A DRAFT GUIDE TO FLOOD RISK ASSESSMENT

DATA COLLECTION SURVEY ON ASEAN REGIONAL COLLABORATION IN DISASTER MANAGEMENT

DECEMBER 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
ALMEC CORPORATION
MITSUBISHI RESEARCH INSTITUTE, INC.

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Abbreviation and Acronym

ASEAN	:	Association of Southeast Asian Nations
AADMER	:	ASEAN Agreement for Disaster Management Emergency Response
ADPC	:	Asian Disaster Preparedness Center
AHA	:	ASEAN Coordination Center for Humanitarian Assistance on Disaster Management
BCP	:	Business Continuity Plan
BCPR-UNDP	:	Bureau for Crisis Prevention and Recovery-United Nations Development Programme
CMYK	:	Cyan-Magenta-Yellow-Black
CRED	:	Centre for Research on Epidemiology of Disaster
DGPS	:	Differential Global Positioning System
DRM	:	Disaster Risk Management
DRR	:	Disaster Risk Reduction
DTM	:	Digital Terrain Model
EM-DAT	:	Emergency Events Database
ESA	:	European Space Agency
FEMA	:	Federal Emergency Management Agency
GDIN	:	Global Disaster Information Network
GFDRR	:	Global Facility for Disaster Risk Reduction
GIS	:	Geographic Information Systems
GRASS	:	Geographic Resources Analysis Support System
HFA	:	Hyogo Framework for Action
ICHARM	:	International Center for Water Hazard and Risk Management
IDRD	:	International Disaster Reduction Day
IIRS	:	Indian Institute of Remote Sensing
IPOCM	:	Incident Preparedness And Operational Continuity Plan
ISDR	:	International Strategy for Disaster Reduction
ISO/IEC	:	International Organization for Standardization/International Electrotechnical Commission
ISO/PAS	:	International Organization for Standardization/Publicly Available Specification
JICA	:	Japan International Cooperation Agency
LIDAR	:	Light Detection And Ranging
MBES	:	Multi Beam Eco-Sounder Surveying
MLIT	:	Ministry of Land, Infrastructure and Transport
NASA	:	National Aeronautics and Space Administration
NCRIM	:	Natural Catastrophe Risk Insurance Mechanisms
NFIP	:	National Flood Insurance Program
OC	:	Operational Continuity
OCM	:	Operational Continuity Management
OCP	:	Operational Continuity Plan

PPP	:	Public Private Partnerships
PRA	:	Participatory Rural Appraisal
RTK-GPS	:	Real Time Kinematic GPS
SAR	:	Synthetic Aperture Radar
UK	:	United Kingdom
UNDHA	:	United Nations Department of Humanitarian Affairs
UNISDR	:	United Nations International Strategy for Disaster Reduction
UNOCHA	:	United Nations Office for the Coordination of Humanitarian Affairs
USACE	:	United States Army Corps of Engineers
WHO	:	World Health Organization
WMO	:	World Meteorological Organization

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CHAPTER 1 INTRODUCTION

1.1 Background

The ten countries of the Association of Southeast Asian Nations (ASEAN), Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam are geographically in one of the most disaster prone regions of the world in particular flood. Almost all types of natural hazards are present, including typhoons, floods, earthquakes, tsunamis, volcanic eruptions, landslides, forest fires, and epidemics. The ASEAN region located between the Pacific Ocean and the Indian Ocean causing seasonal typhoons (strong tropical cyclones). Typhoons are the most prevalent hazard in the region, causing destruction to human life, buildings, agricultures, industries, commerce and infrastructure alike, causing flooding and landslides or mudslides.

Often these disasters transcend national borders and overwhelm the capacities of individual countries to manage them. Most countries in the region have limited financial resources and physical resilience. The level of preparedness and prevention varies from country to country and regional cooperation does not exist to the extent necessary.

