADPC, 2005).

The term vulnerability has different meaning for different people. Vulnerability is divided into the following:

- Physical vulnerability (building age, construction, material, infrastructure, lifeline facilities).
- Social vulnerability (risk perception and the way of life with culture, gender, religion, ethnic, social interaction, age, attitude of population, poverty).
- Economic vulnerability (income, investments, potential loss of stock).
- Environmental vulnerability (water, air, land, flora, fauna).

Vulnerability is 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 (Blaikie, 1994). Vulnerability is generally defined as any condition of susceptibility to external shocks that could threaten people's lives and livelihoods, natural resources, properties and infrastructure, economic productivity, and a region's prosperity. In this context, a hazard is the probability that a natural or human induced phenomena will occur (Uribe et al., 1999). A disaster is the manifestation of vulnerability and the hazard with an impact that surpasses the coping mechanisms of the affected population. The concept of vulnerability (Birkmann, 2005) shown below (figure 2.1).

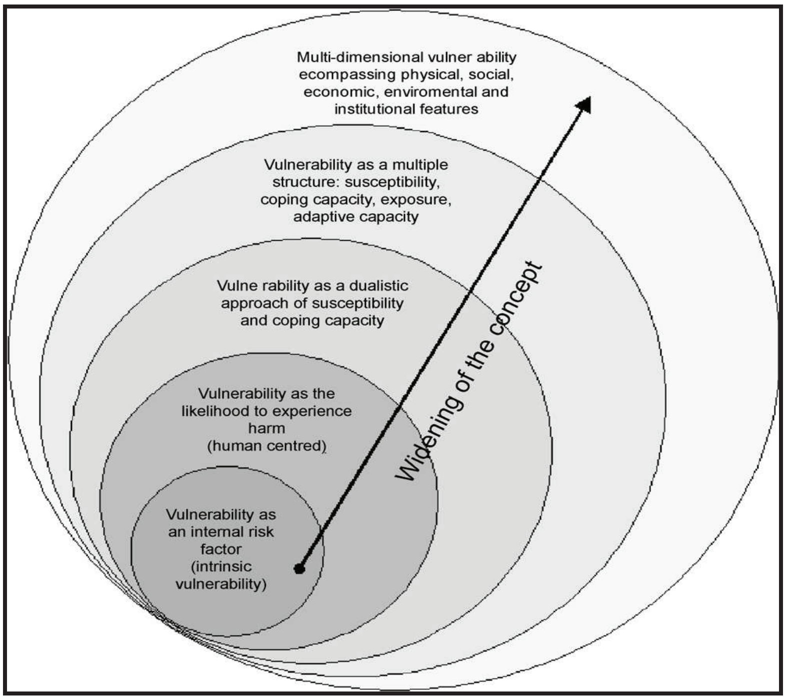


Figure 2.1: key spheres of the concept of vulnerability

Quantifying vulnerability, it is defined as the degree of loss to a given element at risk (or set of elements) resulting from a given hazard at a given severity level. The vulnerability of an element is usually expressed as a percentage loss (or as a value between 0 to 1) for a given hazard severity level. The measure of loss used depends on the element at risk, and accordingly may be measured as a ratio of the numbers of killed or injured to the total population, as a repair cost or as the degree of physical damage defined on an appropriate scale. In a large number of elements, like building stock, it may be defined in terms of the proportion of buildings experiencing some particular level of damage (Coburn et al., 1994).

Social and environmental vulnerability to natural hazards can be explained by several factors. Recent trends in Central America show that causes for an increase in vulnerability to natural hazards are population growth and density, rapid urbanization and unplanned human settlements, poor engineering of constructions, lack of adequate infrastructure, inequities in social structure, poverty, and inadequate environmental practices. Approaches to determining social vulnerability rely on the complementary integration of quantitative and qualitative methodologies. Qualitative approaches have explored the capacity of communities to manage risk information to cope with natural events. Quantitative methods to assess social vulnerability explore the integration of subjective information and analytical processes to develop measures of vulnerability. Such quantitative methods also may be useful when exploring decision making processes concerning socio-economic and community factors (Uribe et al., 1999).

Broadly, economic loss tends to be classified as tangible and intangible and sub-categorised into direct and indirect loss. In terms of estimating loss for natural hazards, tangible direct loss is defined as loss resulting from the impact of the event such as physical damage to buildings and their contents, vehicles and infrastructure. Tangible indirect loss relates to the disruption to business, transport, and utility networks, clean up costs, emergency response and relief incurred as a consequence of the event. The extent of the indirect cost is dependent on the availability of alternative sources of supply, markets for products and the duration of any disruption to production. Intangible indirect losses from natural disasters include death and injury and loss of memorabilia. Intangible direct losses incorporate health effects and household disruption to activities such as schooling and social life. There are no market values for intangible losses, but non market valuation techniques can be applied to provide proxy values. Ideally, an economic assessment of potential or actual losses from a disaster will incorporate all these loss categories. However, in the first instance, tangible loss is likely to be sufficient to provide conservative estimates of economic loss. Intangible loss is more complex to estimate because of the need for proxy values. Direct tangible losses are the simplest to obtain because they follow more directly from the physical impact and are the most readily developed and applied on a regional and national scale (Australia, 2002).

A crucial element in reducing vulnerability to natural hazards is the analysis of human settlements and infrastructure located in high risk areas. The exposure of human populations to natural hazards depends on various factors: (a) location of settlements and infrastructure in areas prone to natural hazards; (b) inadequate design of infrastructure, both private and public; and (c) unstable socio-economic conditions that may increase a population’s vulnerability to disasters (Uribe et al., 1999).

2.5. Integrating risk perceptions with hydrodyanamic modelling

To evaluate the threats posed by floods, as well as vulnerability and risk of local people requires learning from the people’s own knowledge and perceptions (Peters Guarin, 2008). Besides, they are the ones that have to deal with inundations on a regular basis therefore have their own ways of perceiving the threats from flooding. While enduring the impact of flooding they have become aware of their own susceptibility and developed their own coping strategies (Peters Guarin, 2008). These experiences taken into account with the modelling aspects brings to the fore a comprehensive risk assessment that represents reality. Thus the spatial modelling and the people’s perceptions and experiences are incorporated as inputs for flood risk assessment.

3. Study Area

3.1. Location

The study area, Nam Chun watershed consists of an upper catchment and downstream floodplain, which is located mainly in the district of Lom Sak and in part of Khoa Khor district in Petchabun province, the northern part of Thailand (Figure 3.1). It lies between the latitudes $16^{0}40'$ to $16^{0}50'$ North and longitudes $101^{0}02'$ to $101^{0}15'$ East. The watershed covers a total area of about 92 km^2 and it is part of the larger river basin of the Pa Sak River, which flows from the northern part of the country to the south. Farmers living in small villages populate the area. Elevation varies from 1509 to 240 m asl and 136 to 190 m asl in the floodplain. The floodplain has a slope gradient of 0-2% (Prachansri, 2007). This study focuses on the downstream area with farmland dominating the area.

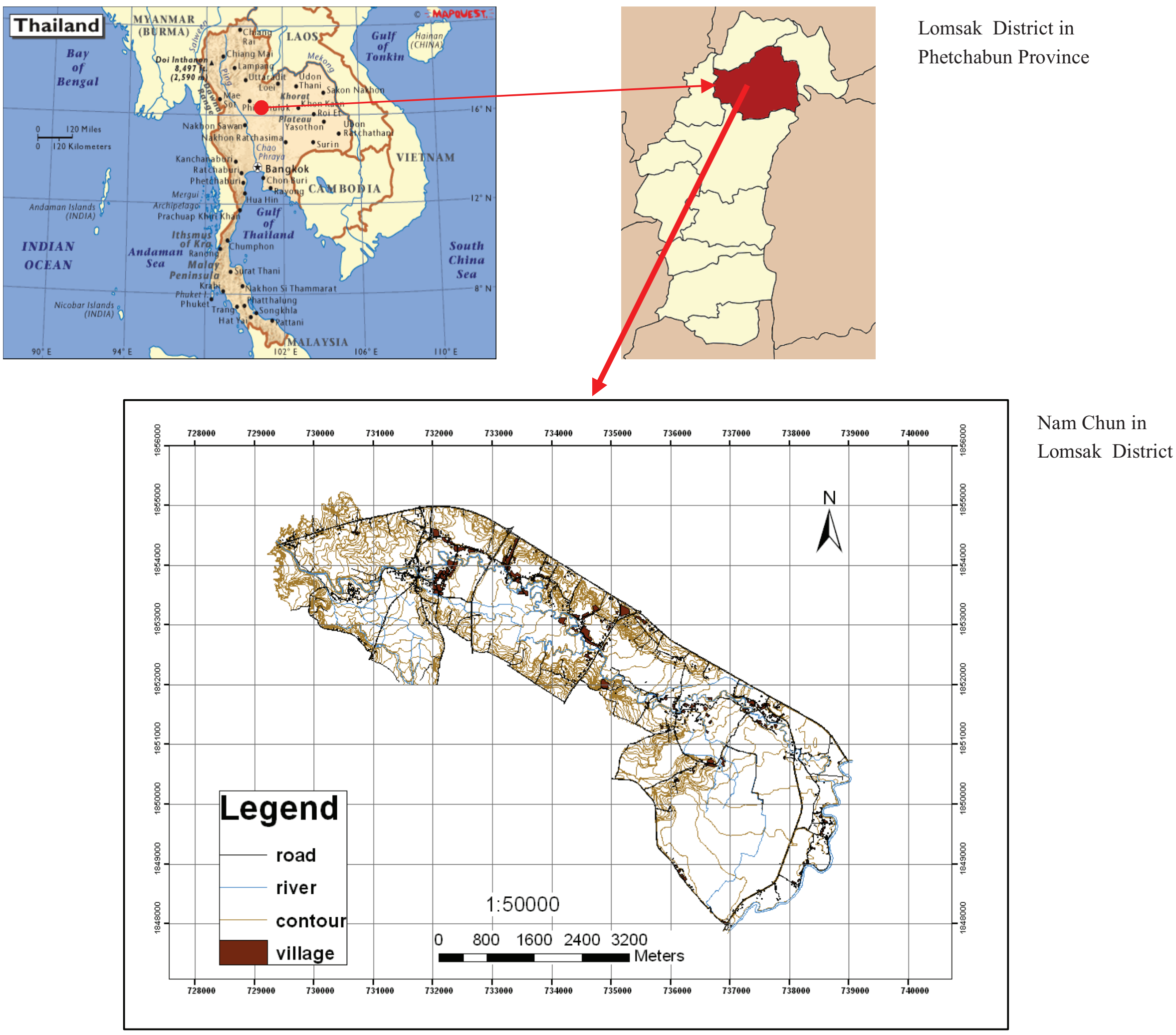


Figure 3.1: Study area in Phetchabun Province of Thailand

3.2. Climate

The climate is influenced by the northeast and southwest monsoons, with dry, hot and rainy seasons. The climate in this area is influenced by the northeast and southwest monsoon (Suwanwerakamtorn et al., 1992). The rainy season starts in May and lasts until October (Patanakanog et al., 2004; Prachansri, 2007). The average annual rainfall of 1078.8 mm is estimated from precipitation data for the period 1972-2007 from Lom Sak Meteorological Station. Figure 3.2 shows the mean monthly rainfall covering 35 years from 1972-2007.

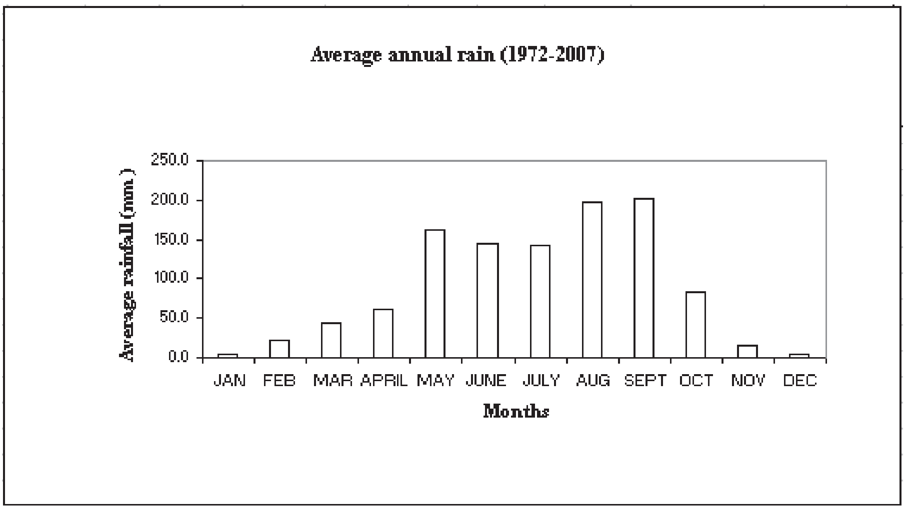


Figure 3.2: Average annual rainfall for the study area.

3.3. Geology

The upstream consists of the sedimentary rocks of the Korat group. The next formation is Nam Phong, which is reddish brown cross bedded sandstone and conglomerate. Both formations belong to the Upper Triassic period. Lithologically, sandstone, siltstone and (andesitic) tuffs are distinguished, of which the latter is very complex in texture, structure and bedding. The lower plain consists of alluvial deposits of sand, silt and clay (Patanakanog et al., 2004; Prachansri, 2007).

3.4. Land use

The dominant land use types include agricultural land, shrub and villages. Agricultural land includes rain fed annual crops, rice fields, orchards etc. The farmers grow mainly rice in the rainy season followed by various crop types such as maize and vegetables in the dry season which are locally irrigated.

Coconut palm, mango, banana, and tamarind are cultivated on the levees, which are also areas of settlement (Prachansri, 2007). Figure 3.3 gives a general overview of the study area in some pictures.

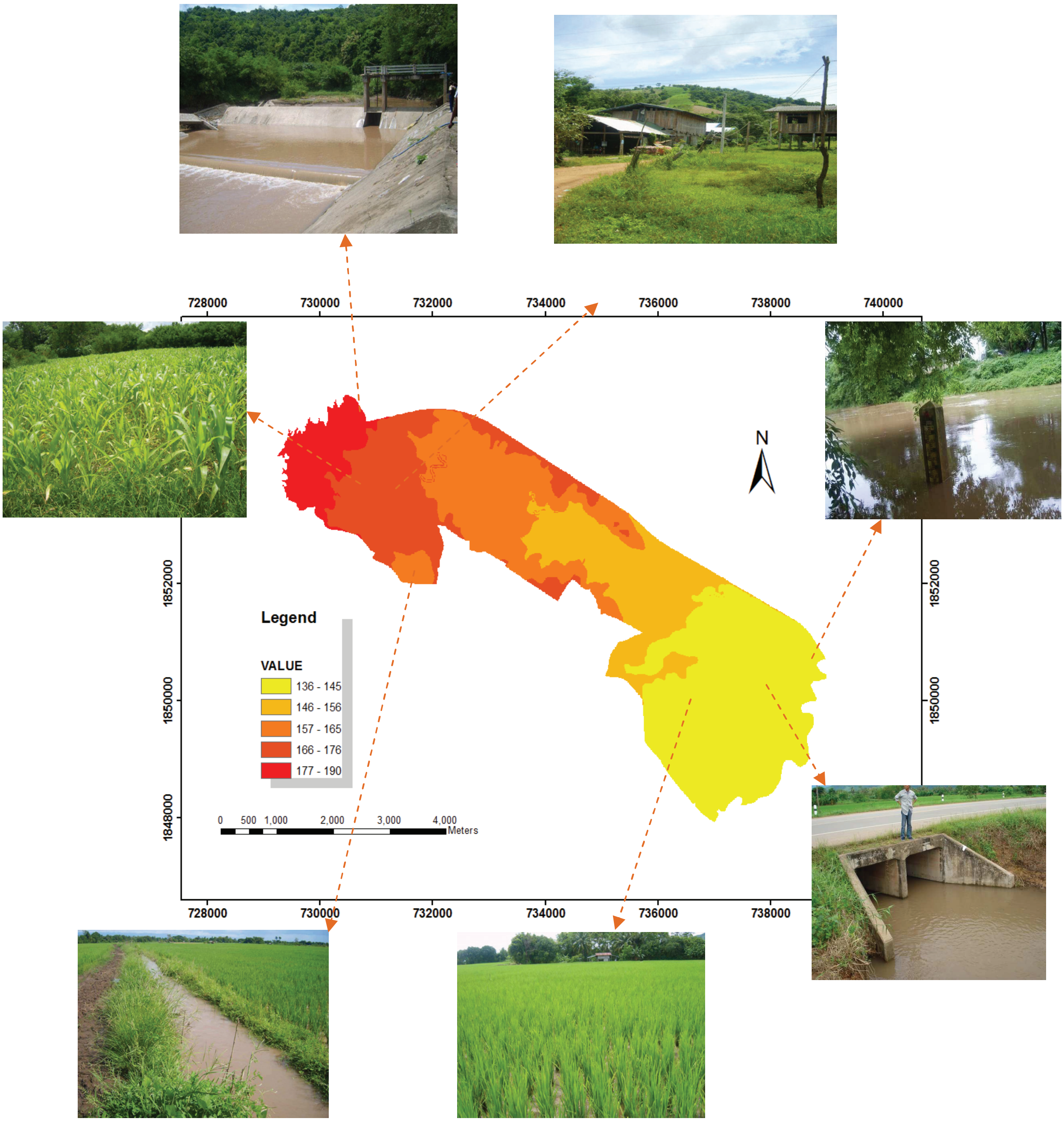


Figure 3.3: General overview of the study area with elevation.

4. Research Methodology

In order to meet the objectives of this study, the overall work would be divided into three stages; the Pre-fieldwork, fieldwork and post fieldwork as shown in figure 4.1.

4.1. Pre-field work

The Pre-fieldwork phase of the study involves selecting a suitable research approach, gathering and organizing available data from previous studies, identifying methods and preparation of materials for field data collection and identifying data gaps. Data need analysis begins with gathering the available data from previous studies in the Nam Chun Watershed. The list of the new data required is prepared based on this and also the research objectives and research questions.

1. Available data (from Prachansri)
   a. Elevation datasets with contour interval 1 meters and height point at downstream
   b. A digital Land use map for year 2002
   c. Climatological and daily rainfall data
   d. Building footprints
   e. DTM 25m

2. Required data
   a. Elements at risk inventory
   b. Water depth for flood caused by the Typhoon Usagi (2001)
   c. Damage to buildings caused by 2001 flood
   d. Cross section of river, bridges and culverts
   e. Social vulnerability of the people and risk perception
   f. Population census data and growth rate

A questionnaire was prepared for rural setup to collect data during interview with the people (appendix 1). With this data on flood height, duration and damage to buildings could be collected and the social vulnerability of the people. From the available data, base map was prepared for fieldwork.

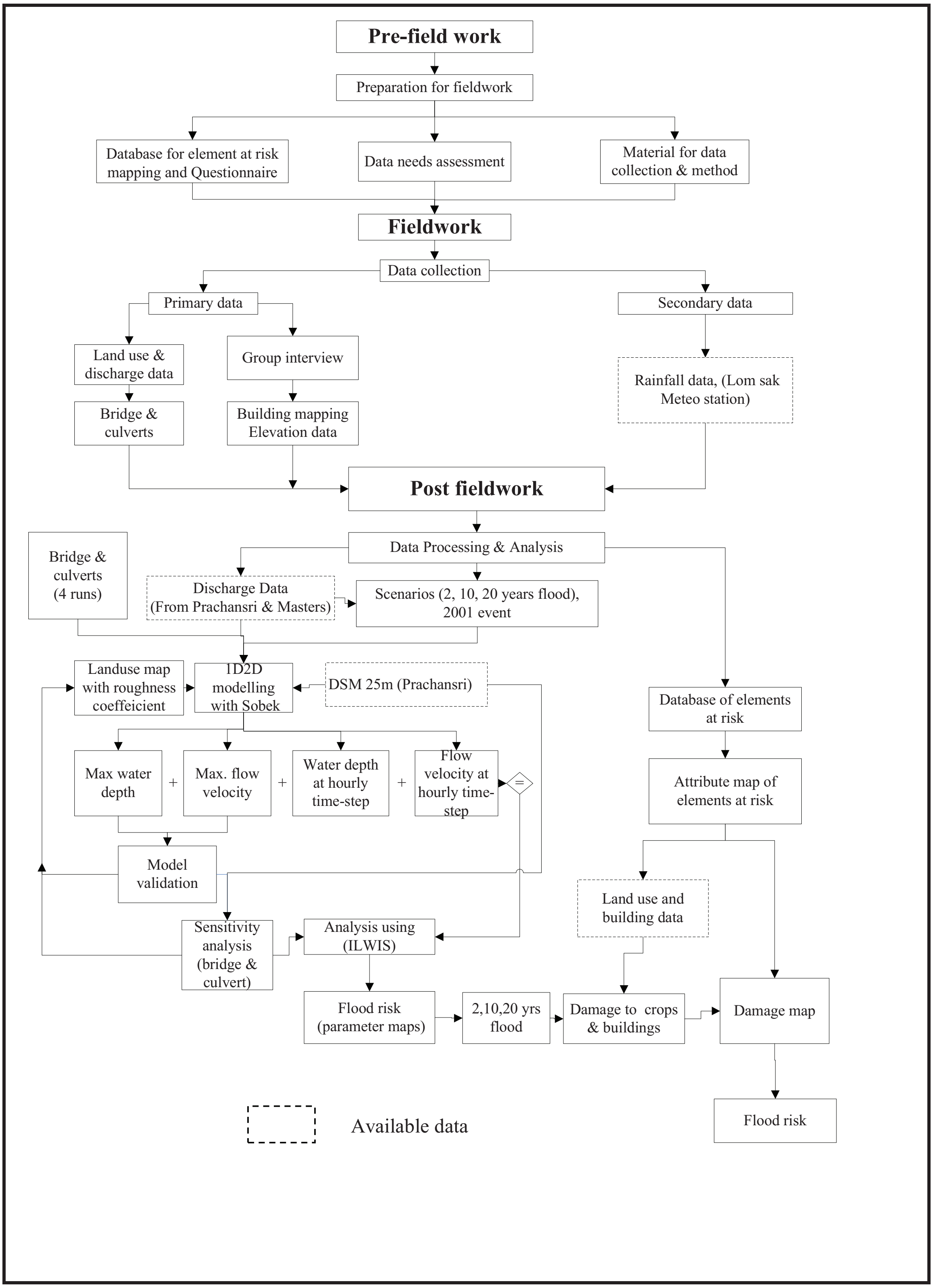


Figure 4.1: Flowchart of general work methodology

4.2. Field work

Fieldwork started from the 8th until 24th of September 2008. The aim of this stage was to collect primary and secondary data relevant to this study. Unfortunately, none of the secondary data was obtained. However, the author visited the village (Namkoh) which is more in the upstream area where the most damage occurred and had interview with the farmers' representative, some of the people and the early warning center at the headwaters in the mountains.

Primary data collection: It was envisaged to collect data on elements at risk such as buildings and population, socio-economic aspect of households, damage estimation due to flood 2001 event, flood depth and duration and coping mechanisms, all based on interviews. However, due to lack of an interpreter, only general meetings were organised and building data only by visual inspection of existing buildings. Further work includes mapping all bridges and culverts, land use, measure daily water level of the Pasak River, River cross section at the catchment outlet, road elevation and embankment height.