With the aim of reducing ASEAN's vulnerability to the risk of disasters, the World Bank, United Nations International Strategy for Disaster Reduction (UNISDR), through the Global Facility for Disaster Risk Reduction (GFDRR), and in collaboration with other international partners have started support for implementing the ASEAN Agreement for Disaster Management Emergency Response (AADMER) to promote sustainable development in the ASEAN region. The AADMER is a regional legally binding agreement that binds ASEAN Member States together to promote regional cooperation and collaboration in reducing disaster losses and intensifying joint emergency response to disasters in the ASEAN region. AADMER is also ASEAN's affirmation of its commitment to the Hyogo Framework for Action 2005-2015 (HFA) endorsed by 168 countries.

As the first phase of AADMER Work Program 2010-2015, the ASEAN Coordination Center for Humanitarian Assistance on Disaster Management (AHA Center) was established in November 2011.

1.2 Purpose

The purpose of the draft guideline on flood risk assessment (hereinafter called the draft guide) is to serve as guideline or reference for all ASEAN countries involving the flood disaster management and risk reduction at the national level, in order to facilitate appropriate procedure or methodology toward establishing a common guideline or standard in the future. At present it does not intend to make a unified guideline among ASEAN countries, but it expects to clarify respective technical and policy level on this subject among ASEAN countries.

The task of the Study Team is to sound consensus building on the draft guide through two workshops scheduled in Jakarta with participation of representatives of the ten countries.

1.3 Contents of the Guide

Contents of the Guide is composed of part which is originally drafted by the Study Team and part which is adopted or edited from the excellent existing guidelines, reports and references identified trough literature survey.

The Guide consists of seven chapters as follows:

1. Introduction
2. Why We need a Standard for Flood Risk Assessment
3. Challenges and Existing Initiatives
4. Framework of Methodology: Definition, Process and Purposes
5. Assessment of Flood Hazard
6. Assessment of Vulnerability and Risk
7. Application of Flood Risk Assessment

Chapter 1 and Chapter 2 address the background why a guidelines or a standard for flood risk assessment is necessary in ASEAN countries. Chapter 3 addresses challenges to be overcome for achieving the goal, and introduces issues and lessons identified in the existing international initiatives, activities and institutional arrangements relating to flood risk assessment.

Chapters 4, 5 and 6 are the key descriptions of methodologies and protocols of flood risk assessment. Those paragraphs, figures and tables in those Chapters specify the essential requirements for flood risk assessment in ASEAN nations that the study team proposes. Technical experts such as those engineers, scientists and professionals may read only the technical core of the Guide; Chapters 4, 5 and 6.

Chapter 4 describes the framework of methodology including basic definition of hazard, vulnerability and risk to avoid confusion or misunderstanding of the difference between the three key analytical objectives required for flood risk assessment. The key definitions of United Nations International Strategy for Disaster Reduction (UNISDR 2004) for hazard, vulnerability and risk are applied to the Guide to achieve the purpose in Section 1.2. In particular risk is defined as the probability of harmful consequences or expected loss instead of various factors or indices. Importance of a probabilistic approach is noted in addition to a deterministic approach. It also clarifies the scale and accuracy of geographic information to be overlaid with specific analysis depending on their purposes.

Chapter 5 presents the methodology how to identify and assess flood hazard and how to produce flood hazard maps which constitutes the basis of flood risk assessment. Chapter 6 addresses technical difference between flood vulnerability assessment and flood risk assessment, and introduces mapping methodology of those. Chapter 7 describes application of the results of flood risk assessment for disaster prevention, mitigation and preparation.

CHAPTER 2 WHY WE NEED A STANDARD FOR FLOOD RISK ASSESSMENT

To tackle with the increasing risk of flood disasters due probably to climate change and development activities**,** it is needed to share knowledge of flood disasters through cooperation in a wide area. Also to respond quickly and effectively when the flood occurred, a regional cooperation in exchanging risk information is very essential. The premise of a wide area of cooperation is common understanding about the flood disasters, their causes and the impacts. In addition, there is a need to promote a common method to implement appropriate flood risk assessment under the cooperative system.