Interview scheme: Based on visual inspection of areas clustered with buildings, the study area was grouped into five zones represented by five villages for general interview (figure 4.2). Present are the local people, the village head, assistant village head and the soil doctor for Nam Chun area. Data on flood hazard and risk perception was collected using the questionnaire and Garmin 12 Global Positioning System.

Building inventory

The buildings were sampled randomly using Garmin 12 GPS, base map and by visual inspection (figure 4.3), data was collected on the maintenance state, wall, floor and roof material, number of floors as stated under physical inventory of buildings (see appendix 1). Total of 51 buildings were mapped representing 5.4 %.

Land use mapping

The available land use map was verified and updated (figure 4.4). This was done by GPS navigation with Garmin 12 GPS and land use map. From the survey, the predominant land use is paddy fields.

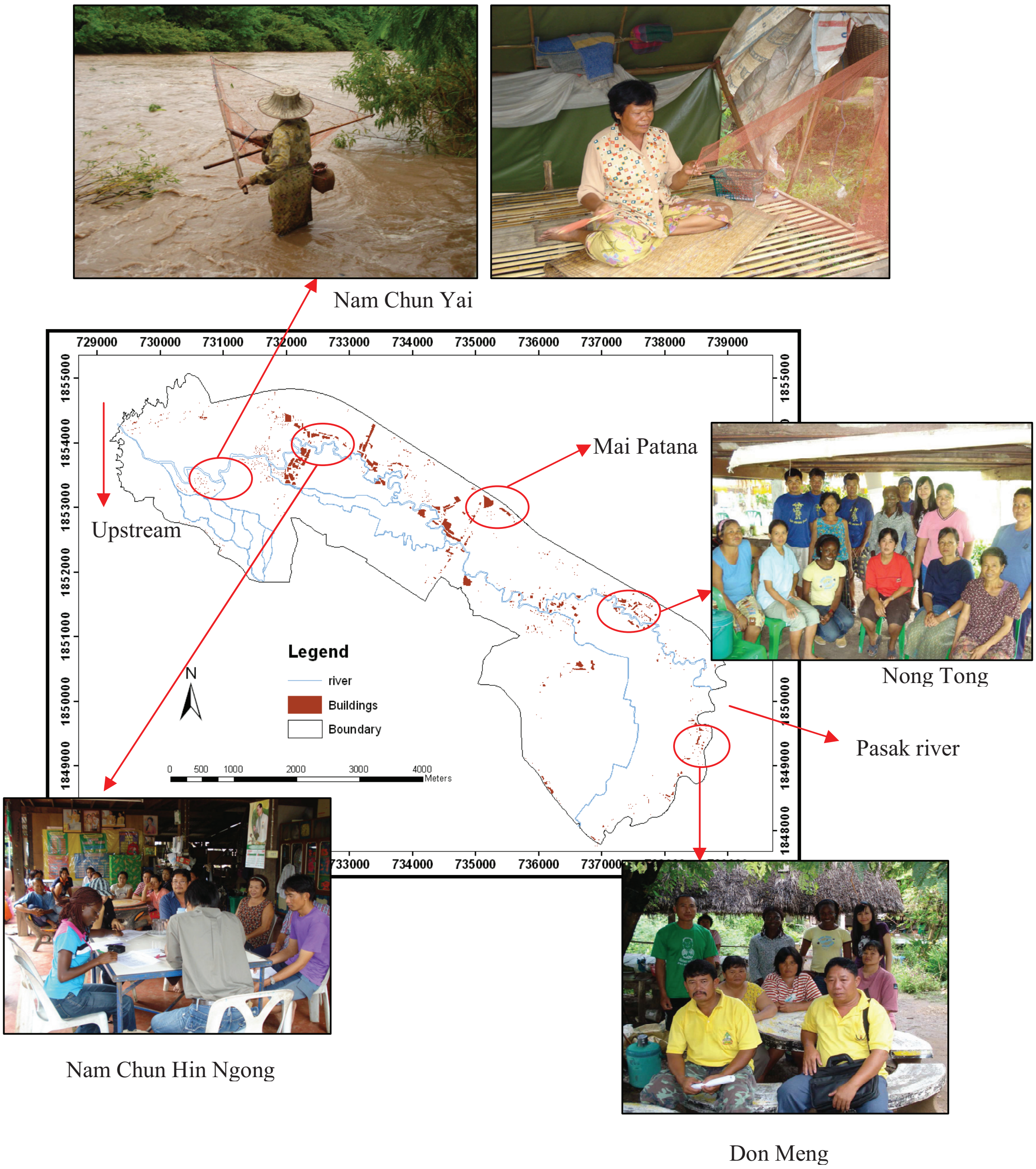


Figure 4.2: Shows the interview scheme in Nam Chun.

Figure 4.3: Mapping buildings.
(Source: field work, 2008)

Figure 4.4: Mapping land use.
(Source: field work, 2008)

Figure 4.5: Structures in the area.
(Source: field work, 2008)

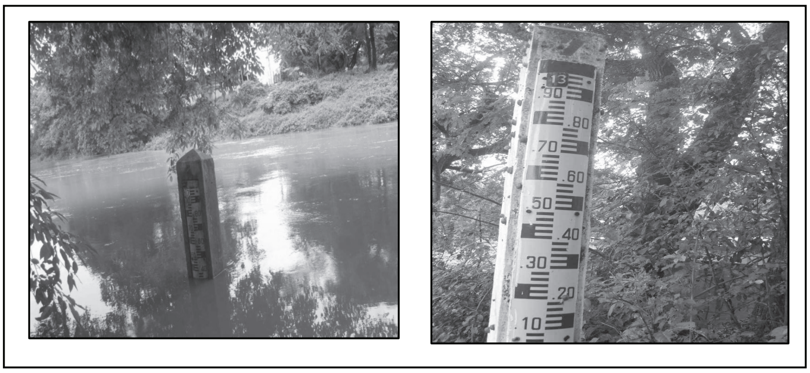


Figure 4.6: Pasak water level.
(Source: field work, 2008)

Bridges and Culverts mapping

These are the hydrologically relevant structure types found in the study area. Mapping was done using the base map, Garmin 12 GPS and measuring tape. The GPS location and elevation are recorded and marked on the base map. Using the tape, the bridge cross section is measured. A total of 14 bridges were mapped.

The same is done for the culverts and culvert shape is included which are necessary parameters for modelling structures in Sobek. Total of 15 culverts were mapped. Some bridge and culvert in the area as shown above (figures 4.5).

Water level of Pasak River

Pasak River is at the lowest part of the study area. The Nam chum river joins it at a point as such the Pasak water level influences the Nam Chun River. It represents the downstream boundary of the study area when modelling with Sobek. Measurement pillars graduated in meters are already erected along the Pasak River where the water level at any time, can be read. During fieldwork, the water level was read almost every day around the same time by recording the figure on the water level mark on the pillars. The highest graduated pillar is marked 7 m (figure 4.6).

River cross section, road elevation and embankment height measurement

In order to calculate the discharge at the upstream boundary condition in the floodplain of the study area, the river cross section is measured. Measurements were taken using measuring tape, current meter and stop clock. This is done daily at the same time of day except on rainy days or when the water level is too low for the current meter. The road elevation was measured using GPS. The road embankment height was estimated with reference to the ground level.

4.3. Post -field work

This is the final phase of the research methodology, concerns data processing and data analysis. Data collected in hard copy and from the interviews were converted into digital format. The building inventory data was processed into spatial information using Arc Map and statistically using R commander statistical software. However detailed statistics could not be done due to limited data.

Further processing and analysis of modelling with Sobek, peoples' flood risk perception and vulnerability are discussed in the subsequent chapters.

5. Flood Modeling

This study uses Sobek-rural, a product of the main Sobek package of hydrodynamic water flow models. Sobek -Rural, developed by WL| Delft Hydraulics, is an integrated modelling package that simulates hydrodynamics of one- dimensional (1D) river/channel network and two-dimensional (2D) overland flow. This model is suited to simulate the dynamics behaviour of overland flow over an initially dry land as well as flooding and drying processes on every kind of geometry including flat land or hilly terrain (Dhondia and Stelling, 2002). This 1D2D Sobek system is design to simulate normal conditions of the river (no flooding) by modelling the hydrograph as 1D network. When larger areas are inundated then the system becomes two dimensional with rectangular grid cells that represents floodplain topography. For detailed description and equations see (Hesselink et al., 2003).
Sobek has modules such as Rainfall-runoff, channel flow, Sewer flow, Real time control, Water quality, Emission, Overland and Groundwater. The channel and overland flow module of Sobek Rural is used in this work. This module is designed to calculate two dimensional (2D) flooding scenarios. The program has the capability to import GIS data into the model and export results to GIS system format for analysis (Delft Hydraulics).

According to Stelling et al, (1998) Sobek has a wide range of applications including practical problems such as overland flow, dam breaches, hydraulic jumps, flooding and drying of tidal flats, tidal bores etc (Hesselink et al., 2003). Sobek computes on a rectangular grid enabling geometrical input data to be specified in a number of ways and land layout features such as bridges, culverts, dikes, railroads etc., to be included in the analysis (Alkema et al., 2007). It also support further studies such as flood damage assessment, risk analysis, landscape and infrastructure planning (Dhondia and Stelling, 2002).

5.1. Input Data

The implementation of 2D propagation models for flood hazard assessment is a complex process because of handling large amounts of spatial and non spatial data. In this study **ILWIS** (Integrated Land and Water Information System) a GIS / Remote sensing software is used in parallel with the flood model to pre-process the required input data for the model, and post-process the model results and transform them into flood parameter maps. The main input data used for 1D2D hydraulic modelling are:

a) Spatial data

- Digital surface model DSM;
- Surface roughness;
- River cross section;
- User-defined structures such as bridges and culverts.

b) Temporal data

- Initial water levels;
- Upstream and downstream boundary conditions (water levels and fluxes).

The methodology followed is shown in figure 5.1 below with detailed description in subsequent sections.

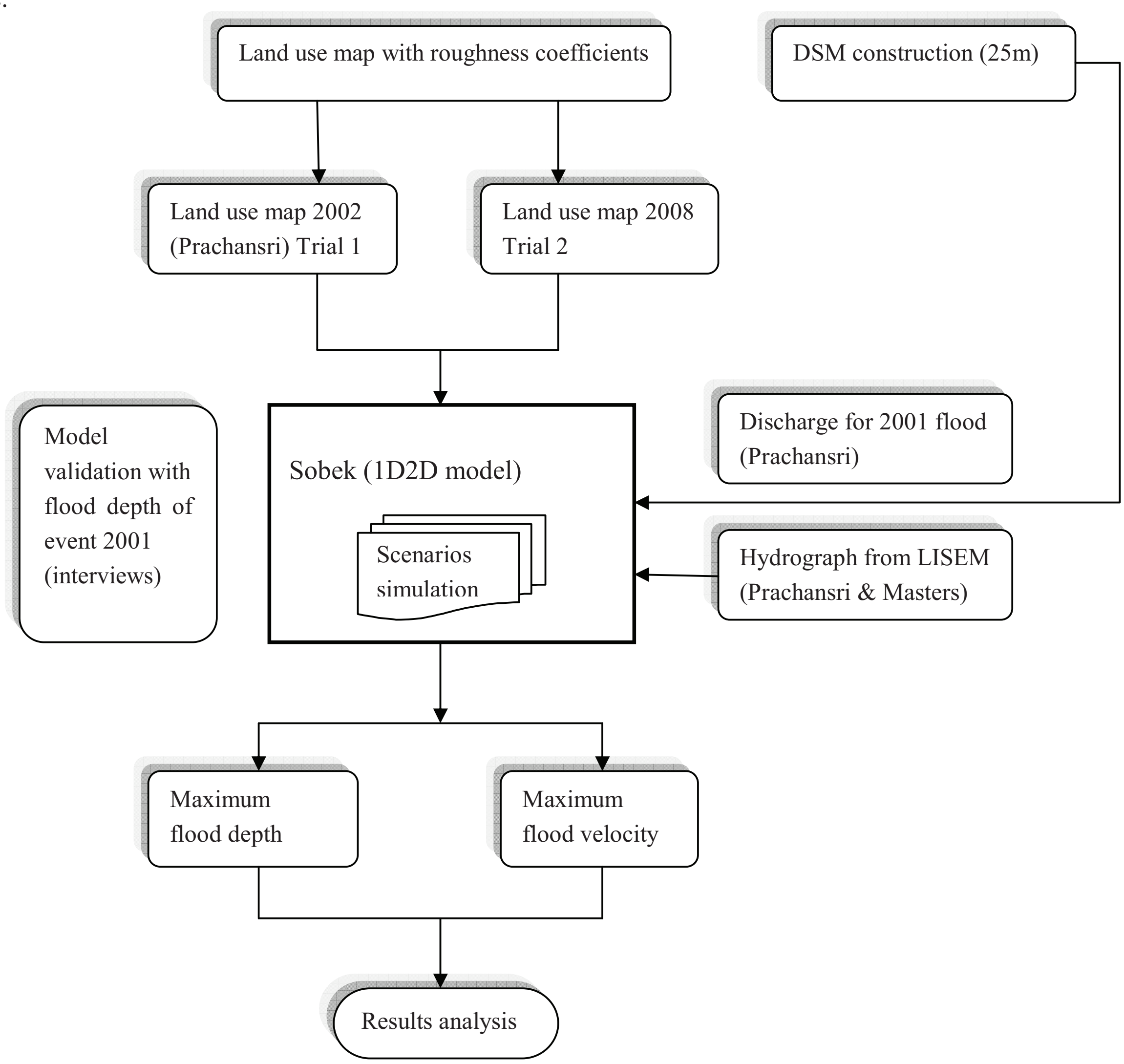


Figure 5.1: General methodology for flood modeling.

a) Spatial data

5.1.1. DSM generation

The most important spatial data are the digital surface model (DSM) and surface roughness. According to Alkema (Alkema et al., 2007) a DSM is an elevation map that contains all the surface elements that can affect water flow.

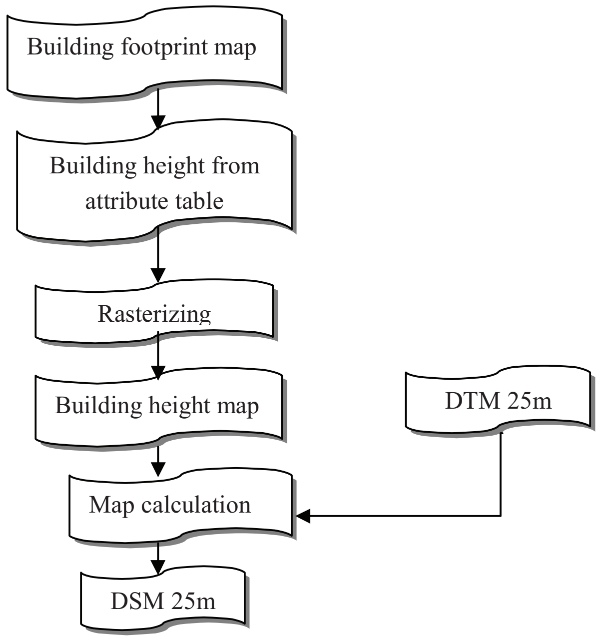


Figure 5.2: DSM generation flow chart.

The elements include embanked infractstructure, dikes, roads, buildings, riverbed morphology etc. From the available data set such as building footprint map and DTM the DSM was generated which include main roads, river and villages for this study through the procedure shown in figure 5.3. The DSM wan then converted to standard ArcInfo asci (.asc) format, which is the format required by Sobek.

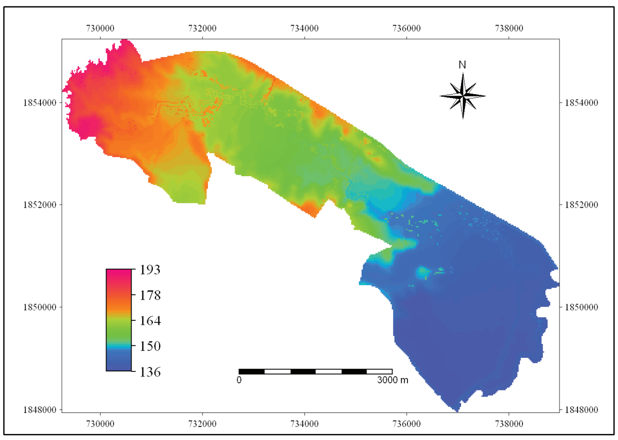


Figure 5.3: DSM 25m used in modeling

5.1.2. Surface roughness

The surface roughness provides resistance to the flow of water. The surface roughness map has to be generated at the same resolution as the DSM to ensure each cell has both the elevation information and the roughness values (Alkema et al., 2007). The surface roughness map is derived from land use/ cover map. In this study, the land use map from the available data (Prachansri, 2007) was used which was updated during field work and based on the field observations and the guidance of values in literature the roughness map was prepared containing Manning's coefficients (Arcement and Schneider, 1990; Chow, 1959) as shown in table 5.1. The Manning's coefficients were linked to the land cover map as an attribute data to generate a spatial representation of roughness coefficient and then converted to Arc Info asci (.asc) format as required by Sobek. The new land cover map consists of 12 classes among which 55 % of the total area is rice fields (figure 5.4).

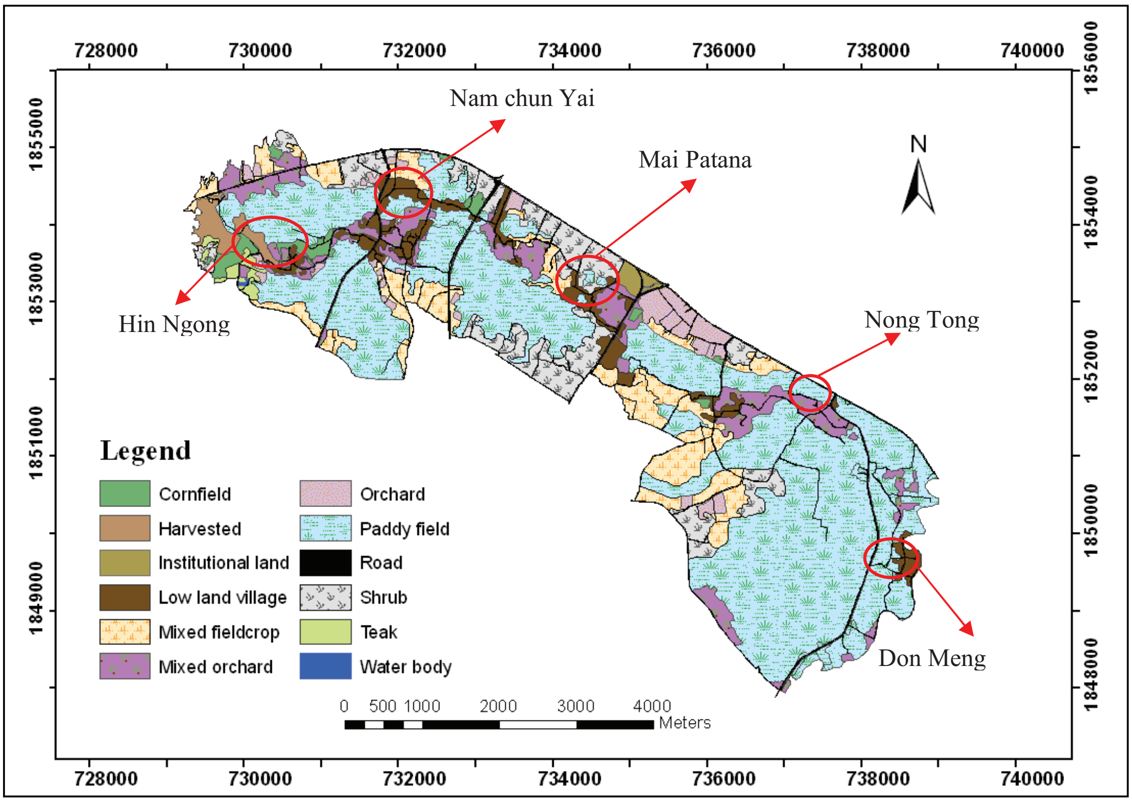


Figure 5.4: Land cover types in Nam Chun floodplain.

Table 5.1: Manning's roughness coefficient used for floodplain surface roughness in the model.

Land cover type	Manning's coefficient
Corn field	0.045
Harvested corn field	0.004 *
Institutional land	0.001
Lowland village	0.150
Mixed field crop	0.035
Mixed orchard	0.150
Orchard	0.100
Paddy field	0.100
Road	0.001
Shrub	0.040
Teak	0.0015 *
Water body	0.033

(Source: Prachansri, 2007; * values from Arcement and Scheider, 1990)

5.1.3. River cross sections

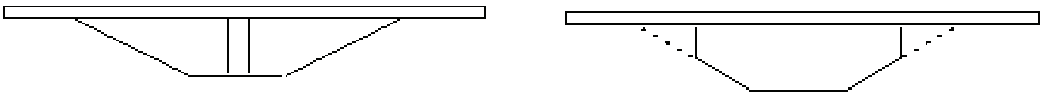
The cross section of the river is needed for parameterizing the 1D model. Sobek requires a lot of cross section data and requires lots of field measurements. For this study, a total of 42 cross sections are needed as each reach needs at least two cross sections. This number of cross sections could not be measured during field survey. It was therefore derived from the DEM in addition to field survey work.

5.1.4. Structures

Structures can be viewed as local discontinuities (jump in water level upstream and downstream of the structure) in a channel. At these discontinuities the relation between discharge and the water level is not defined by the "de Saint Venant Equations" but by the structure formulas. Structure formulas describe the relation between the upstream and downstream of the water level and discharge through the structure. Unfortunately, the relation between these quantities depends on the flow conditions. The flow conditions in turn depend on the upstream and downstream water level and the discharge. (WL|Delft hydraulics). In the Sobek flow module the structure types that can be modelled are: bridge, culvert, siphon, orifice, pump, weir, compound structure, river weir, and river pump.

Bridge

The following types of bridges can be modelled: Pillar Bridge, Abutment Bridge, Fixed Bed Bridge and soil Bed Bridge. In this study, only pillar and abutment bridges are considered. A pillar bridge has one or more pillars that affect the discharge through the bridge. The plate of the bridge is always so high that it does not affect the flow through the bridge. For an Abutment bridge the plate of the bridge can affect the flow through the bridge. The cross section is closed. Figure 5.5 below shows the bridge types.

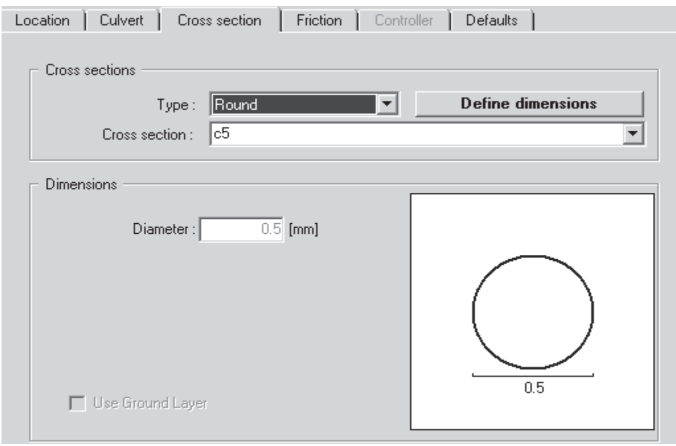


a) Pillar bridge b) Abutment bridge

Figure 5.5: Pillar and Abutment bridge types.

Culvert

A culvert is an underground structure that normally is connecting two open channels. The flow through this pipe is affected by its begin and end bed level, the size and shape of the closed cross section, the friction and the entrance and exit losses (WL|Delft hydraulics). In Sobek, a culvert can be modelled by a Flow - Culvert node. For this node, a cross section, bed levels on sides, length and some other parameters are defined. Below is the cross section definition screen where the shape of the culvert is specified (Figure 5.6).



The required measurements were taken during field survey. Rectangular and circular shape culverts were identified during field survey with majority being rectangular shape culvert.

Figure 5.6: Culvert cross section definition screen.

b) Temporal data

5.1.5. Initial water levels

The initial condition describes the state of the system, referred to as the water level and fluxes at the start of the computation. A restart file is created by running the model starting with dry conditions until the hydraulically stable starting point of simulation is reached. The restart file was used to define the initial condition of the model in this study.

5.1.6. Upstream and downstream boundary conditions

Boundary conditions define the inflows and outflows elements of the model domain. They are expressed in term of mass and momentum exchanges (Alemseged and Rientjes, 2005). This exchange of material exists between the model area (study area) and the universe.

In this study, there was one upstream boundary condition and three downstream boundary conditions. Discharge data was used for the upstream boundary condition, water levels of the Pasak River was used and constant water levels were used for the remaining two downstream boundary conditions. The hydrographs used at the upstream boundary were generated from LISEM by Prachansri (2007) and Masters (in press) based on 2, 10 and 20 years return period rainfall events (see appendix 2). Also used is discharge data of 2001 Typhoon Usagi from Prachansri.

5.2. Model Schematization

The schematization involves adding model components in a network editing interface called NETTER available in Sobek. The model components added consist of river cross section, flow calculation points, 1D boundary upstream and downstream nodes, 1D2D internal boundary node, connection nodes, measurement stations and hydraulic structures such as bridges and culverts. In NETTER, attribute values are assigned to the various nodes. Figure 5.7 shows the model schematization with the model components in Sobek.

The schematization start by importing the 2D network which is the terrain elevation (DSM) in ASCII file format. The river is defined by reaches connected together by connection nodes. The 1D water flows is characterized by the characteristics which are defined by the cross section, bed and surface levels and the roughness coefficient. The 1D flow was represented by a series of cross sections perpendicular to the river flow direction. The trapezium cross section type was used in this study. Bridges and culvert are added and their attributes defined (figure 5.8). Pillar and Abutment Bridge type is used and rectangular and spherical culverts used in this study. History stations were placed in the area to record water depth at specific pixels which are used to further assess the performance of the model.

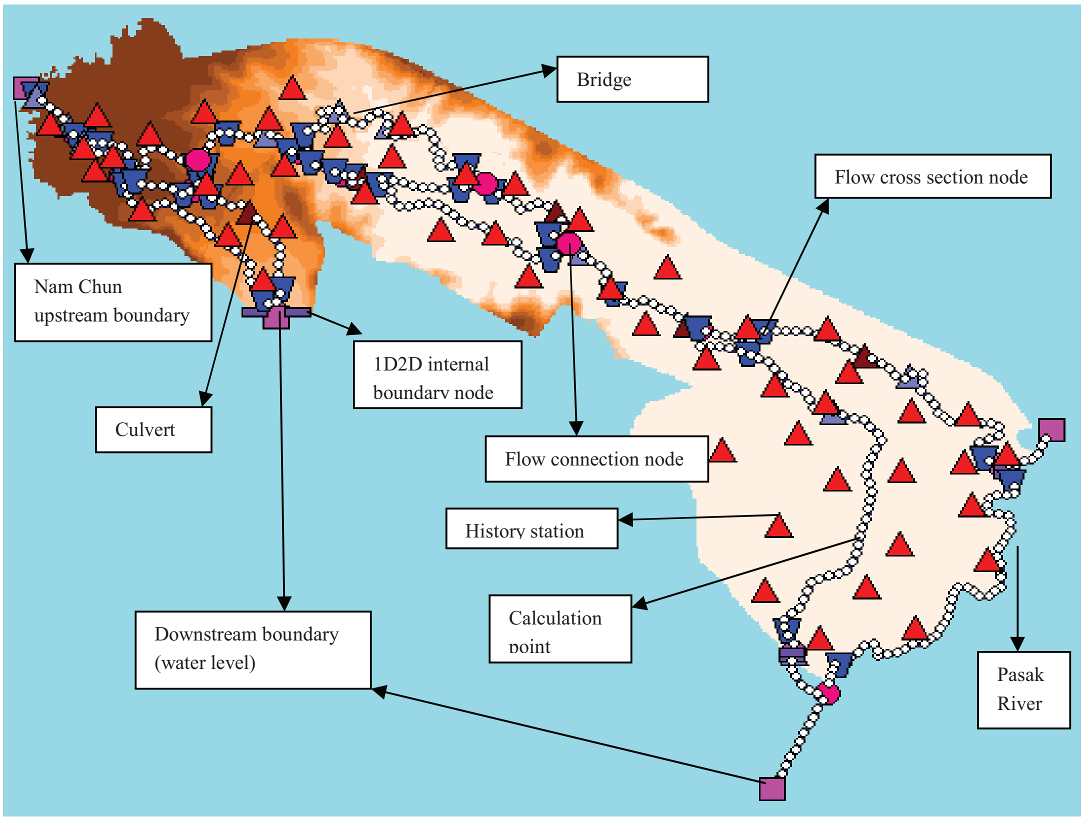


Figure 5.7: 1D2D model schematization in Sobek.

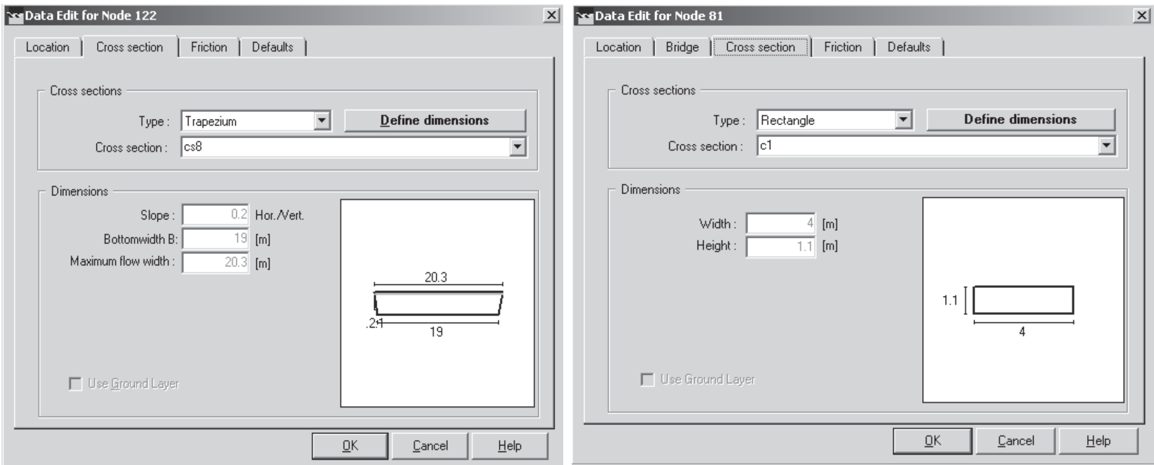


Figure 5.8: Abutment Bridge (LHS) and culvert (RHS) cross section input window.

5.3. Model output

Several output maps are generated by Sobek and stored in ASCI file format which is imported into GIS system. It also produces animation file that show the progression of the flood. The output consists of water depth series maps, maximum water depth map, time at maximum water depth, water flow velocity series maps, maximum flow velocity map and the time at maximum velocity map. These maps are imported using Arc/Info.ASC into ILWIS (see script in appendix 3). These maps are then used further in flood hazard and flood risk assessments in chapter 8. From the model output, the influence of structures and sensitivity analysis discussed in section 5.5.

5.4. Model Validation

In order to access the performance of a model, the model results are compared with real world information. This shows how well the model is able to predict real situations. The difference between observations and simulated model response are basically caused by errors in meteorological input data, errors in recorded observations, errors and simplifications inherent in the model structure and errors due to the use of non-optimal parameter values (Refsgaard and Storm, 1996).

To verify and validate inundation models, there are two ways to test the models. The first way is to test the numerical scheme of the models. This is typically done by comparisons with analytic solutions, theoretical analyses of consistency, stability and convergence, and by laboratory experiments where the model simulation results are compared with the results of an inundation experiment. The second type is by comparing the model results with real world flood events.

This type of validation tries to answer the question, ‘‘what accuracy can we expect from inundation models for practical purposes?’’ until now, only few attempts have been undertaken to evaluate the performance of inundation models in the real world. This is due to model complexity and absence of field measurements (Hesselink et al., 2003).

In this study, model validation is based on information on water depth of typhoon Usagi on 2001 obtained from interviews during fieldwork. During the interviews, only 5 flood depth points were collected due to lack of an interpreter. Thus, the model performance was based on flood depth, which was the only available information.

Due to limited data, it was impossible to carryout detail statistical analysis. However, functions such as bias and root mean square error (RMSE) were used to evaluate the model performance by comparing the model results with observed data. Bias is the mean difference between paired observed and simulated values. Bias values closer to zero indicate better overall model performance. RMSE is measures the discrepancy between modelled and observed values on an individual basis which indicates the overall predictive accuracy of a model. Due to the quadratic term, greater weight is given to the larger discrepancies. With this measure, smaller values indicate better model performance (Prachansri, 2007). The calculated value for bias is -1.48 m, which implies that the model results underestimate the true depth. The RMSE is 1.92 m that means quite a good measure of the overall accuracy of the model. Though the model predicted poorly at two some places (figure 5.9), it was perfect at one place, which may account for the RMSE value obtained and the information from the interview may be an overestimation. Figure 5.10 shows the simulation results for flood depth of 2001 flood event.

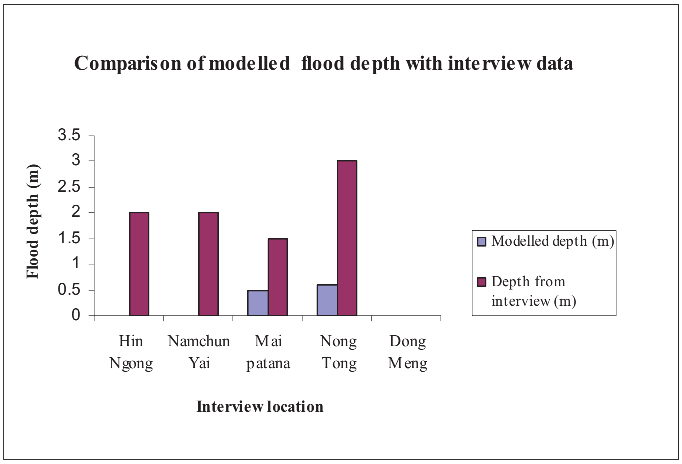


Figure 5.9: Shows modelled flood depth and depth from interviews.

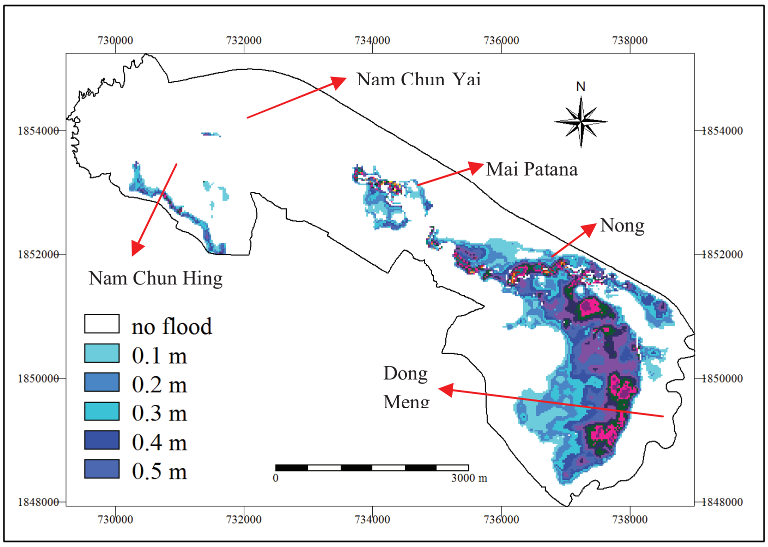


Figure 5.10: Shows simulation results of areas inundated by 2001 flood event.

5.4.1. Uncertainties

Of these types of uncertainties, only knowledge uncertainties may be reduced through research within a reasonable span of time. To deal with natural variability, the concept of probability is commonly adopted. Knowledge uncertainty, however, is dealt with in very different ways, ranging from neglecting the uncertainty to approaches in which all uncertainties are taken into account in a comprehensive manner. An overview of uncertainties in flood risk assessment is shown below (Most and Wehrung, 2005):

Table 5.2: Overview of uncertainties in determination of flood risk (Most and Wehrung, 2005).

Type	Source			
	Categories of uncertainty	Hydraulic loads	Strength of water defences	Consequences of flooding
Inherent uncertainties	Natural variation	Temporal variation of discharges, waves and water levels	Spatial variation of soil properties	Economic consequences of flooding
	Future developments/ policies	Climate change, Space for river policy		Economic and demographic development
Knowledge uncertainties	Lack of data (statistical uncertainty)	Probabilistic model of discharges, waves and water levels	Characteristics of dikes and subsoil, Idem structures	Casualties in relation to evacuation
	Lack of knowledge of processes (model uncertainty)	Mathematical models for water levels and waves	Mathematical models for failure mechanisms 'Aging' of dikes, structures	Mathematical models of flood dynamics, Behaviour of people during floods

Errors from flood model simulation

These errors may be introduced by the local terrain that cannot be represented in the DSM, an example the resolution. The ground water table of the area is not considered. Ditches and minor streams in the area were not taken into account. The cross section data was estimated from the DEM since Sobek requires lots of cross section data, that survey data was limited. The discharge data contain errors introduced by inaccurate rainfall measurements, as the rainfall amount is not representative.

Errors from field work

The flood depth information obtained from the people may be biased since it was not recorded but derived through approximations.

5.5. Flood Hazard assessment

Hazard assessment implies the determination of the magnitude or intensity of a hazard over time . The degree of hazard depends on the severity of the flood event. Flood events with high magnitude tend to occur less frequently as compared to those with low magnitudes (Rugai, 2008).

To assess flood hazard for Nam Chun area Sobek 1D2D hydrodynamic model was used to simulate flood scenarios for 2, 10 and 20 years return periods with present land use. This is to know how the water flow distribution and the flood characteristics are in the downstream area. The flood hazard zonation is shown in figure 5.10. The table 5.4 shows model results of flood hazard characteristics for 2, 20 and 20 years return period floods.

Table 5.3: Summary of flood characteristics for various return periods.

	Return period (years)		
Flood characteristics	2 years	10 years	20 years
Total Area flooded (km^2)	1493.93	6500.80	8327.90
Maximum depth (m)	1.4	2.3	2.5
Average depth (m)	0.8	1.2	1.3
Maximum velocity (m/s)	0.6	2.7	4.1
Average velocity (m/s)	0.3	1.2	1.7
Maximum impulse (m^2/s)	0.42	2.16	3.24
Average impulse (m^2/s)	0.14	0.68	0.98

From the results (Table 5.3), there is an increase in the area inundated by flood as the return period increase. Figure 5.8 below show the hazard map for the various return periods. The high hazard zone (20 years flood) covers 48.5 % of inundated area, medium hazard zone cover 37.9 % of inundated area and low hazard zone cover 13.6 % of inundated area. The average flood depth increase as 0.7 m, 1.2 m and 1.3 m for 2, 10 and 20 years return period respectively.

However, it can be seen that the maximum flood depth was up to 1.4 m, 2.3 m and 2.5 m for 2, 10 and 20 years return period respectively. The same trend is observed for the velocity and impulse. The spatial distribution of the flood characteristics are shown in figure 5.11 to 5.14.

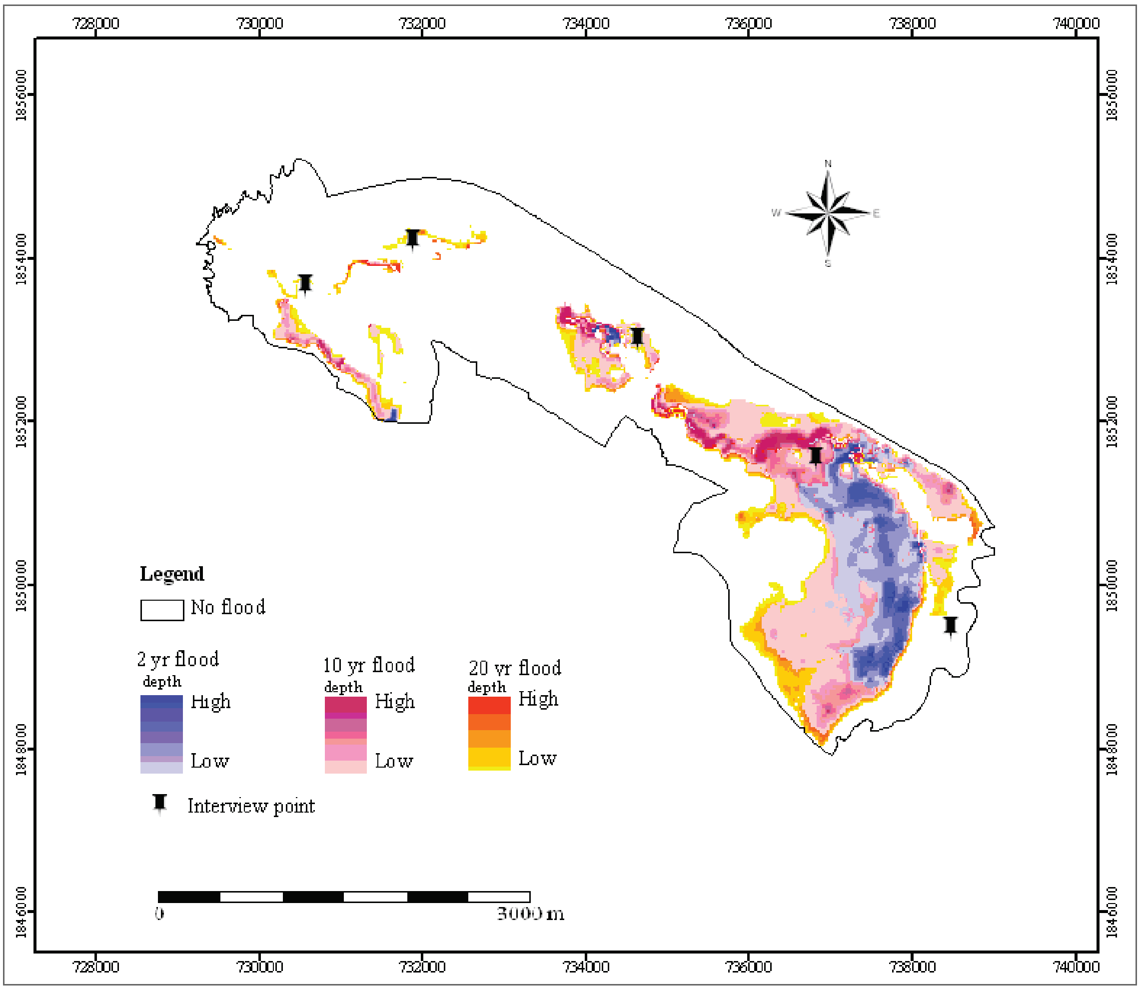


Figure 5.11: Hazard map showing inundation areas of 2, 10, 20 year recurrence.

From figure 5.12, majority of the area flooded lies in the lowest flood velocity range of 0.1-1.0 m/s for all scenarios whilst the maximum range was 2-3 m/s for 20 return period floods, which occurs in very small area. The trend is same for the impulse with the high impulse range occurring in the areas of high velocity (5.13). The flood depth range is however distributed with the larger area flooded in the range of 0.1-0.5 m (5.14).

From figure 5.15 it can be seen that the warning time varies with location with the maximum (9 hrs) occurring at the lower part in the area for all scenarios. Thus, people living closer to the upstream have lesser warning time to evacuate in the event of flooding.

2 years | 10 years | 20 years

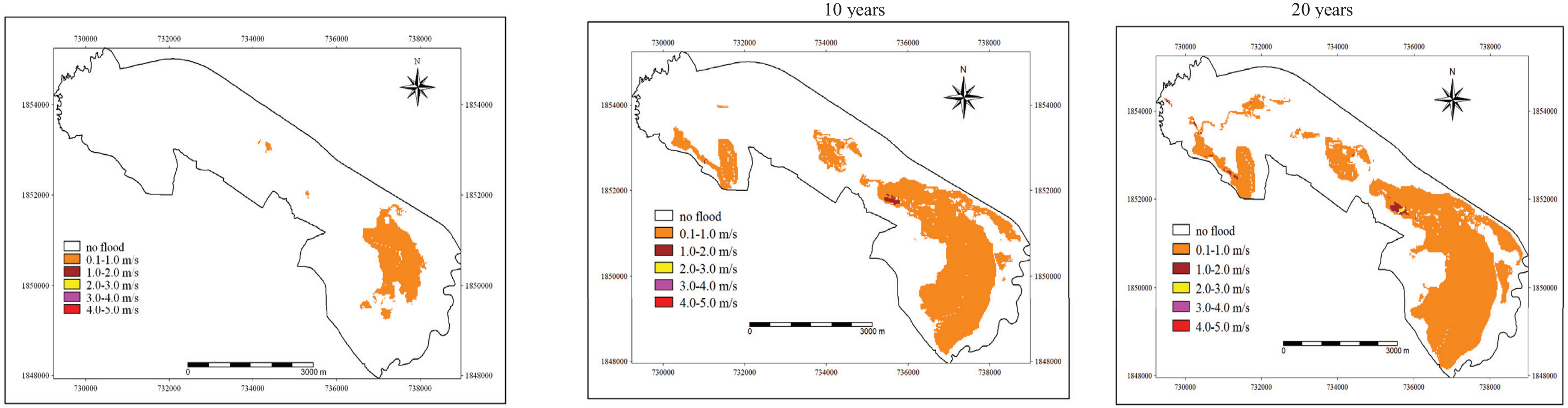
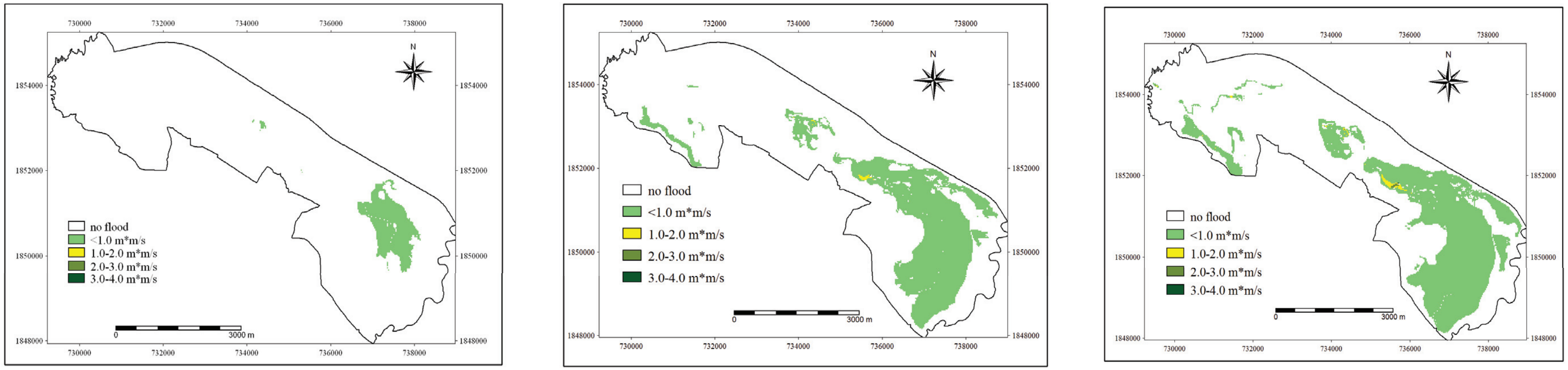


Figure 5.12: Shows spatial distribution maximum velocity for 2, 10 and 20 years return period flood.