2.1 Understanding Flood

(1) Definition of flood

A flood is defined by Oxford English Dictionary as “An overflowing or irruption of a great body of water over land in a built up area not usually submerged.”, or by The Random House Dictionary of the English Language as “A great flowing or overflowing of water, especially over land not usually submerged, or any great outpouring of stream.”

Flood, by Pacific Disaster Centre (PDC) is defined as “Any condition, meteorological or otherwise in which normally dry land is covered by standing or moving water. Flash flooding, according to a report by the Alabama Cooperative Extension, is the No. 1 cause of death associated with thunderstorms; and NOAA reports that flooding is the No. 2 weather-related cause of death.” EM-DAT simply defines flood as “Significant rise of water level in a stream, lake, reservoir or coastal region.”

How floods are generated? Floods are not able to be explained by amount of rainfall only. Floods usually result from a combination of meteorological, hydrological and hydraulic extremes, such as extreme precipitation (rainfall), infiltration into the ground, runoff from ground surface and underground and flows in and/or over river channels, lakes, ponds, ground surface, etc. However they can also occur as a result of human activities such as unplanned growth and development in flood plains, or from the breach of dams, miss operation of reservoir operation or overtopping of an embankment that fails to protect planned development.

(2) Types and causes of flooding

In the ASEAN Region floods are the most frequently occurring destructive natural events, affecting both rural and urban settlements.

In terms of disaster management, it is necessary to understand flood hazards during flood emergencies, as well as before an event actually takes place, in order to allow for mitigation, preparation and damage reduction activities. The management of flood risk requires knowledge of the types and causes of flooding.

This understanding is essential in designing measures and solutions which can prevent or limit damage from specific types of flood. Equally important is the knowledge of where and how often flood events are likely to occur. This is a critical step in understanding the necessity, urgency and priority for flood risk mitigation.

Understanding flood hazard requires knowledge of the different types of flooding, their probabilities of occurrence, how they can be modelled and mapped, what the required data are for producing hazard maps and the possible data sources for these. A detailed understanding of the flood hazard relevant to different localities is also crucial in implementing appropriate flood risk reduction measures such as development planning, forecasting, and early warning systems.

As flood risk evolves over time it also becomes relevant to explore how these decisions will need to change in the light of anticipated climate changes. Information about the existing models used to account for climate change at different scales and the uncertainties regarding those results are both important issues which need to be accommodated in any decision making process[1].

Table 2.1 Types and Causes of Floods

Types of flooding	Causes		Onset time	Duration
	Naturally occurring	Human induced		
Urban flood	Fluvial (river), Coastal, Flash, Pluvial (overland), Groundwater	Saturation of drainage and sewage capacity, Lack of permeability due to increased concretization, Faulty drainage system and lack of management	Varies depending on the cause	From few hours to days
Pluvial and overland flood	Convective thunderstorms, severe rainfall, breakage of ice jam, glacial lake burst, earthquakes resulting in landslides	Land used changes, urbanization, Increase in surface runoff	Varies	Varies depending upon prior conditions
Coastal (Tsunami, storm surge)	Earthquakes, Submarine volcanic eruptions, Subsidence, Coastal erosion	Development of coastal zones, Destruction of coastal natural flora (e.g., mangrove)	Varies but usually fairly rapid	Usually a short time however sometimes takes a long time to recede
Groundwater	High water table level combined with heavy rainfall, Embedded effect	Development in low-lying areas; interference with natural aquifers	Usually slow	Longer duration
Flash flood	Can be caused by river, pluvial or coastal systems; convective thunderstorms; GLOFs	Catastrophic failure of water retaining structures, Inadequate drainage infrastructure	Rapid	Usually short often just a few hours
Semi-permanent flooding	Sea level rise, land subsidence	Drainage overload, failure of systems, inappropriate urban development, Poor groundwater management	Usually slow	Long duration or permanent

Source: Cities and Flooding 2012, pp 56-57

[1] Content of the sub-sections (2) is mainly adopted from Cities and Flooding 2012, p 54-55.