2 years | 10 years | 20 years

Figure 5.13: Shows spatial distribution of maximum impulse for 2, 10 and 20 years return period flood.

2years 10years 20years

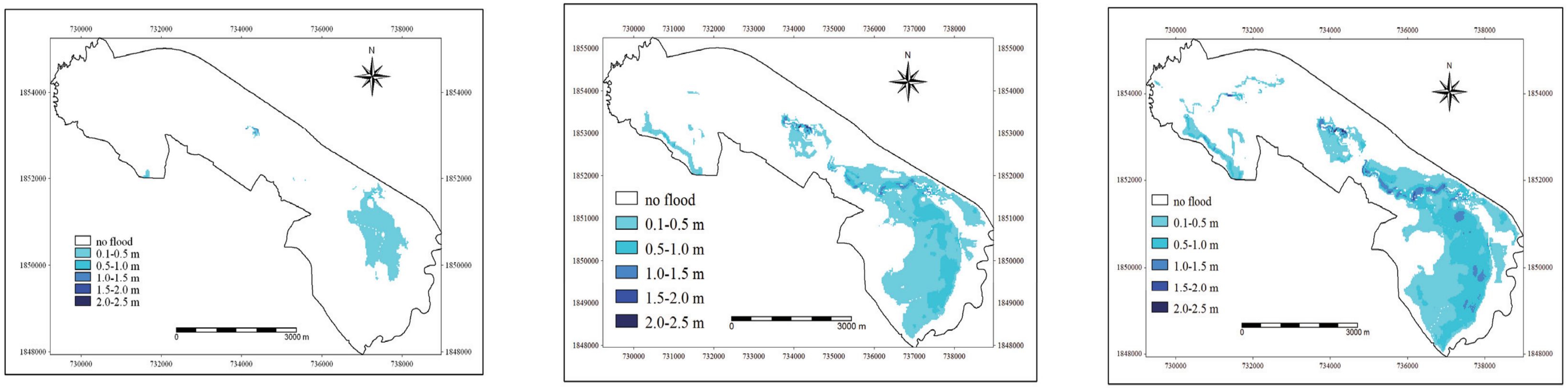
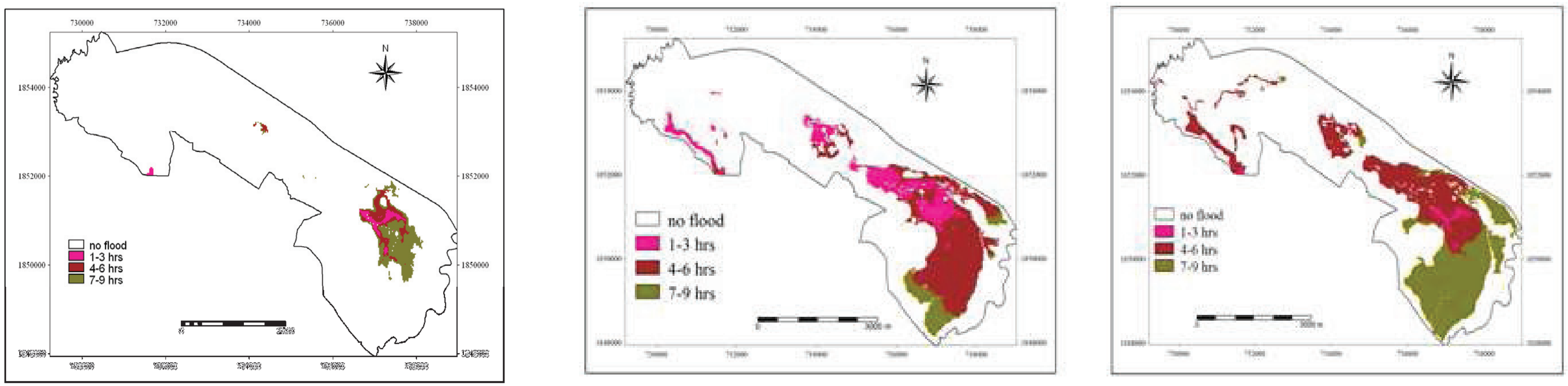


Figure 5.14: Shows spatial distribution of maximum depth for 2, 10 and 20 years return period flood.



2years 10years 20years

Figure 5.15: Show spatial distribution of maximum warning time for 2, 10 and 20 years return period flood.

5.6. Impact of structures on flood characteristics

Structures can be viewed as local discontinuities in a channel. The presence of structures may worsen or mitigate the effect of floods. According to Federal Emergency Management Agency (FEMA, 2001), bridges and culverts can block the flood flow and trap debris, causing increased flooding upstream and increased velocity downstream. Bridge piers obstruct flow and can cause an increase in water levels upstream of the bridge for subcritical flows. The increase in the water level is called backwater. The amount of backwater caused by piers depends mainly on their geometric shape, their position, flow rate and amount of channel blockage (Charbeneau and Holley, 2001).

Bridges and culverts are the structure types considered in this study, as there are a lot of them in the study area. They were included in the hydrodynamic modelling to determine their effects on flood propagation characteristics.

The simulation run in Sobek was done with the bridges and culverts with 20 years return period flood. The higher is return period was used because it reveals better the effects on the structures under larger flooding whereas the floodwater may pass under the structures without any effects in a small return period flood. The simulation run was repeated with the same return period flood without any structures. Table 5.4 shows summary of simulation results with no structures and with structure present. The spatial distribution of the results is shown in figure 5.16.

Table 5.4: Summary of flood characteristics with and without structures present.

Flood characteristics	No structures	Structures present
Total area inundated (km**2**)	7755.75	8327.90
Maximum depth (m)	2.1	2.5
Maximum velocity (m/s)	4.8	4.1
Maximum impulse (m^2/s)	2.55	3.24

The results indicate that with the presence of structures, there is an increase in the area inundated by 572.15 km^2. The flood characteristics such as maximum flood depth have increase from 2.1m without structures to 2.5 m with structures present and maximum impulse from 2.55 without structures to 3.24 m^2/s with structures present. However, with no structures the maximum velocity is the parameter that has increased. Thus the presence of structures has reduced that flood velocity whilst causing an increase in the other flood propagation characteristics. This implies flood hazard is worsened and threaten human safety and buildings in particular due to the destructive force (impulse) which is the combination of depth and velocity.

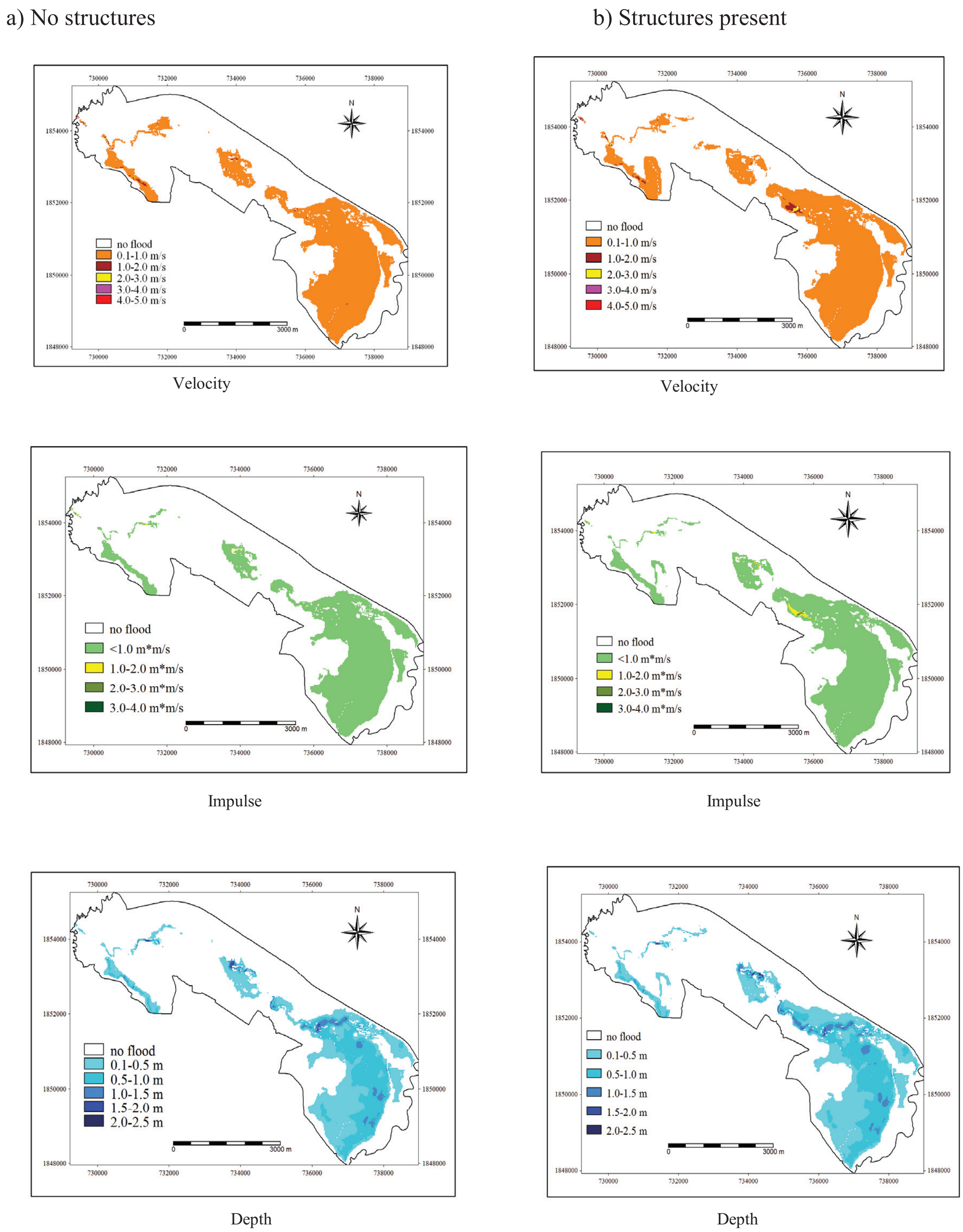


Figure 5.16: Show spatial distribution of flood characteristics with a) no structure and b) with structures present.

5.6.1. Sensitivity Analysis with structures

The simulation runs were repeated in Sobek for bridge and culvert types. All the bridges were made Pillar types and later changed to Abutment type. This was repeated for the rectangular and circular shape culvert types. It was assumed that the bridge and culvert type may influence the flood flows. During simulation for abutment bridge and culverts, it was assumed that sediment on the culvert floor would be washed out during flooding and there is no debris or undergrowth. The depth, velocity and impulse bridge and culvert types are shown in the histogram plot below (figure 5.17).

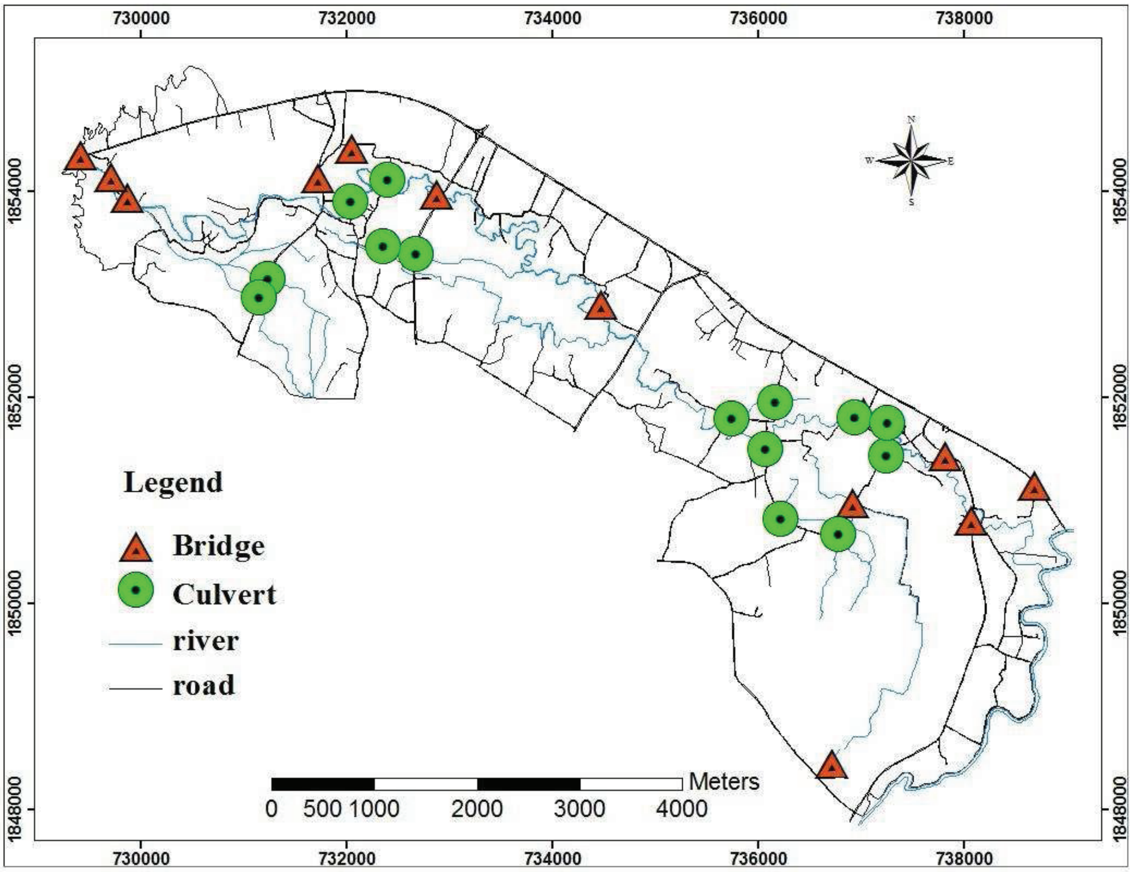


Figure 5.17: Spatial distribution of bridges and culverts in the study area.

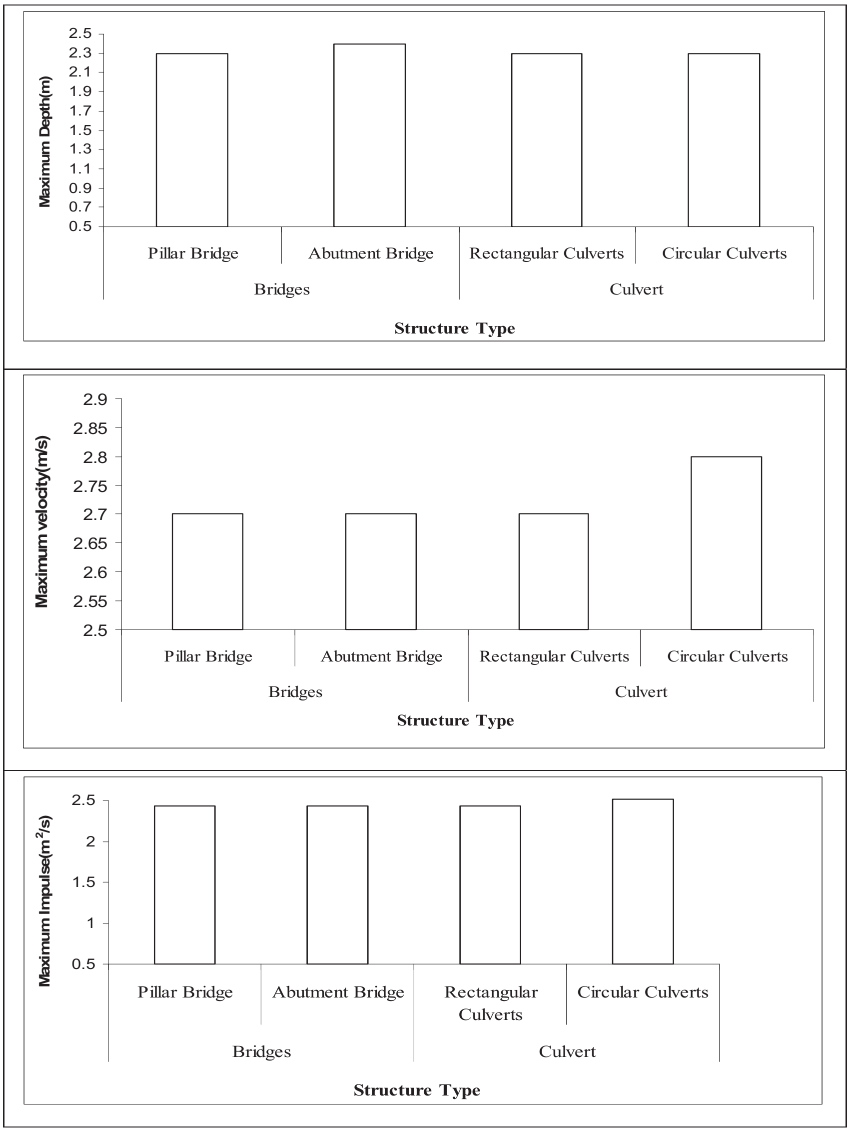


Figure 5.18: Histogram plot for maximum water depth, velocity and impulse for structure types.

The results indicate for the bridge types, the maximum flood depth is the parameter influenced while the rest remain same (5.18). The abutment bridge cause the flood depth to increase to 2.4 m. Thus depending on the bridge type, the flood peak may increase which pose increased flood risk as flood depth has the strongest influence on the amount of damage (Wallingford, 2006). For the culvert types, circular culvert has the main influence on the flood characteristics (see figure 5.20). There is increase in the maximum flood velocity (2.8 m/s) and impulse (2.5 m^2/s). Thus the type of bridge or culvert present in an area has influence on the characteristics of the flood propagation.

According to Konrad (Konrad, 2003), dense network of culverts reduce the distance that runoff must travel overland or through subsurface flow paths to reach streams and rivers. Often in the event of flooding, culverts cannot do their job, which can result in significant damages to roads (Gauthier et al.).

a) Pillar bridge

b) Abutment bridge

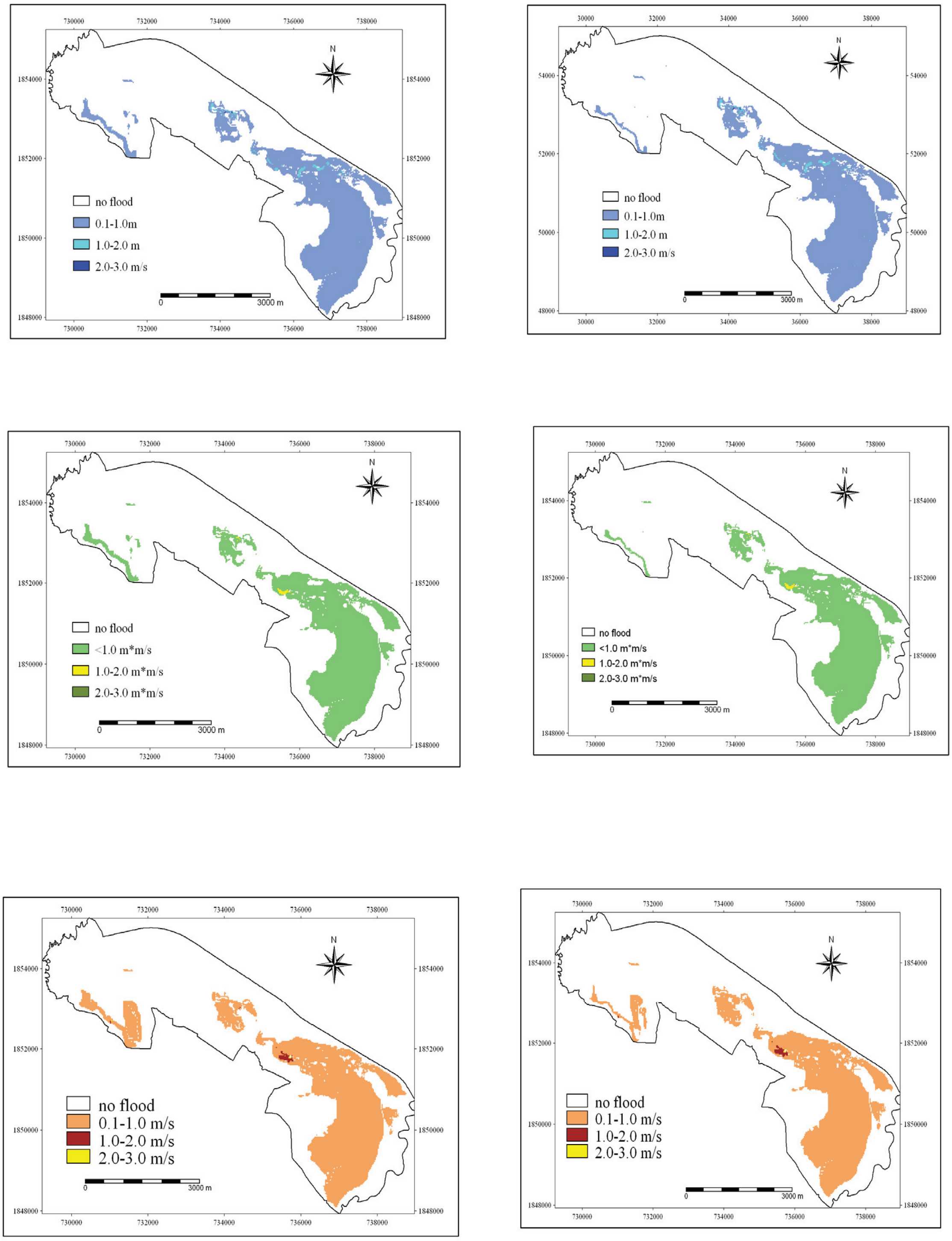
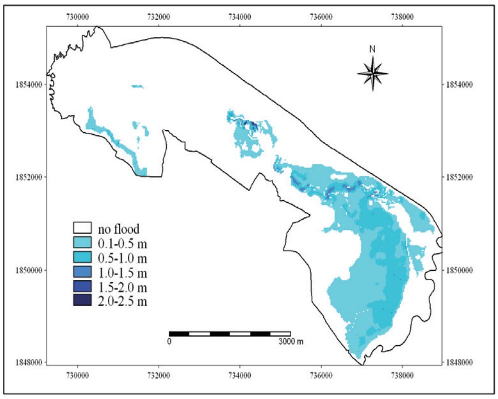
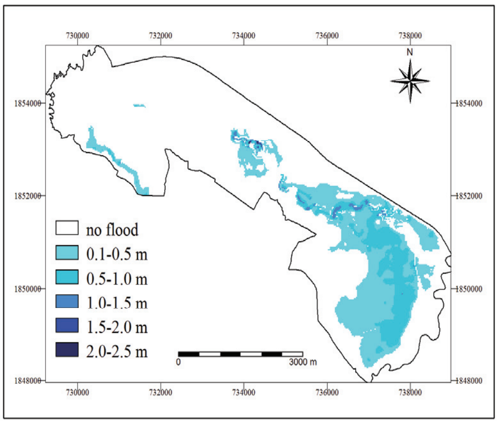


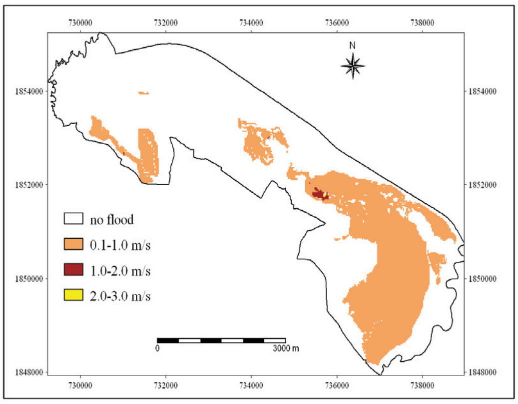
Figure 5.19: Spatial distribution of maximum water depth, velocity and impulse for pillar and abutment bridge types.



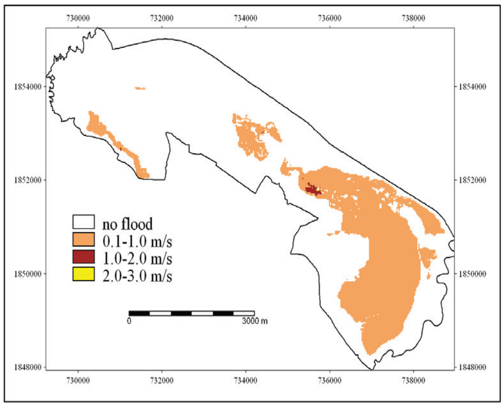
Maximum depth for circular culvert



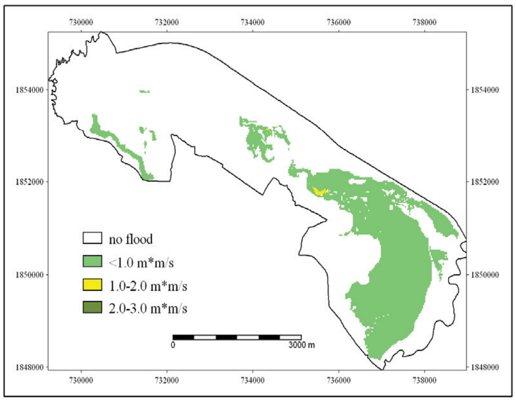
Maximum depth for rectangular culvert



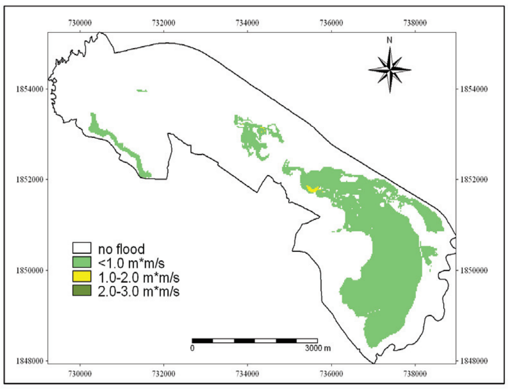
Maximum velocity for circular culvert



Maximum velocity for rectangular culvert



Maximum impulse for circular culvert



Maximum impulse for rectangular culvert

Figure 5.20: Spatial distribution of flood characteristics for culvert structure types.

6. Flood Risk Perception

This chapter discusses the flood hazard and risk perception of the people based on group interviews using the questionnaire.

6.1. Introduction

Developing a better understanding of how local people understand flood risk and account for their flood 'awareness' might make a critical contribution to awareness campaigns. To incorporate this perspective into the field of flood risk research means exploring how those identified as living with such risk construct, understand and respond to it (Burningham et al., 2008).

Nam Chun sub-watershed in Thailand was covered by dense forest about 35 years ago. After the government of Thailand gave concession to companies to cut down trees as a way to eliminate communist movement in the past, nonselective cutting down of trees has led to deforestation. The forest is now replaced with maize cultivation. The rainy season starts in May and lasts until October. Previous study shows that deforestation that occurred in the past two decades is the cause of flooding in the area (Patanakanog et al., 2004).

Flood caused by typhoon Usagi (2001)

The flood occurred around 3:30 am on 11th August 2001. The flood water full of debris and fallen trees destroyed several houses and claimed 136 lives with over 5 million U S dollars in property damage (Yumuang, 2006). The rains caused landslides in the highlands and flooding in the lowlands, which resulted in destruction of properties and heavy loss of human lives. It caused damage to roads bridges, houses, farms and livestock (Patanakanog et al., 2004).

6.2. Method and Data collection (downstream)

The aim is to gain insight in the determinants that control the risk perception of flooding. This was done by adapting the National Coordination for Risk Reduction (CONRED) questionnaire (Peters Guarin, 2003) for the rural setting. The questionnaire (appendix 1) was verified through information from secondary sources. To get reliable information, a group of knowledgeable people on local level were invited to the group meetings. They include formal community leaders such the village head, assistant village head; soil doctor who is a representative for the area trained by Land Development Department and the local people.

6.3. Flood hazard perception of the people in Nam Chun

Flood risk perception was assessed through group interviews in 5 zones (figure 6.1) by identifying different factors: the cause of flood, flood type, flood level, frequency of flooding, cropping calendar versus flood period, coping capacity of the people, awareness level and the effects of floods.

Zone 1: **Namchun Hin Ngong** is the first village to receive floodwaters and is close to the upstream boundary.

Cause of flooding: this is due to deforestation in the mountains. The waters from the mountains flood the lowland area when it rains. This is a yearly phenomenon. The floodwater come suddenly and leaves quickly leaving behind mud in its trail. For the people of this area, flooding becomes a hazard because it leaves mud behind on their farms that destroy their crops. For a crop such as rice that is able to keep up with the water, the yield is low due to mud left on it.

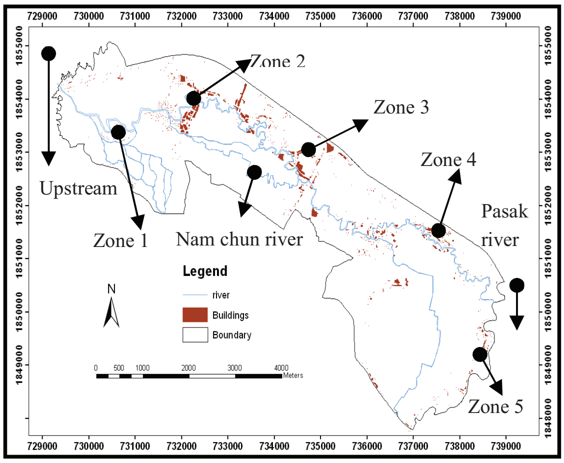


Figure 6.1: Interview locations.

The flood caused by typhoon Usagi occurred on the 11th August 2001 at 3am. The water height was 2m above bank full stage and it lasted for 2 hours. It caused damage to buildings and loss of lives. The people climbed unto rooftops and trees to save their lives. Rescue workers later come from the Government to rescue them and provide food aid. Before this event occurred, there was no warning or awareness through communication. Now there is a kind of early warning message to tell the people when flood is about to occur.

Zone 2**: Namchun Yai** is the next village downstream after Namchun Hin Ngong. The experience here is the same as that of the previous village. Whereas in this village, aside aid from the Government, the people receive help from World Vision, a Non Governmental Organization (NGO). They give the villagers fish to sell in order to generate income for themselves.

Zone3: **Ban Mai Patana** village is further downstream. Here also, flooding is due to deforestation in the mountains. The waters come from the mountains and the preceding villages which flood the area when it rains. This is a yearly phenomenon.

The 2001 flood event on 11 August and reached this village at 5am. The water height was 1.5 m above bank full stage and lasts for 3 days in the village which is disturbing to the people. It lasts for 1 week on their farms damaging crops. The reported damage was crops and buildings but no lost of lives here. They have to rebuild some houses and replant crops on the farms afterwards, which bring economic pressure.

Zone 4: **Ban Nong Tong** is last village downstream affected by the 2001 flood event. It occurred at 5am on 11th of August. The water height was 3 m above bank full stage. The water was retained with mud for one and half months on the farms. There was no damage in the settlements but damaged the crops on farms. Flooding occurs yearly. The Government send workers to drain the water. Previously there was no warning but now there is early warning message.

Zone 5**: Ban Dong Meng** is the lowest part of the study area. It is along the Pasak River. The people here had no effect from the 2001 flood event. The Pasak River causes flooding in this area almost every year. It destroys crops and has to replant. Damage buildings and sometimes they have to rebuild their houses.

6.3.1. Flood hazard perception in the Upstream area.

In order to understand the flood risk perception of the people living upstream, the local people were interviewed in the village of Nam koh which north of Nam Chun. Resource person such as the Chairman for Farmers' Association in charge of 17 provinces including Phetchabun and personnel at the Early warning Center were interviewed to get reliable information and to verify information obtained from the people (Figure 6.2). The village of Nam ko is partly in the mountain and at the foot of the mountain. There is canal in the mountain which the people call the headwaters (Figure 6.3) which is the source of flooding Nam ko and Nam Chun downstream. According to the people, during the 2001 flooding, the maximum death toll and destruction was recorded here.

According to the resource person the people have been cutting down trees on the mountain forests. This has left the rocks exposed and when it rains erosion and flooding occurs. There is increase in speed of the runoff and volume. As the water moves downhill it carries boulders and trees stumps which killed many people and destroyed much property during the 2001 flooding event (Figures 6.4 to 6.6).

Figure 6.2: After interview with resource person (LHS) and the local people.

(Source: field work, 2008)

Figure 6.3: Canal of the headwaters from the mountains.

(Source: field work, 2008)

Figure 6.4: Aftermath of flooding in 2001 after typhoon Usagi.

(Source: Ministry and Environment and Natural Resources, Phetchabun)

Figure 6.5:Tree stump carried here by the floodwaters from the mountains (Nam koh).

(Source: field work, 2008)

Figure 6.6: Dead bodies retrieved after 2001 flood event.

(Source: Ministry and Environment and Natural Resources, Phetchabun)

Figure 6.7: Water level mark on building of 2001 event.

(Source: Ministry and Environment and Natural Resources, Phetchabun)

Figure 6.8: Early warning center located at the headwaters in the mountains.

(Source: field work, 2008)

According to the people, the water height was 1.5 m above bank full stage and moved with much speed it destroys a lot within few minutes. The number of houses destroyed is 1,749 and 47,824 farmlands destroyed. The Government sent Rescue workers to the area to help people and retrieve dead bodies (figure 6.6). Both wooden and brick houses were destroyed and left mud marks on some buildings (Figure 6.7). Currently, some people have relocated from the area whilst others are rebuilding their houses because they have nowhere to go. For the people here, flooding is a disaster because the floodwaters come suddenly with much speed and destroys houses and cause loss of lives of their relatives. The crop calendar is the same as that of Namchun Yai.

Early warning: The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response. After the 2001 flood event, the government has setup an Early Warning Center (Figure 6.8). The canal in the mountains is monitored 24 hrs a day by visual inspection of the water level. When the level keeps rising, the villages are informed in a warning message using siren.

6.4. Flood risk perception in Nam chun

The socioeconomic level of the people is rated as low income, middle income and high income. The type of seasons such as wet season and the crop calendar, which indicates the crop type, months for planting and harvesting, affects the income of the people through the year. The crop calendar generated for each village is based on information received from the local people confirmed by the formal community leaders such as the soil doctor and village heads. The main economic activity is farming and rearing of animals for sale and domestic use.

Zone 1**:** this is the village of **Namchun Hin Ngong** and its environs that are closest to the upstream. According to their crop calendar (table 6.1), the main crop season is November when they plant and harvest in February. Crops planted earlier are destroyed when the flood comes. They get about 50% of rice from the farm because it is able to survive with the floodwaters but the low yield due to the mud in the flood waters leave on the crops that actually destroy them. Fertilizers applied on the farms are lost when the flood comes. As a result, they become poor during the wet season. After harvest in the months of March-April (Figure 6.9), their income level rise when they sell the farm products. It is concluded from table 6.1 that the white areas imply the land is mostly not cultivated from March until October. This will make the people poorer as there is no food to bring income before the floods begin.

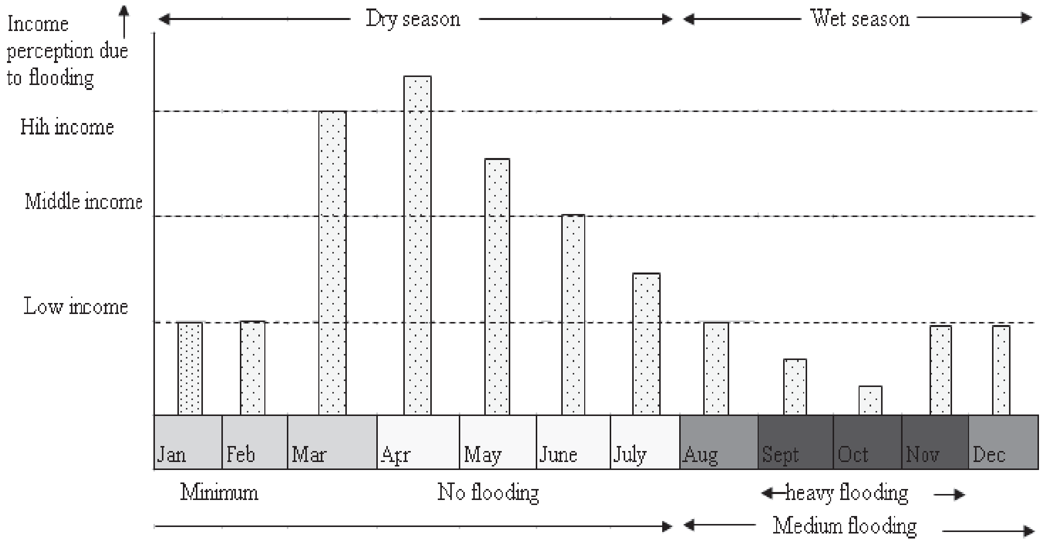


Figure 6.9: General distribution of peoples' perception of flood risk.

The annual distribution of flood risk perception (figure 6.9) is based on information gathered during interview and has no statistical background. All the villages interview report of flooding yearly. On the horizontal axis is the stage of flooding, the top represents the seasons of the year while their income perception due to flooding is indicated by the vertical bars. The raining season starts in the august to December with heavy flooding occurring between September and November. The dry season starts in January until July with minimum to no flooding. The people become poor during the period of flooding. This is because the crops are damaged except rice, which gives low yield. The damage is also due to mud in the floodwater. As seen in the figure above, the income level is improved especially in the months of March and April because the crops are harvested and sold to generate income.

Zone 2**:** The village of **Namchun Yai** and its environs. The crop types and calendar of Nam chun Hin Ngong (Table 6.1) is the same as that for Nam Chun Yai. They practice crop rotation with onions. The annual distribution of risk perception is the same (Figure 6.9). Here, the people have a new economic venture that is fishing when the flood comes to support the family. This makes the people here less poor than those of the first village.

Zone 3**: Ban Mai Patana** and its environs. Farm animal such as cows are reared for economic purposes. The price of a mature cow is 8000 Baht (approximately 167 Euros). Their major crop season is January-February and harvest in the month of May (table 6.2). Apart from rice that keeps up with the floodwaters, most of the crops are destroyed during the raining season.

Poverty sets in at this time, as money spent on fertilizers becomes waste in addition to loss of farm produce. Each home has silos for storing the crops. The income level of the people gets better after the harvest when they have sold the farm products.

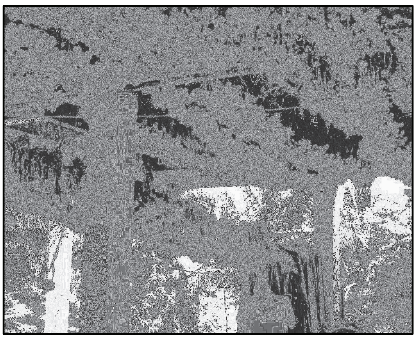


Figure 6.10: Storage of onions.
(Source: field work, 2008)

Apart from the months of June and July (table 6.3), the land is cultivated most part of the year. Besides most rear animals as an extra source of income, hence it is concluded that the people here are less poor than those of the previous two villages are.

Zone 4: The village of **Ban Nong Tong:** here, the people plant crops throughout the year (table 6.4) hence they harvest more than once in the year. Fertilizer is applied on the farms and everything is lost when the floods come. The other source of income is from the sale of cows, which costs 7000 - 10,000 Baht (approximately 146 - 209 Euros). The crops are sold out quickly when the market is good; otherwise, they are stored in the house. There is a special silo built in most homes for storing rice. As the people of Ban Nong Tong village cultivate the land throughout the year this means that they are better economically than the other villages.

Table 6.1: Crop calender for Namchun Hin Ngong.

Crop Calender for Namchun Hin Ngong (from interviews)

Crop Type	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
Rice							Planting	Growing			Harvest	
											Planting	Growing
maize	Growing	Harvest										
											Planting	Growing
Tobacco	Growing	Harvest										
							Planting	Growing				
Chilli	Growing	Harvest										
											Planting	Growing
Onions	Growing	Harvest										

Tabe 6.2: Crop calender for Ban Mai Patana.

Crop Calender for Ban Mai Patana (from interviews)

Crop Type	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
Rice	Harvest							Planting	Growing			Harvest
Onion	Planting		Growing		Harvest							
cabbage	Planting		Growing		Harvest							
Eggplant	Planting		Growing		Harvest							

Table 6.3: Crop calendar for Ban Nong Tong.

Crop Calender for Ban Nong Tong (from interviews)

Crop Type	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
								Planting	Growing			Harvest
Rice	Harvest(H)	Planting(P)	Growing		Harvest			Planting	Growing			Harvest
Onion	Planting		Growing		Harvest	Planting	Growing		H P	Growing		Harvest
cabbage	Planting		Growing		Harvest	Planting	Growing		H P	Growing		Harvest
Cucumber	Planting		Growing		Harvest	Planting	Growing		H P	Growing		Harvest

Table 6.4: Crop calender for Ban Dong Meng .

Crop Calender for Ban Dong Meng (from interviews)

Crop Type	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
Rice					Planting	Growing						Harvest
Chilli					Planting	Growing				Harvest		
cabbage	Planting	Growing			Harvest							
Eggplant	Planting	Growing			Harvest							

(Source: fieldwork, 2008)

Zone 5: the village of **Ban Dong Meng** and its environs is the last place of interview in the downstream of the study area. The crop types are show in Table 6.4. Each house has silos as storage when the crops do not sell quickly after harvest. Here also, poverty starts when the rains start. Income level gets better after harvest. Another source of income is from the rearing of cows. Its price range is 8000-13,000 Baht (approximately 167- 275 Euros). The people here also cultivate almost throughout the year.

In conclusion, the flood risk perception of the people living downstream has to do with their economic level. For such, flood is hazard or disaster when their crops are destroyed by the mud it leaves behind on the farms. However, considering the crop calendar for each village from the upstream to the lowest part downstream, it is not the same. There is a shift in the distribution of annual risk perception in terms of the months of harvest for most crops after which the economic level gets better. In some villages, the land is cultivated early while others cultivate late. The economic level is different as for the various villages as some cultivate the land throughout the year and others get additional source of income.

The maximum floodwater height is 3m at bank full stage at Zone 4: Ban Nong Tong and it was retained on farms for a month. At the lowest part, which is further down around the Pasak, there is no effect of flooding from the mountains by the Nam Chun river since it does not reach there. Flood here is due to Pasak River.

For the people of Namkoh in the mountains, flooding is a disaster because of the speed of the floodwaters as it comes to destroy both lives and properties. The perception of flood risk is not the same for people living in the downstream and upstream. Thus, risk perception varies with location within the catchment.
The discussion continues on the results from the questionnaire on vulnerability and coping in the next chapter.

7. Vulnerability

This chapter deals with vulnerability of the people, building and crops to flooding and coping strategies employed by the people. The sections on vulnerability of people and coping are results from the group interviews.

7.1. Vulnerability of people to flooding

Nam Chun Hin Ngong village: According to the people both the men and women become helpless and all depend on external assistance in the event of flooding. The level of vulnerability is independent on gender.

Nam Chun Yai: in this villge, the experience is same as the previous village. Both the men and women become helpless and all depend on external assistance. The level of vulnerability is independent on gender.

Ban Mai Patana: Here, the women and children are helpless and depend on the men while the men are independent and help the more vulnerable. Thus the vulnerability of the people in this village depends on gender and age.

Ban Nong Tong: in this village, the vulnerability is gender dependent as in the previous village.

Ban Dong Meng: Here also, vulnerability is gender dependent. The women and children are more vulnerable while the men help themselves.

The level of vulnerability varies for the villages as to whether women are more vulnerable than men. It was identified that vulnerability is independent of gender in villages from the upstream and those further downstream; the level of vulnerability depends on gender.

7.2. Vulnerability of Buildings to Flooding

Flood characteristics such as water depth, duration, velocity, impulse, concentration of sediment, pollution load and speed of rising determines the damage (Alkema et al., 2007; Wallingford, 2006). The flood damage to buildings is based on the susceptibility of the building considering attributes such as the function of the building, age, the state of the building, wall, roof and floor material, protection and number of floors of the building and the flood characteristics such as water depth and impulse or destructive force or energy of the water.

According to the people, it was noted that flood water carries large tree stumps and boulders in its way, which in addition to the high flood velocity causes damage to buildings and in most cases total collapse

Figure 7.1: Buildings destroyed in the upstream by tree stumps carried by floodwater of 2001 event.
(Source: Ministry of Environment and Natural Resources, Phetchabun)

7.2.1. Assessing Building Vulnerability Characteristics

An inventory is made of the buildings in the area. Recorded was type of wall, roof and floor material. Also taken into account is the physical maintenance state of the building. The building attributes considered in this study are: the function of the building, the state of the building, wall, roof and floor material, protection and number of floors of the building.

The buildings are mainly residential buildings. It was envisaged to carryout individual or house-to-house interviews aside the group meetings to get information on individual houses concerning vulnerability to flooding. Considering the 2001 flood event, some houses would have been repaired; rebuild or some do not exist anymore after the event. This information the author could not gather due to lack of translator. Therefore, vulnerability assessments of houses were determined by visual inspection of the maintenance state of the houses and the material type (appendix1) of the existing houses and the location recorded using Garmin 12 GPS and base map. A total of 51 buildings were mapped representing 5.4 %. Information on the floodwater depth for 2001 event was gathered during the group meetings at the five zones. Based on the inventory, three structural types were identified.

7.2.2. Description of Building Structures

The roof material is the same for all buildings mapped in the area, which is iron sheet.

Structural type 1

House structural type 1 has the wall made of wood, a roof of iron sheet and wooden floor. Majority of houses in Nam Chun are of this type. Most are in a state of moderate to good.

Figure 7.2: Building structure type 1.

Structural type 2

House made of brick wall, concrete floor and a roof of iron sheet. There was three of this structural type found. They were all in a good state.

Figure 7.3: Building structure type 2.

Structural type 3

The houses of this structural type has wall is made from a combination of wood and iron sheet, a roof of iron sheet and wooden floor. There was three of structural type 3 found during fieldwork. One deteriorated and the other two in a moderate state.

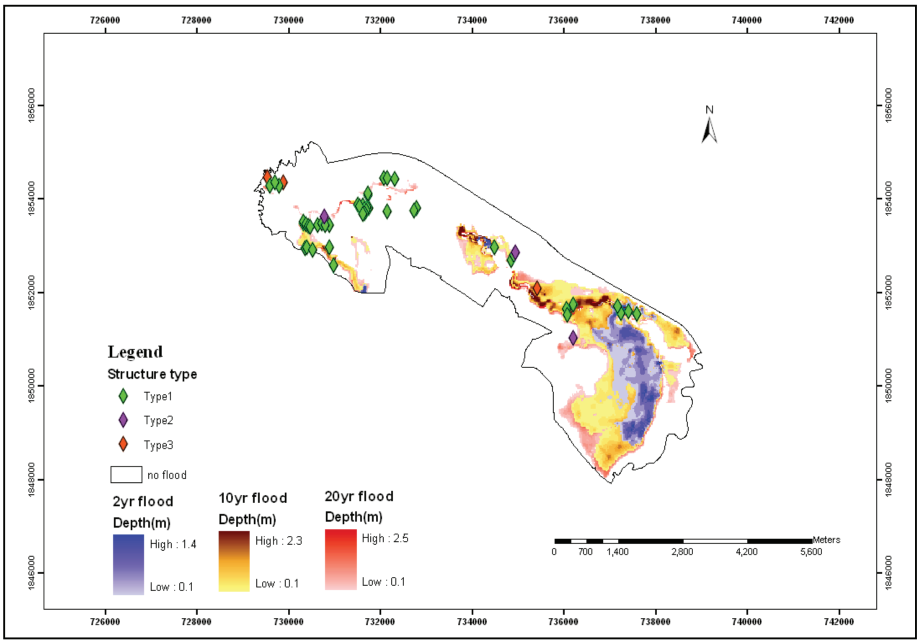


Figure 7.4: Spatial distribution of building structural types mapped in the study area.

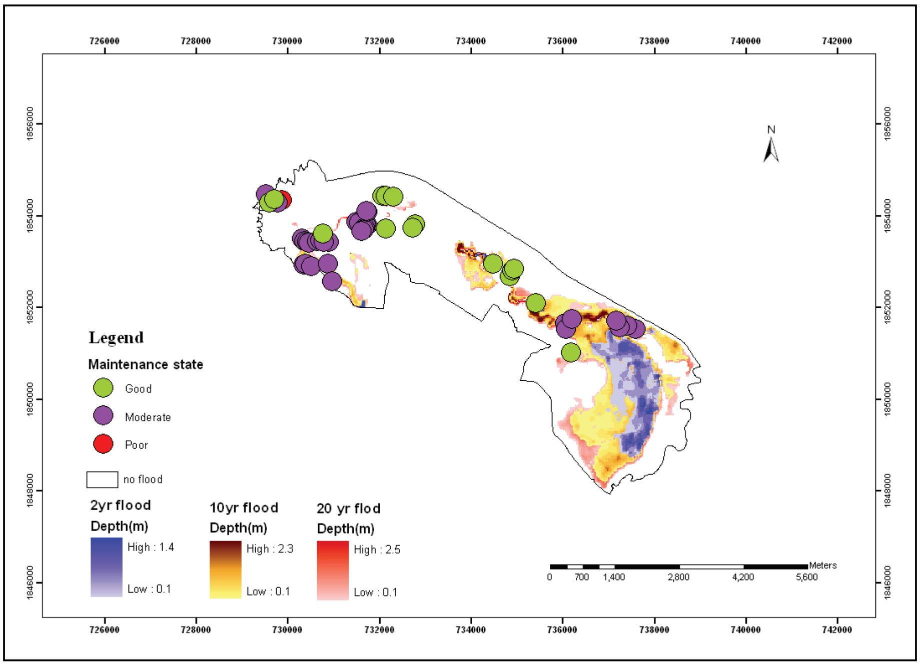


Figure 7.5: Spatial distribution of building structure maintenance state.

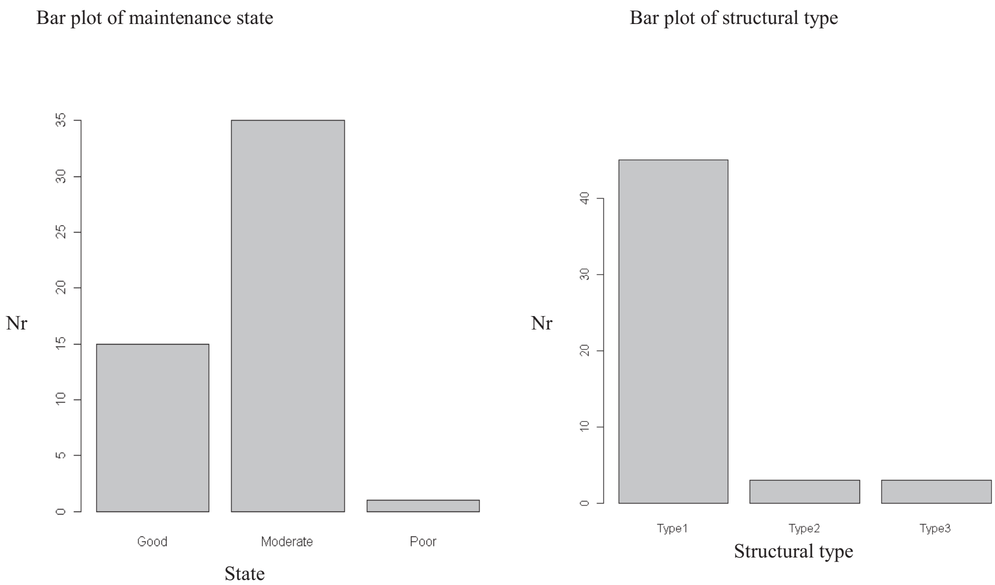


Figure 7.6: Building structural maintenance state and structural type distribution.

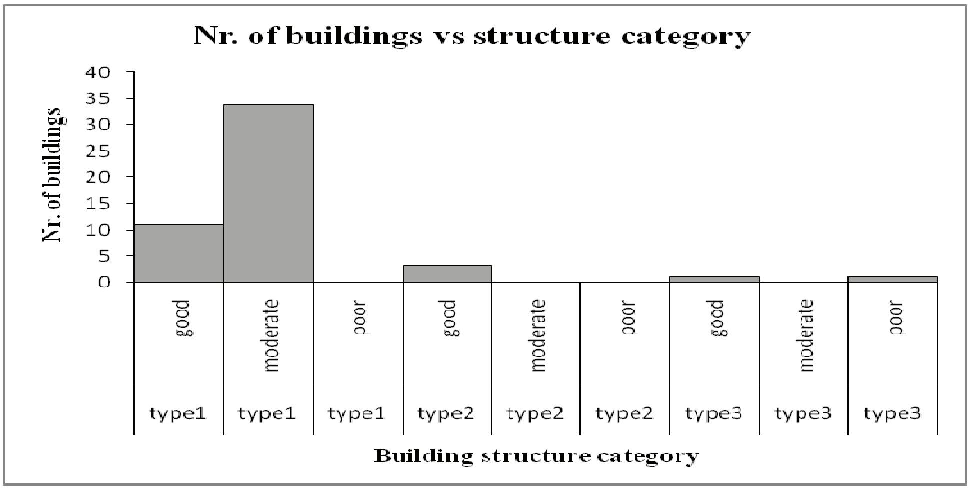


Figure 7.7:Combination of building structure maintenance state with structure types.

Figure 7.6 above shows the structural types and maintenance state distributions. From the bar plots, the maintenance state most houses is moderate representing 35 houses, 15 houses are in good state and 1 in a poor state. Structural type 1 is the most common representing 45 and 3 each of structural type 2 and type 3. Figure 7.7 shows the combination of the building structure maintenance state with the various structure types.

7.3. Vulnerability of crops to Flooding

Flooding is a major risk to fresh vegetables production. Plant responses to flooding include stomatal closure and premature leaf aging, reduced leaf growth, nutrient uptake, net rates of photosynthesis, and root and shoot growth and increased susceptibility to predators and pathogens. Leaf conductance and reduction in net carbon di-oxide assimilation are usually found to decline following 1 to 3 days of flooding (Rao et al., 2002). Moreover, long periods of saturated soils are well known to increase the incidence and severity of plant chili diseases due to over irrigation or heavy rainfall or both (Davila et al., 2004).

The earliest symptoms of flooding stress of subtropical and tropical fruit trees are the reduction in net carbon di-oxide assimilation, stomatal conductance and transpiration. Mango is considered a moderately flood-tolerant species. However vegetative growth of mango trees generally declines if the trees are flooded for more than 2-3 days (Schaffer, 1998). Rainfall is the most important factor involved in banana root system deterioration. It interacts with the topographic factors that may result in severe adverse conditions for banana root development the most possible interactions are flooding, puddles of rains, shallow water table and areas too close to sea level to be effectively drained (Gauggel et al., 2003b).

Agricultural land in the study area includes crops such as, rice fields, maize, vegetables and orchards of coconut palm, mango and banana

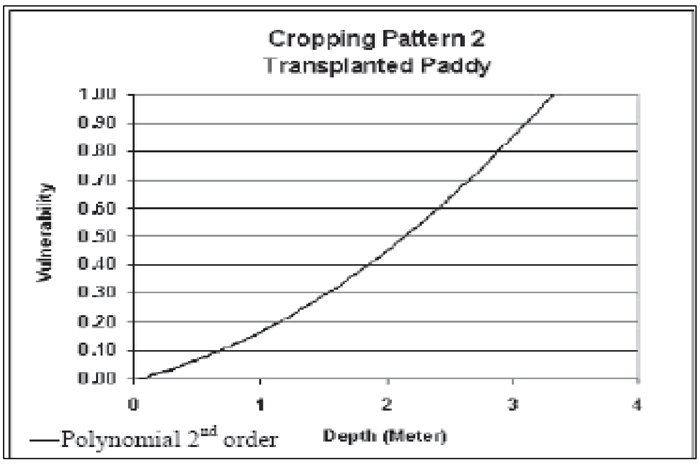


Figure 7.8: Vulnerability curve for rice.
(Source: Maiti, 2007)

According to Khush, Thailand is the world's leading exporter of rice, selling about 4-6 million tons annually. Paddy yield is 2.2 tons per hectare (Khush, 1997) and also FAO gives rice and corn yield for

2003 (FAO). The unit prices of the various crops are also given (Biz Dimension). From the above literature information, the risk is determined in the next chapter.

7.4. Coping Capacity

Coping is the manner in which people act within the limits of existing resources and range of expectations to achieve various ends. Coping include defence mechanisms, active ways of solving problems and methods for handling stress (Blaikie, 1994). Often it is assumed that the objective of coping strategies is survival in the face of adverse events. Though this is common it overshadow other important purposes. When people know an event may occur in the future because it has happened in the past, they set up ways of coping with it. Such coping strategies depend on the assumption that the event itself will follow a familiar pattern, and that people's earlier actions will be a reasonable guide for similar events. Almost all coping strategies for adverse events which are perceived to have precedents consist of actions before, during and after the event.

During interviews the people were asked about their coping mechanisms: before, during and after flood event using the questionnaire. The information gathered from the interviews was the same for the five zones. The coping strategies employed before, during and after the event at individual and government levels are shown below (Table 7.1).

Table 7.1: Coping strategies employed by the people of Nam Chun.

Flood	Individual level coping strategy	Government level coping strategy
Before	Store some food in silos.	Send Warning message using siren.
During	Climb in trees and on top of roofs	Send rescue workers around.
After	Rebuild houses damaged houses. Relocate houses in areas of higher ground.	Cleans debris and drainage system.

7.4.1. Impact-minimizing strategies

These are referred to as 'Mitigation' especially where they are the aim of government policy. These strategies seek to minimize loss and facilitate recovery. Local level indigenous responses include people's own way of dealing with flood risks. These involve a combination of self protection and social protection by communities or non-governmental agencies.

In Nam Chun, rural houses are built on wooden pillars that raise the houses 1m to 2m high above the ground. This is their traditional way of reducing the impact of flooding of their houses. In terms of awareness, the people know when to expect flooding through past experiences.

Most often, the rural people are helpless and depend on the Government. World Vision, a non-governmental agency provides aid and economic ventures so that the people can generate income for themselves.

8. Risk Assessment

This chapter deals with risk assessment for 2, 10 and 20 years return period floods integrating flood modelling, vulnerability and risk perceptions from the previous chapters. It examines the economic loss to agricultural crops in and loss to rice in particular, which is the main crop type in the study area using vulnerability data from literature. Due to lack of data on population, risk to people is assessed based on Smith (1994) graph, to assess areas hat pose risk to people and property. Data on flood depth-damage and other information for structural types was not obtained from fieldwork due to luck of an interpreter, as such loss estimation for buildings made use of number of buildings affected. The risk of flood after typhoon Usagi of 2001is also considered.

8.1. Introduction

The term risk refers to the expected losses from a given hazard to a given element at risk, over a specified future time period. According to the way in which the element at risk is defined, the risk may be measured in terms of expected economic loss, or in terms of number of lives lost or the extent of physical damage to property (Coburn et al., 1994). Assessment of flood risk, which is the expected flood losses, is important both for planning mitigation measures and for knowing how to cope with an emergency situation (Michaud and Pilon, 1999).

Risk assessment involves the following steps (Coburn et al., 1994; FEMA, 2001; Michaud and Pilon, 1999):

1. Estimation of the hazard: this includes location, frequency and severity;
2. Estimation of the exposure: this includes the number of people, buildings, factories etc exposed to the hazard called “elements at risk”;
3. Estimation of vulnerability of the elements at risk: this is usually expressed as percentage losses of people, buildings, crops etc. and
4. Multiplication of the hazard, exposure and vulnerability to obtain the expected losses.

This is usually expressed by the formula:

Risk = Hazard*Vulnerability*Amount

To evaluate the threats posed by floods, as well as vulnerability and risk of local people requires learning from the people’s own knowledge and perceptions. Besides, they are the ones that have to deal with inundations on a regular basis therefore have their own ways of perceiving the threats from flooding. While enduring the impact of flooding they have become aware of their own susceptibility and developed their own coping strategies (Peters Guarin, 2008).

These experiences taken into account with the modelling aspects bring to the forefront a comprehensive risk assessment that represents reality. Thus the spatial modelling and the people's perceptions and experiences are incorporated as inputs for flood risk assessment which is the approach used in this study.

Risk assessments can be quantitative or qualitative. Previous work (Peters Guarin, 2008) on qualitative aspect of risk assessment involves assigning some vulnerability indices based on the people's perceptions for an urban area which have long duration floods. This method is not applicable to Nam Chun, a rural area which experiences flash flood with short duration and also based on the peoples experiences indicators such as water level at ankle, knee and waist level are not recognised by the people Nam Chun.

Community based approach using semi quantitative technique is the right method for this study. Semi quantitative implies more quantitative analysis than qualitative. This is done by integrating the people's perceptions into the risk assessment and quantifying results in numerical values and where possible, in terms of money (Baht). Figure 8.1 gives the general procedure followed in this chapter for flood risk assessment for Nam Chun.

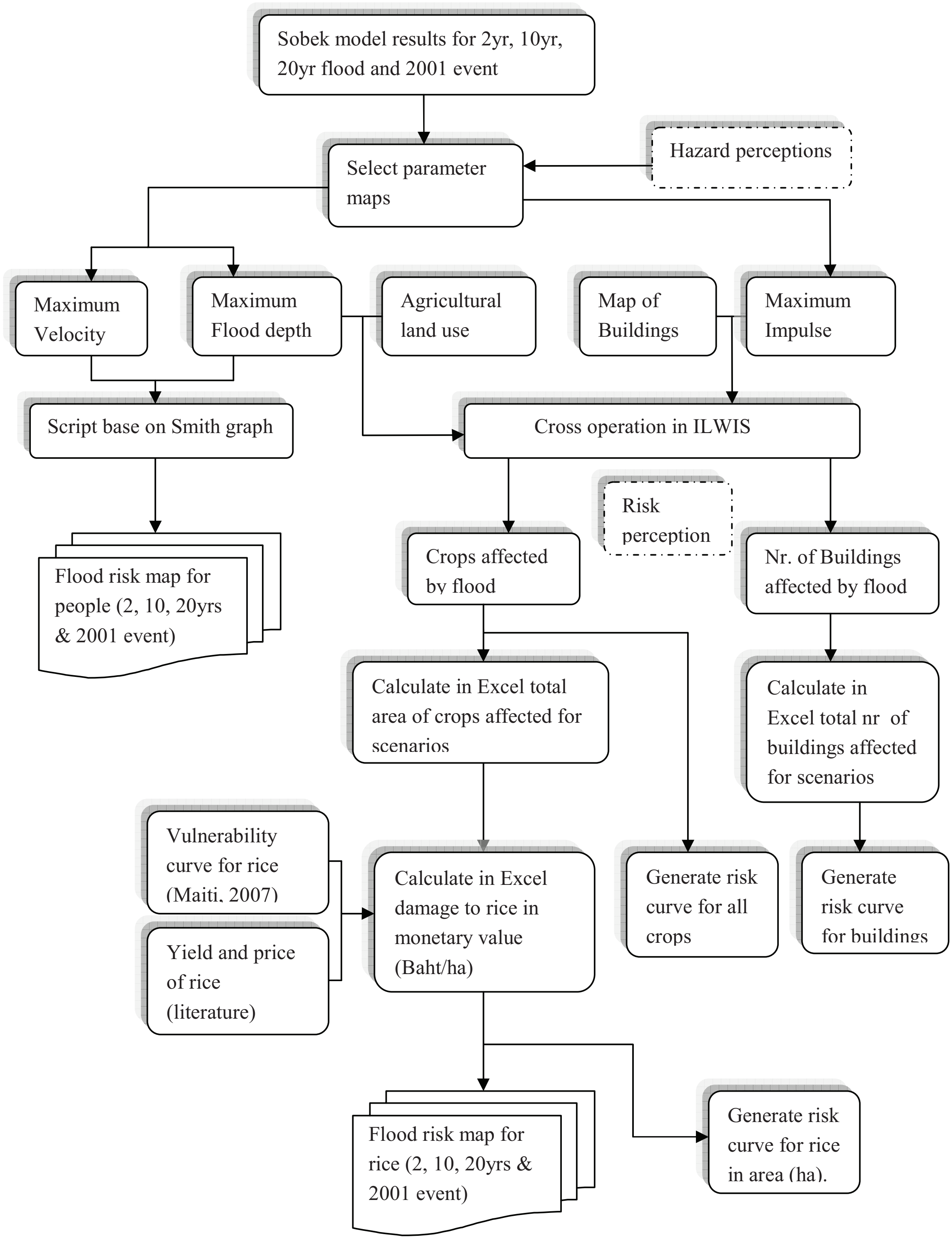


Figure 8.1: Shows general procedure for risk assessment integrating the people's perception with hydrodynamic modeling.

The 1D2D Sobek modelling (chapter 5) output hazard parameter maps are used in risk assessment. The appropriate parameter maps were selected based on the hazard information received from the people during interviews. According to the people (as stated earlier in chapter 6), the flood velocity is high and causes much destruction within a short time. The floodwater does not last for more than a day. Their crops are destroyed when flooding occurs. The actual destruction of crops in the field is due to mud left on the crops by the flood waters as it moves downstream. The aspect of sediment concentration of the floodwaters is being studied by Kerice Masters (In press). The subsequent sections deal with risk to crops, people and buildings.

8.2. Loss estimation

Agricultural vulnerability involves crop loss economically. Flood inundation depth is generally the most commonly used parameter in damage evaluation. The other flood characteristics are rarely used so that it is difficult to quantify their influences for damage assessment (Maiti, 2007). Flood duration is an important parameter to estimate agricultural damage because many crops, like fruit bearing trees and vineyards can withstand inundation of their stems for a short time (usually some days), but if the period becomes too long the roots will starve from oxygen depletion and the trees will die (Alkema et al., 2007; Gauggel et al., 2003a; Rao et al., 2002; Schaffer, 1998; Stotzky and Martin, 1969).

The crop grown in the study area is mainly rice. The other crop types are orchards of banana, coconut and mango, chilli and eggplant named “field crop” and corn. In this study, vulnerability information was not collected during fieldwork due to lack of an interpreter. Besides the vulnerability curve for rice obtained from literature, none was found for the other crop types. The approach used in assessing loss does not include stage damage curves for crops and buildings. Implicitly, each parameter holds information on its consequences: deeper water depths create higher flood risk, and so does longer duration and shorter warning times. This implicit information can be used to assess flood risk (Alkema et al., 2007).

8.2.1. Loss to crops

Flash flood is the flood type considered in the study area and has duration less than half a day from the model result. As such the flood duration could not be considered for assessing crop damage therefore the flood depth was used. The flood depth from the model result (figure 5.14 in chapter 5) was combined with agricultural land use based upon the peoples concerns (see chapter 6). Using “cross” operation in ILWIS, the area affected by floods of 2, 10 and 20 years return period flood and also for 2001 flood event for the various crop types was estimated. Rice as the major crop in the study area, risk calculation was done in monetary value.

Further calculation is carried out in excel to determine total area in hectares of the various crop types affected by flooding for all scenarios and generate the rick curve as shown below (figure 8.2).

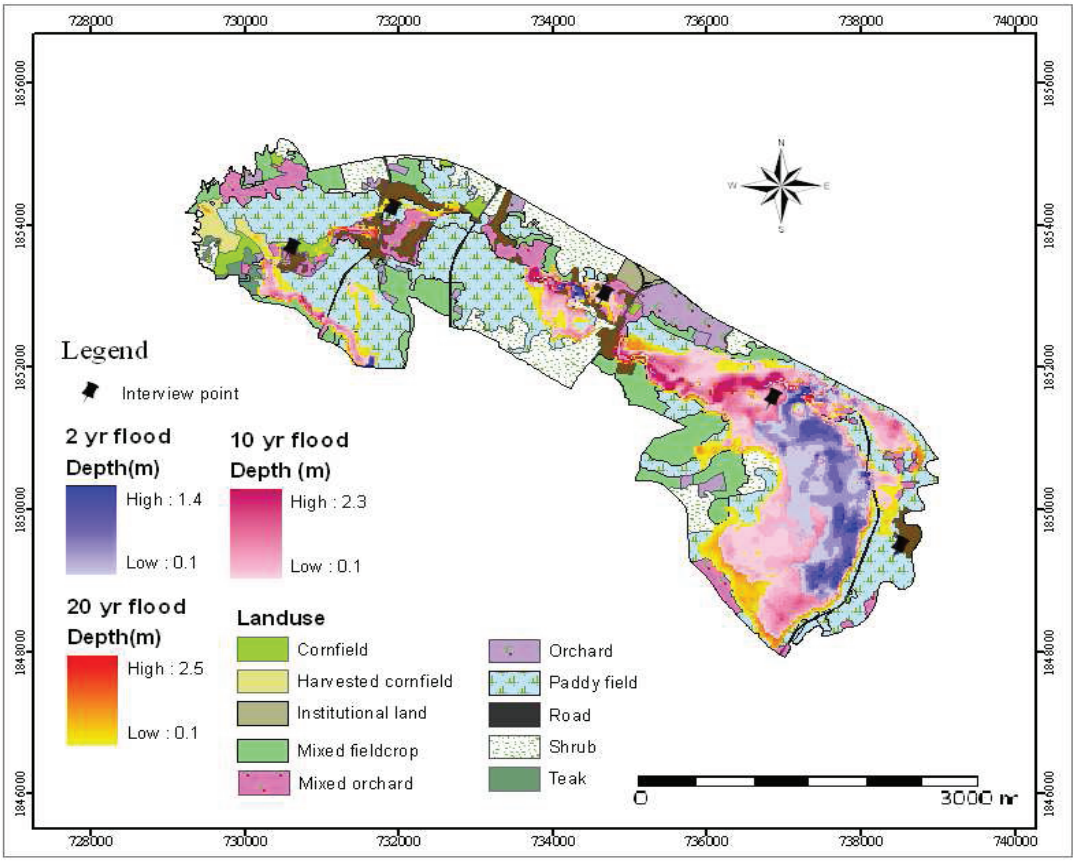


Figure 8.2: Spatial distribution of landuse in flood hazard zones.

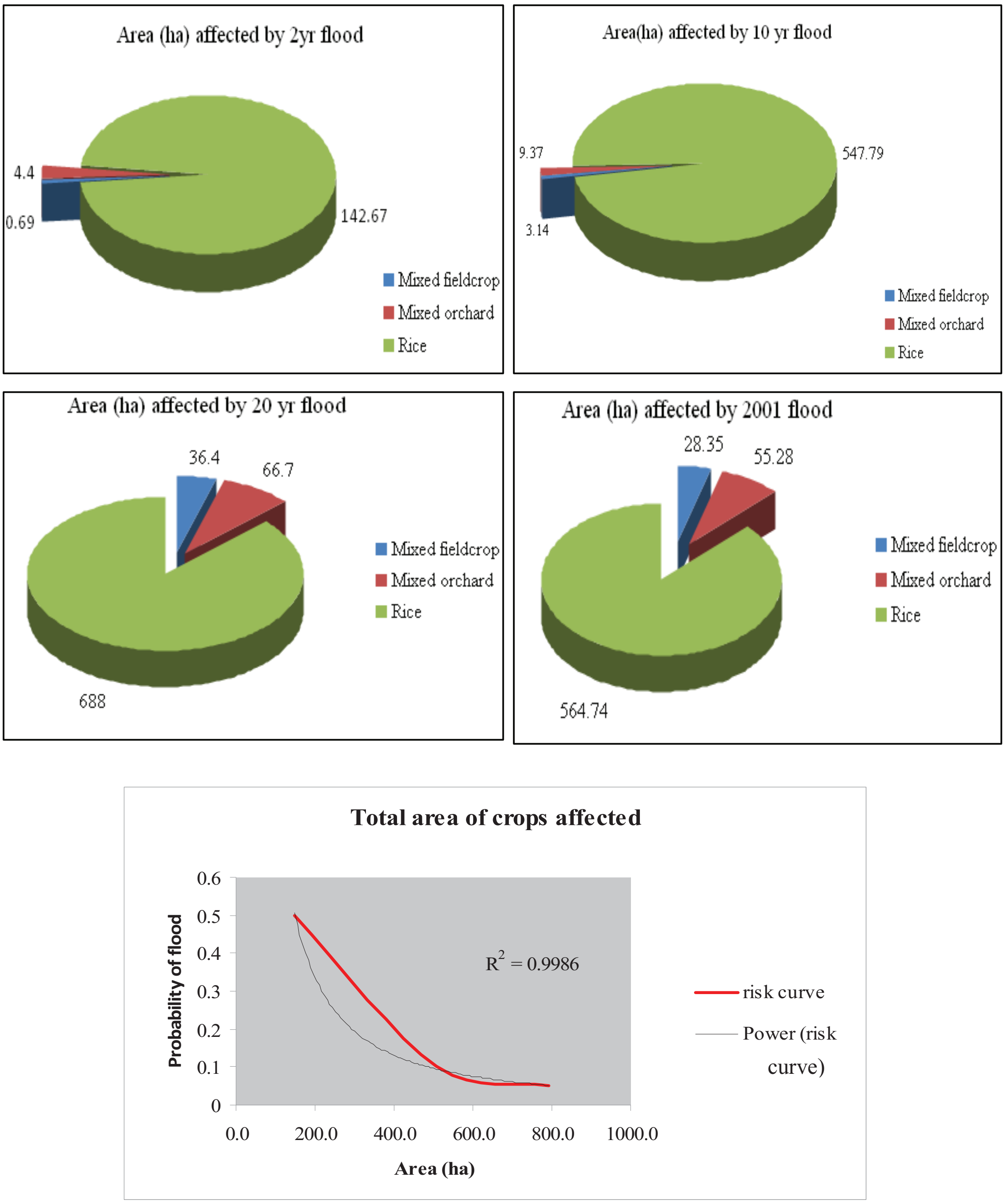


Figure 8.3: Shows total area of crops affected by 2, 10 and 20 years flood and risk curve.

From the results shown above in the pie chart (figure 8.3), the number of crop types affected by flood increases with return period. The risk curve (figure 8.3) shows the total area of agricultural crop affected for each flood hazard probability of occurrence. Thus, the higher return period gives bigger flooding which affects a larger area resulting in increase in loss. The damage to rice is 9,061494, 86,533711 and 89, 800542 (Baht/ha) for 2, 1 0 and 20 years return period flood respectively. The total area of all crops affected is 230.7, 356.4 and 799.8 (ha) for 2, 10 and 20 years return period flood respectively.

Rice loss estimation: The analysis continues with incorporating the vulnerability values from the vulnerability curve (figure 7.8, chapter 7) of Maiti (Maiti, 2007) in the loss estimation for rice. From the webpage (Biz Dimension), the standard price of rice in Thailand is 780 Baht per 100 kg. Rice yield is 2.45 mt/ha (FAO). Following the procedure mentioned above and with this information, the loss of rice due to flooding for all scenarios was determined in Baht per hectare then used to generate risk curve (rice risk curve in figure 8.3) and risk maps. Figure 8.4 shows the risk maps for rice.

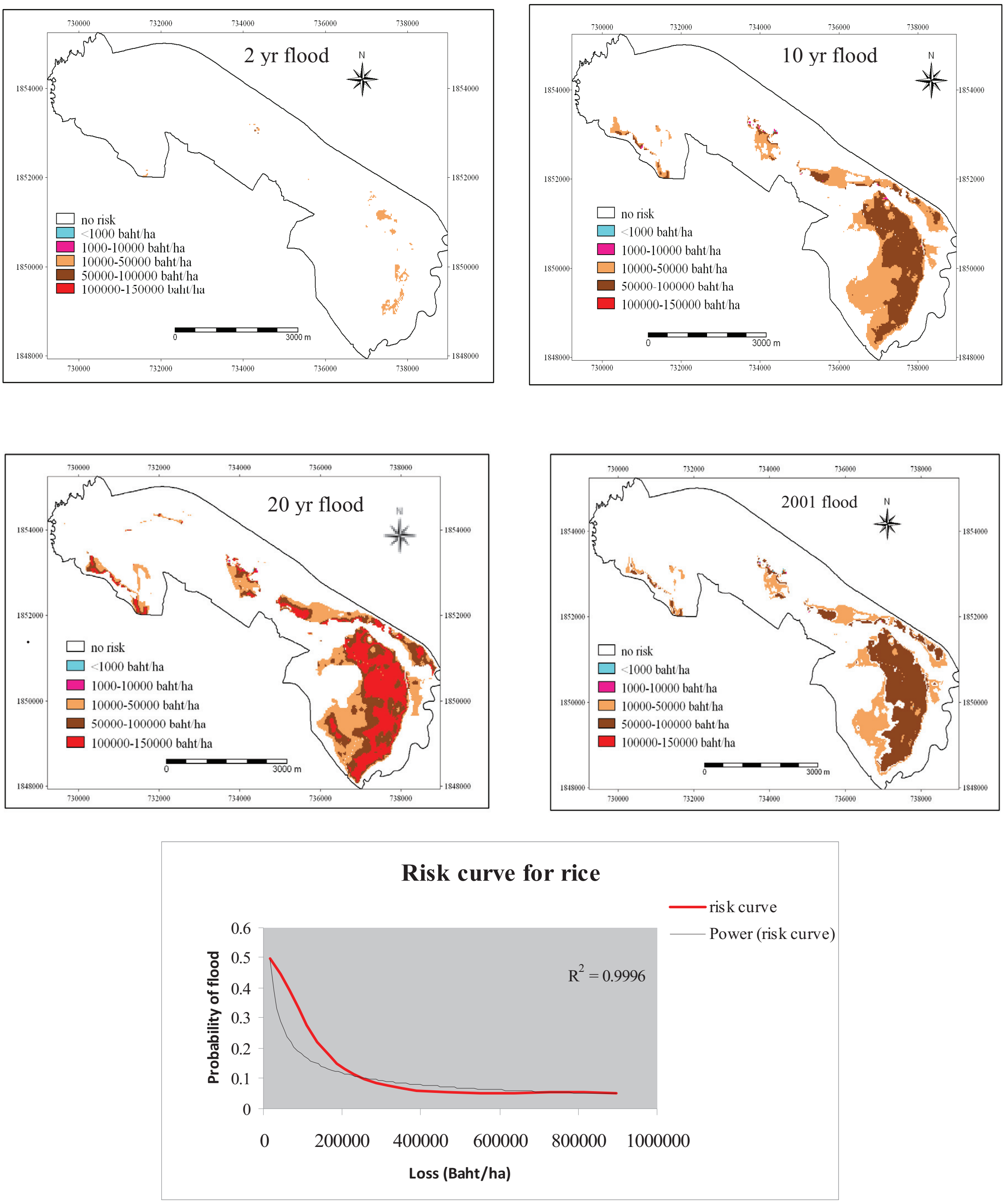


Figure 8.4: Spatial distribution of risk for rice for 2yr, 10yr, 20 years flood, 2001 event and risk curve.

From the results, the 10 and 20 years return period flood which rarely occurs causes much loss, the most loss being caused by the 20 years flood and less in the 2 years return period flood.

To evaluate the actual economic loss incurred by the people, their expenditure in terms of cost fertilizer used of farm per hectare or annually, labour cost, pesticides etc. should be considered. For this study, these were not taken into account because during the general interviews, the people could not give this necessary information.

The flood event of 2001 has not a defined return period. Though much damage was reported (World Vision; Yumuang, 2006) and from the general field interviews, this assessment does not portray it.

8.3. Risk to people and property

Population data is not available for this study hence the risk could not be quantified in term of population affected. The approach from literature (Smith graph) was used.

Flood risk can be expressed as a combination of other flood parameters such as flood velocity and depth for risk assessment (Ramsbottom et al., 2003; Smith, 1994). Smith, 2002 (Alkema et al., 2007) developed vulnerability relationship between hazard magnitude and the impact on elements exposed like stage damage curves that predict under what circumstances pedestrians and cars etc are washed away. The flood risk assessed by a combination of the flood velocity and depth based on the curves defining pedestrian safety to brick veneer (figure 8.5).

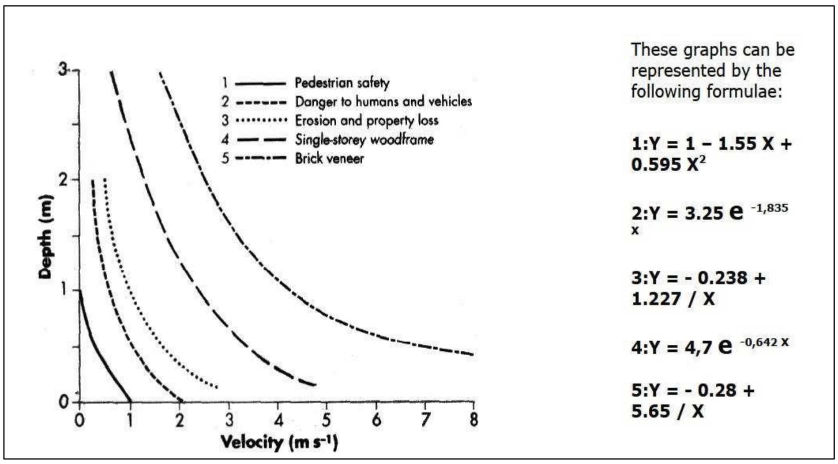
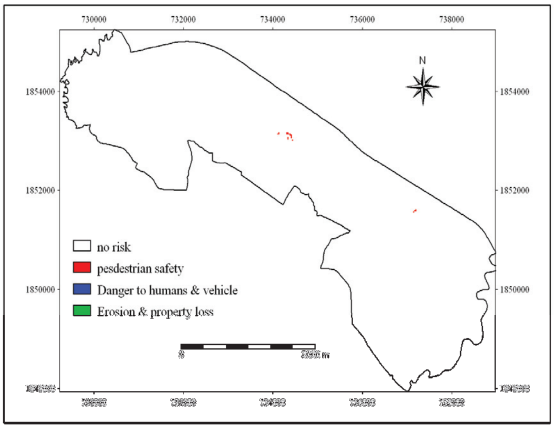
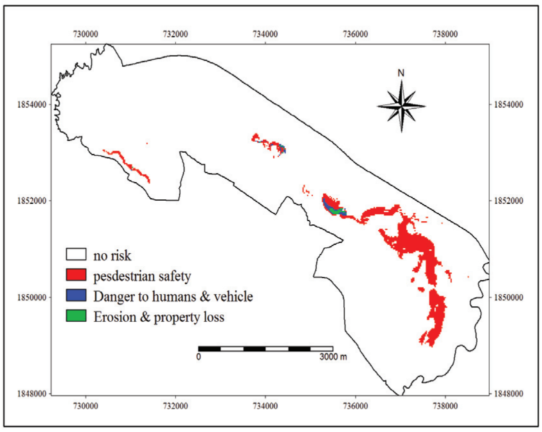


Figure 8.5: Smith graph

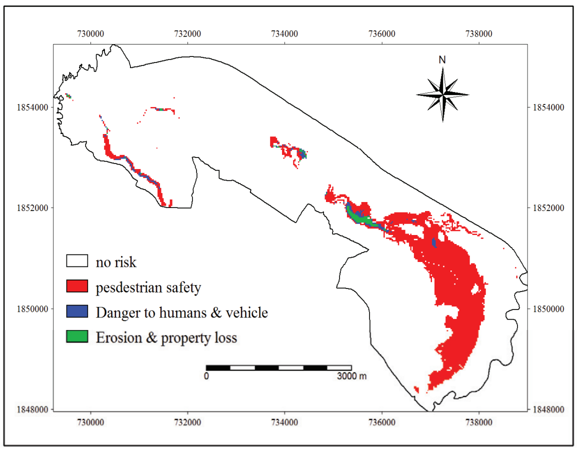
The flood risk assessment in this study is restricted to equations 1 to 3 which refers to 1) pedestrian safety, 2) danger to human and vehicles and 3) erosion and property loss. The results from (figure 5.12 and 5.14, chapter 5) the flood propagation modelling in Sobek gives maximum flood velocity and depth for each pixel. The maximum flood depth and velocity maps were combined using a script (appendix 4). If the velocity map is used for X, the critical depth is obtain if the actual depth map gives a higher value than the critical value, pedestrians, cars, buildings etc., are in danger. The output map of the script is then classified into flood risk map for all scenarios as shown below (figure 8.6).



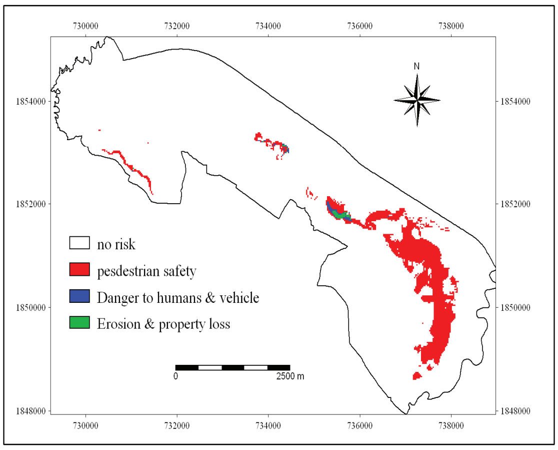
2 yr flood



10 yr flood



20 yr flood



2001 flood event

Figure 8.6: Shows spatial distribution of risk to people and property.

Table 8.1: The area affected by flood posing risk to people and property.

Risk category (by Smith)	Total area (ha) affected by flood			
	2 years	10 years	20 years	2001 flood
Pedestrian safety	1.23	139.21	320.91	200.83
Danger to humans & vehicle	nil	5.09	14.78	5.03
Erosion & property	nil	3.02	8.86	3.58

The results in Table 8.1 shows that the area that place pedestrians at risk is greatest compared to area for vehicle and property loss and it increase as the flood return period increase.

8.4. Risk to buildings expressed in number of buildings.

Due to lack of the required data as stated earlier (chapter 7), risk to buildings is expressed in terms of number of buildings affected by 2, 10 and 20 years return period flood. The flood parameter according to the people was the velocity, which causes destruction. Shallow water with a high flow velocity does not have a lot of kinetic energy (destructive force) or momentum and neither has deep, but practically still-standing water. Deep, fast flowing water however is dangerous especially to buildings (Alkema et al., 2007). The vulnerability of the buildings is considered related to the impulse, high impulse implies high vulnerability.

In this study impulse is used instead of the commonly used flood depth approach to assess risk building risk. The study area experiences flash floods which are usually associated with high velocity. The impulse is calculated at each time step by multiplying water depth and flow velocity maps (see script in appendix 3) from Sobek model results. The maximum impulse map (figure 5.13, chapter 5) is then crossed with the buildings footprint map in ILWIS using cross operation to obtain the buildings affected at various levels of impulse. Detailed calculation was done in Excel to calculate risk to buildings for all scenarios and generate risk curve as shown below (figure 8.8). Below is the spatial distribution of buildings with flood impulse.

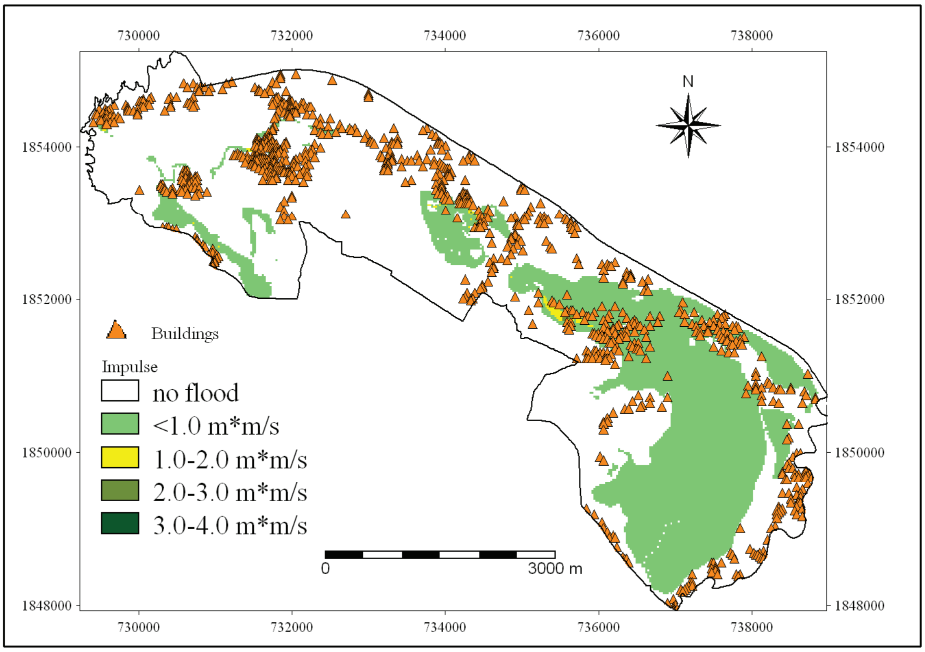


Figure 8.7: Spatial distribution of buildings and maximum flood impulse.

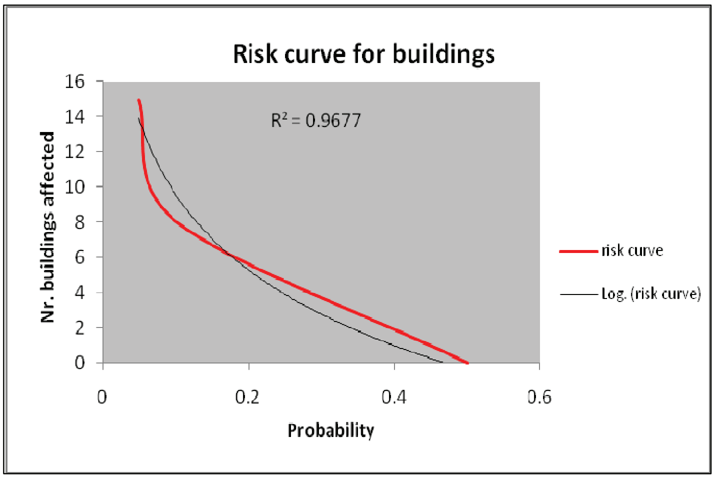


Figure 8.8: Risk curve for buildings.

From the results, no building was affected by 2 years flood, 8 and 15 buildings were affected by 10 years and 20 years flood respectively. This work does not include building cost, repair or contents cost. In risk assessment for building structures, it is ideal to include the cost of building, repair cost and cost of contents etc., to obtain a comprehensive assessment; and possibly require a structural engineer to evaluate the cost of buildings.

9. Conclusions and Recommendations

9.1. Conclusion

The general objective of this is to develop a methodology for semi-quantitative flood risk assessment for a rural area. This was done to find the best way of assessing flood risk for a rural setup. Flood hazard was assessed by simulating scenarios for the Nam Chun area using a hydrodynamic model (Sobek) and taking into account physical structures like bridges and culverts (section 5.5 and 5.6). Interviews generated a better insight and understanding of the flood risk perception of the people (section 6.2 and 6.3); Integration of this perception with the hydrodynamic modelling resulted in a rural flood risk assessment (section 8.2). To meet the study objectives, research questions (section 1.5) were development whose answers are provided below.

- What are the water flow distribution and the flood characteristics in the downstream area?

The study show that the total area inundated by flood increase as the rainfall amount and intensities increase. The average flood depth increases accordingly. There is an increase in the average velocity and impulse for 2, 20 and 20 years return period flood. The results of the modelling are presented in section 5.5, table 5.3 and figures 5.11 to 5.15. These show that the high hazard zone (20 years flood) covers 48.5 % of inundated area, medium hazard zone cover 37.9 % of inundated area and low hazard zone cover 13.6 % of inundated area. The average flood depth increase as 0.7 m, 1.2 m and 1.3 m for 2, 10 and 20 years return period respectively. The maximum flood depth was up to 1.4 m, 2.3 m and 2.5 m for 2, 10 and 20 years return period respectively. The same trend is observed for the velocity and impulse. Maximum velocity was 0.6, 2.7 and 4.1 m/s for 2, 10 and 20 years recurrence and the maximum impulse 0.14, 0.68 and 0.98 m^2/s for 2, 10 and 20 years recurrence respectively. Maximum warning time (figure5.15) for all scenarios vary from 1 hr to 9hrs with the lesser warning time to people living close to the upstream while those living further down at the lower part have more warning time for evacuation when flooding occurs.

- How do physical structures (such as bridges and culverts) affect the flow of floodwaters?

The presence of structures has increase the area inundated towards the upstream area. The total inundated area increase by 572.15 km^2 (section 5.6, table 5.4). Both the flood depth and impulse have increased. However, the maximum flood depth increased primarily towards the upstream side of the structures, whereas the maximum impulse and velocity increased towards the downstream part of the study area (figure 5.16). The velocity is 4.1 m/s without structures and 4.1 m/s with structures present.

The maximum flood depth has increase from 2.1m without structures to 2.5 m with structures and maximum impulse from 2.55 without structures to 3.24 m^2/s with structures present. The flood depth and impulse are the most influenced by the presence of structures

Comparing bridge and culvert (Figure 5.17), culverts has more influence on the characteristics particularly the circular shape culvert. An increase in the dimensions of both bridges and culvert will reduce the effect on flooding. Therefore it is concluded that the floodwater is influenced the bridge type and culvert shape.

- What is the rural public perception of the risk of flood hazard does it differ with location?

According to the people, the speed of flood coupled with short duration causes lots of damage to farms, buildings loss of lives. For those living downstream, their main concern is their economic status that is at stake when flood occurs because their farms are destroyed making them poor. The level of poverty varies with village in this area as some cultivate the land throughout the year whiles other do not and some villages rear cattle for extra income to farming. Those living upstream express more concern about the speed of flood because it cause loss of lives as 135 died in the 2001 flood caused by typhoon Usagi. The people expressed that the floodwater comes with much speed and within minutes causes destruction as it goes down stream with depth of 2m. There is no warning and limited time to move to safety.

- What is the risk in floods of 2, 10 and 20 years return periods?

Crops, people and buildings were the main concerns of the people hence the risk was assessed considering them for 2, 10 and 20 years return period floods. The total area of all crops affected by flood of 2, 10 and 20 years return period flood is 230.7, 356.4 and 799.8 (ha) respectively. Loss to rice was assessed in monetary terms (Baht per hectare) and the results show an increase in loss as the return period increases. Areas that place pedestrians at risk is greatest compared to the areas where vehicle and property are at risk; All areas increases with increase in the flood return period. The trend is same for buildings. No buildings were affected by the 2 years return period flood, 8 and 15 buildings were affected by 10 and 20 years return period floods respectively.

9.2. Recommendations

The inundated areas from the flood model (Sobek) output are less than expected. Since Sobek requires many cross section data, it is recommended that measurement of cross section for the entire Nam Chun River is carried out with at least two on each branch of the river. Regular and accurate rainfall measurement should be done at a number of locations in the catchment to obtain data that is representative of the area. Bridge type and culvert shape affect flooding as identified in this study. It is therefore recommended that further studies should consider the optimal location, type and size of these structures needed at a particular location in the event of storm to reduce flood hazard. It should also identify safe evacuation routes in the area.

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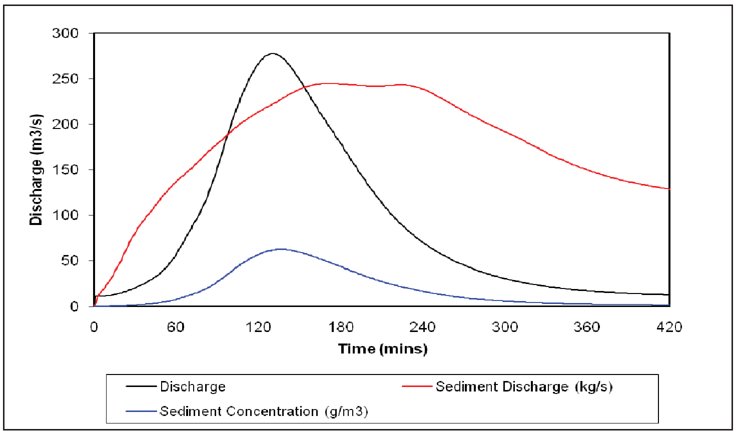
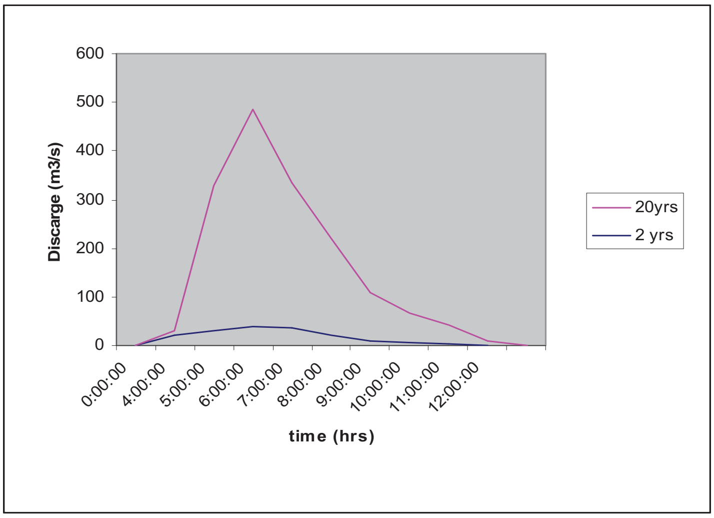
Appendix 1: Questionnaire

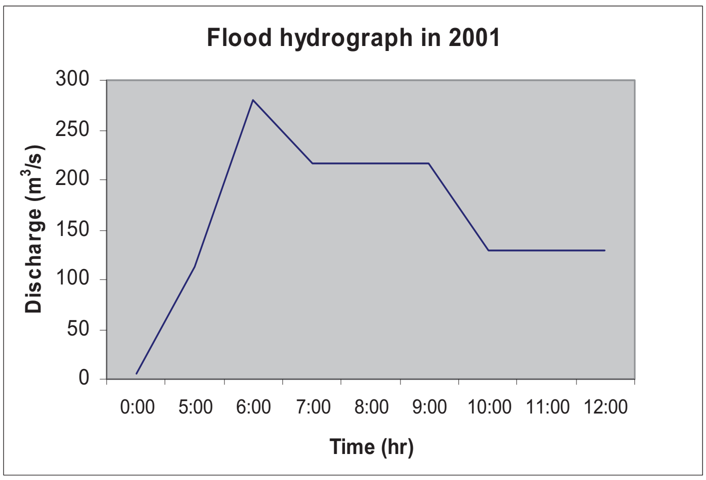
Questionaire						
Elements at risk inventory						
Place: Nam chun	Coordinates		Date	**Remarks**		
Zone: 2 (Namchun Yai)	X: 728881	Y:1854723	18/09/2008	Present at interview is Soil doctor and Village head		
Plot Id:						
Elevation:185m						
Physical Inventory						
Building				Materials		
Type:	Function:	Age:	State:	Roof:	Floor:	Protection:
House **x**	Residential x		New	Brick tile	Earth	Fenced
Mosque	Store		Recently renovated	Asbestos	Wood x	Not fenced x
Installation	Education		Good x	Iron sheet x	Concrete	Elevated x
Hut	Health center		Moderate	Wood	Tiles	Not elevated
Church	Religious center		Deteriorated	Other	other	
School	Other		Ruined			
			Abandoned			
				wall material: wood	Nr. Floors:	
Agriculture						
Farmland	Crop Type:	Animal Type:	Price of land	Price of livestock		
Livestock	mainly corn, tobacco, onions	Duck, chicken (for family)				
Crop Calender						
crop type	Planting month	harvest month				
maize	November	February				
Tobacco	November	February				
Rice	July	November				
chilli	July	February				
Onions	November	February	crop rotation with onions			
Economic Inventory						
Socioeconomic level:	Season:	Month				
Low income (wet season)	Crop season	Nov-Dec				
Middle income	Wet season	Aug-oct				
High income (After harvest) March-April	Other	Dry				
Do you store up crops in your house/ **Yes**/No						
Parcel ownership/rented/other						
Do you have another parcel/ Yes/No/ if yes where?						
Social Inventory						
Adults	Age	Education level	Occupation	Number		
Man/woman						
Elderly						
Flood Hazard						
Flood date	11-Aug-01					
Reported damage	2m of water	destroyed many buildings and killed people				
When did the flood occur? 3am						
Where did the water came from? From the mountains						
When does the flood waters become a disaster and how does it affect crops? The flood water comes suddenly and leaves quickly. Then leaves behind mud on their crops and destroy it. That is the problem						
How often does flood occur? Yearly						
How did you cope? Cannot do anything. There was no early warning.						
Did you leave your house? **Yes**/No/ if yes where did you go? Climb unto roof top and trees.						
Did you get help? **Yes**/No/if yes from where? Gov, NGOs other countries.						
After the 2001 event, do you now know what to do should such occur? **Yes**/No						
If yes what? Have early warning. The Gov has trained one person from each village to tell the people when its about to occur.						
Water height	2m					
Duration	3 hrs					
Do you know what to do in case of flood? Yes/**No**						
If yes what?						
How did you get this infomation? TV/radio,newspaper, etc						
Have you heard about World Vision? **Yes**/No They give the villagers fish to sell in order to generate income for themselves						
Do you know/are you a community leader? **Yes**/No						
Comments : Govt send trucks to remove the mud which takes 1month. The vulnerability of the people is gender independent; same level for both men and women. The information received from the soil doctor and the villagers was same.						

Appendix 2: Hydrographs used in Sobek.



a. Discharge for 10 years return period flood (source: Masters)





b. Discharge data for modelling (source: Prachansri)

Appendix 3: Script used to generate hazard parameter maps.

Impulse

```
Rem impulse

i02:=depth02*vel02
i03:=depth03*vel03
i04:=depth04*vel04
i05:=depth05*vel05
i05:=depth05*vel05
i06:=depth06*vel06
i07:=depth07*vel07
i08:=depth08*vel08
i09:=depth09*vel09
i10:=depth10*vel10
i11:=depth11*vel11
i12:=depth12*vel12

rem cal maximum impulse
max1:=max(i02,i03,i04)
max2:=max(i05,i06,i07)
max3:=max(i08,i09,i10)
max4:=max(i11,i12)

maxa:=max(max1,max2,max3)
puls:=max(maxa,max4)

del i??.mpr -force

del max?.mpr -force
del max??.mpr
```

Duration

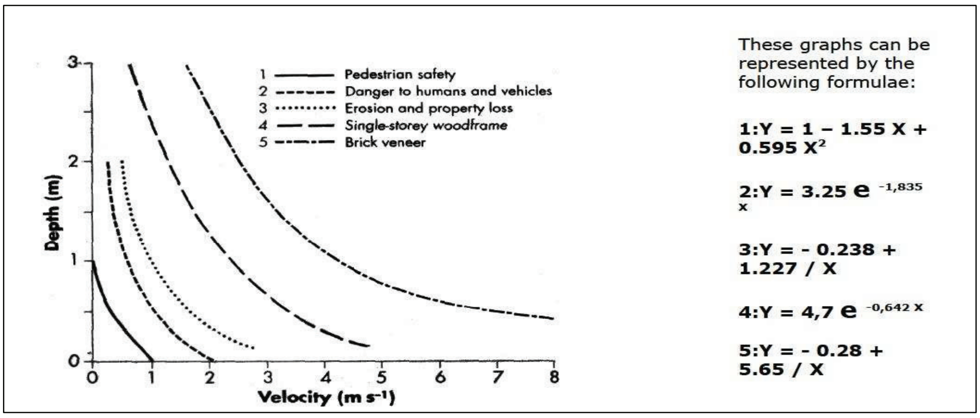
```
rem duration

t_hmax3:=iff(depth03>depth02,3,0)
t_hmax4:=iff(depth04>depth03,4,t_hmax3)
t_hmax5:=iff(depth05>depth04,5,t_hmax4)
t_hmax6:=iff(depth06>depth05,6,t_hmax5)
t_hmax7:=iff(depth07>depth06,7,t_hmax6)
t_hmax8:=iff(depth08>depth07,8,t_hmax7)
t_hmax9:=iff(depth09>depth08,9,t_hmax8)
t_hmax10:=iff(depth10>depth09,10,t_hmax9)
```

```
t_hmax11:=iff(depth11>depth10,11,t_hmax10)
t_hmaxh:=iff(depth12>depth11,12,t_hmax11)

duration:=(-1*depth_max)/((depth12-(depth_max+0.001))/12-tmaxh))+t_maxh

del t_hmax?.mpr -force
del t_hmax??.mpr –force
```

Warning time

```
rem warning time

wt01:=iff(depth01>0,1,999)
wt02:=iff(depth02>0,2,999)
wt03:=iff(depth03>0,3,999)
wt_a:=min(wt01,wt02,wt03)

wt04:=iff(depth04>0,4,999)
wt05:=iff(depth05>0,5,999)
wt06:=iff(depth06>0,6,999)
wt_b:=min(wt04,wt05,wt06)

wt07:=iff(depth07>0,7,999)
wt08:=iff(depth08>0,8,999)
wt09:=iff(depth09>0,9,999)
wt_c:=min(wt07,wt08,wt09)

wt10:=iff(depth10>0,10,999)
wt11:=iff(depth11>0,11,999)
wt12:=iff(depth12>0,12,999)
wt_d:=min(wt10,wt11,wt12)

wt_1:=min(wt_a,wt_b,wt_c)
wt:=min(wt_1,wt_d)
warning time:=if(wt<12,wt,undef)

del wt??.mpr -force
delwt_?.mpr -force
```

Appendix 4: Script used to generate risk maps.



Source: Lecture notes (Alkema, 2008)

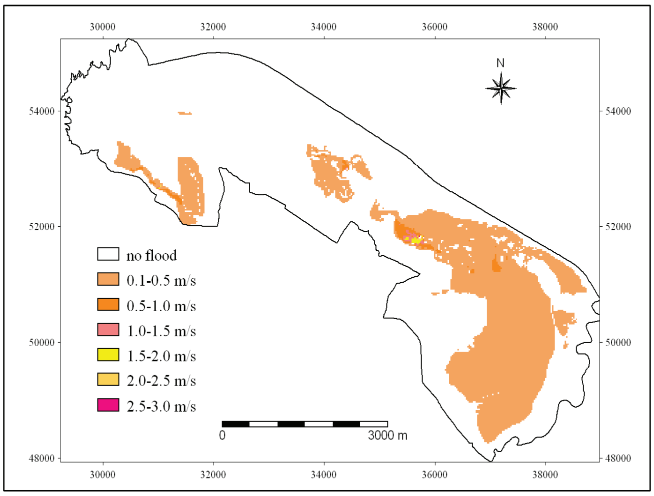
Flood risk

```
rem pedestrian safety

ps_02:=iff(depth02>(1-1.55*vel02+0.595*vel02^2),1,0)
ps_03:=iff(depth03>(1-1.55*vel03+0.595*vel03^2),1,0)
ps_04:=iff(depth04>(1-1.55*vel04+0.595*vel04^2),1,0)
ps_05:=iff(depth05>(1-1.55*vel05+0.595*vel05^2),1,0)
ps_06:=iff(depth06>(1-1.55*vel06+0.595*vel06^2),1,0)
ps_07:=iff(depth07>(1-1.55*vel07+0.595*vel07^2),1,0)
ps_08:=iff(depth08>(1-1.55*vel08+0.595*vel08^2),1,0)
ps_09:=iff(depth09>(1-1.55*vel09+0.595*vel09^2),1,0)
ps_10:=iff(depth10>(1-1.55*vel10+0.595*vel10^2),1,0)
ps_11:=iff(depth11>(1-1.55*vel11+0.595*vel11^2),1,0)
ps_12:=iff(depth12>(1-1.55*vel12+0.595*vel12^2),1,0)

p1:=max(ps_02,ps_03,ps_04)
p2:=max(ps_05,ps_06,ps_07)
p3:=max(ps_08,ps_09,ps_10)
safe_ped:=max(p3,ps_11,ps_12)

rem human and vehicles
hv_02:=iff(depth02>(3.25*exp(-1.835*vel02)),2,0)
hv_03:=iff(depth03>(3.25*exp(-1.835*vel03)),2,0)

hv_04:=iff(depth04>(3.25*exp(-1.835*vel04)),2,0)
hv_05:=iff(depth05>(3.25*exp(-1.835*vel05)),2,0)
```

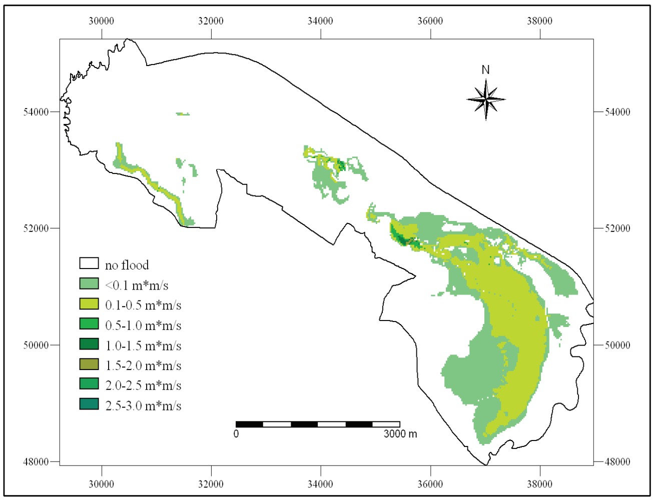
```
hv_06:=iff(depth06>(3.25*exp(-1.835*vel06)),2,0)
hv_07:=iff(depth07>(3.25*exp(-1.835*vel07)),2,0)
hv_08:=iff(depth08>(3.25*exp(-1.835*vel08)),2,0)
hv_09:=iff(depth09>(3.25*exp(-1.835*vel09)),2,0)
hv_10:=iff(depth10>(3.25*exp(-1.835*vel10)),2,0)
hv_11:=iff(depth11>(3.25*exp(-1.835*vel11)),2,0)
hv_12:=iff(depth12>(3.25*exp(-1.835*vel12)),2,0)

h1:=max(hv_02,hv_03,hv_04)
h2:=max(hv_05,hv_06,hv_07)
h3:=max(hv_08,hv_09,hv_10)
safe_hv:=max(h3,hv_11,hv_12)

rem erosion and property loss
pl_02:=iff(depth02>(-0.238+1.227/(vel02+0.0000001)),3,0)
pl_03:=iff(depth03>(-0.238+1.227/(vel03+0.0000001)),3,0)
pl_04:=iff(depth04>(-0.238+1.227/(vel04+0.0000001)),3,0)
pl_05:=iff(depth05>(-0.238+1.227/(vel05+0.0000001)),3,0)
pl_06:=iff(depth06>(-0.238+1.227/(vel06+0.0000001)),3,0)
pl_07:=iff(depth07>(-0.238+1.227/(vel07+0.0000001)),3,0)
pl_08:=iff(depth08>(-0.238+1.227/(vel08+0.0000001)),3,0)
pl_09:=iff(depth09>(-0.238+1.227/(vel09+0.0000001)),3,0)
pl_10:=iff(depth10>(-0.238+1.227/(vel10+0.0000001)),3,0)
pl_11:=iff(depth11>(-0.238+1.227/(vel11+0.0000001)),3,0)
pl_12:=iff(depth12>(-0.238+1.227/(vel12+0.0000001)),3,0)

pl1:=max(pl_02,pl_03,pl_04)
pl2:=max(pl_05,pl_06,pl_07)
pl3:=max(pl_08,pl_09,pl_10)
epl:=max(pl3,pl_11,pl_12)

max02:=max(ps_02,hv_02,pl_02)
max03:=max(ps_03,hv_03,pl_03)
max04:=max(ps_04,hv_04,pl_04)
max05:=max(ps_05,hv_05,pl_05)
max06:=max(ps_06,hv_06,pl_06)
max07:=max(ps_07,hv_07,pl_07)
max08:=max(ps_08,hv_08,pl_08)
max09:=max(ps_09,hv_09,pl_09)
max10:=max(ps_10,hv_10,pl_10)
max11:=max(ps_11,hv_11,pl_11)
max12:=max(ps_12,hv_12,pl_12)


max_a:=max(max02,max03,max04)
```

```
max_b:=max(max05,max06,max07)
max_c:=max(max08,max09,max10)

Max_floodrisk:=max(max_c,max11,max12)

del ps_??.mpr -force
del hv_??.mpr -force
del pl_??.mpr -force

del h??.mpr -force
del p??.mpr -force

del max??.mpr -force
del max_?.mpr –force
```

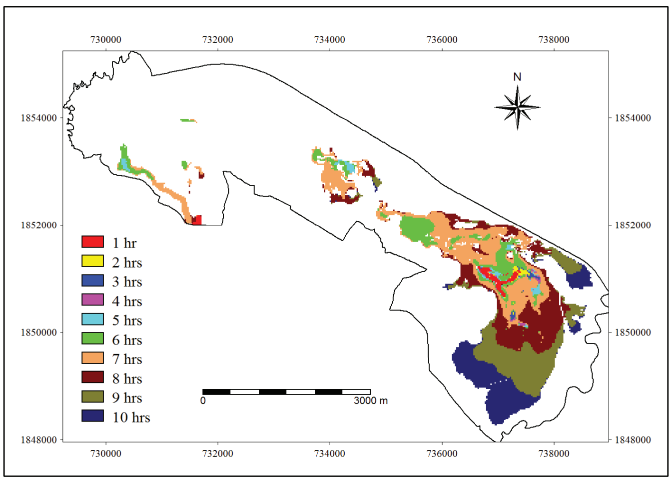
Appendix 5: Maximum flood velocity, impulse and warning time for 2001 event.



Maximum velocity



Maximum impulse



Appendix 6: Structural type and maintenance state observed during field survey.

Maint state	Structure Type	X	Y
Good	Type1	732781	1853811
Moderate	Type1	730316	1853483
Moderate	Type1	730314	1853506
Moderate	Type1	730362	1853453
Moderate	Type1	730425	1853431
Moderate	Type1	730453	1853408
Moderate	Type1	730629	1853444
Moderate	Type1	730711	1853478
Moderate	Type1	730782	1853460
Moderate	Type1	730885	1853435
Moderate	Type1	730781	1853439
Moderate	Type1	730350	1852948
Moderate	Type1	730384	1852960
Moderate	Type1	730516	1852907
Moderate	Type1	730869	1852967
Moderate	Type1	730960	1852576
Moderate	Type1	731738	1853809
Moderate	Type1	731701	1853820
Moderate	Type1	731607	1853854
Moderate	Type1	731490	1853880
Moderate	Type1	731650	1853796
Moderate	Type1	731541	1853851
Moderate	Type1	731677	1853743
Moderate	Type1	731653	1853704
Moderate	Type1	731605	1853681
Moderate	Type1	731724	1854085
Moderate	Type1	731715	1854116
Good	Type1	732056	1854439
Good	Type1	732132	1854439
Good	Type1	732307	1854421
Good	Type1	732726	1853749
Good	Type1	732141	1853726
Good	Type1	734475	1852965
Good	Type1	734838	1852690
Good	Type1	734888	1852808
Moderate	Type1	736039	1851656
Moderate	Type1	736065	1851525
Moderate	Type1	736187	1851744
Moderate	Type1	737577	1851533
Moderate	Type1	737396	1851602
Moderate	Type1	737230	1851562
Moderate	Type1	737157	1851707
Good	Type2	734937	1852857
Poor	Type3	729127	1854698
Moderate	Type3	729109	1854721
Moderate	Type1	729187	1854650
Good	Type1	729261	1854687
Good	Type1	728881	1854723
Good	Type2	730765	1853626
Good	Type3	735403	1852098
Good	Type2	736183	1851023