Descriptions and categorizations of floods vary and are based on a combination of sources, causes and impacts. Based on such combinations, floods can be generally characterized into river (or fluvial) floods, pluvial (or overland) floods, coastal floods, groundwater floods or the failure of artificial water systems. Based on the speed of onset of flooding, floods are often described as flash floods, urban floods, semi-permanent floods, and slow rise floods[2].

All the above-mentioned floods can have severe impacts on both urban and rural areas. It is important to understand both the cause and speed of onset of each type to understand their possible effects on urban and rural areas and how to mitigate their impacts. Table 2.1 summarizes the type and causes of flooding.

(3) The Probability of flooding

A sound understanding of the likelihood of occurrence of a flood hazard is a fundamental step in dealing with flood risk[3].

Prediction of weather event and flood event in terms of probability

It is important to distinguish between the probability of occurrence of a weather event and the probability of occurrence of a flood event. Flooding is primarily driven by weather events which are hard to predict due to what is termed their chaotic nature. In other words, despite the great advances in weather forecasting, it cannot be determined with certainty when and where rain will fall or storms will form. This means that it is impossible to know exactly when and where a flood will occur in the future, nor how high (either in water level or discharge) the next flood will be. Hazard predictions are commonly given in terms of probabilities, computed using historical data for the area of interest.

Uncertainties involved in recurrence interval

The recurrence interval or return period is defined as the average time between events of a given magnitude assuming that different events are random. The recurrence interval or return period of floods of different heights varies from catchment to catchment, depending on various factors such as the climate of the region, the width of the floodplain and the size of the channel. The recurrence interval is specific to a particular river catchment.

In Europe and Asia, partial records extending over centuries may be found, a data may be scarce and records are rarely longer than for 50 years. This poses an important limitation to the calculation of recurrence intervals which must be taken into account when evaluating and communicating uncertainties in flood probability estimations.

Uncertainties involved in flood provability estimations

Once the recurrence intervals are determined based on the historical record, some assumption about the flood frequency distribution has to be made in order to extrapolate or interpolate to events that have not been recorded historically. To achieve this, an assumption about the distribution of flood frequency has to be made. In this way the recurrence interval for any

[2] Refer to the definition of different type of floods in Section 1.2 of Cities and Flooding 2012, p 55-64.
[3] Refer to further details of the probability of flooding in Section 1.3 of Cities and Flooding 2012, p 64-70.

discharge (and not just those present in the observational record) can be inferred. In short various uncertainties are involved in flood provability estimations.

Difference of recurrence interval and flood probability

The recurrence interval, as discussed above, refers to the past occurrence of floods, whilst flood probability refers to the future likelihood of events. The two concepts are related because the recurrence interval of past events is usually used to estimate the probability of occurrence of a future event.

For any discharge, or alternatively, any recurrence period, the probability of occurrence is the inverse of the return period p=1/T

Using the relationship between return period T and flood probability p, it is clear that a flood discharge that has a 100-year recurrence interval has a one percent chance of occurring (or being exceeded) in a given year[4].

2.2 Understanding Flood Hazard and Impacts

2.2.1 Flood hazard

(1) Definition of flood hazard

The concept of hazard is defined as the potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (UNISDR 2004).

Hazard events have a probability of occurrence within a specified period within a given area and have a given intensity. Studies related to analysis of physical aspects and phenomena through the collection of historical or near real time records are called hazard assessment. For a better understanding of the nature of flooding, three main aspects are taken into consideration: the probability of occurrence, the magnitude and intensity of occurrence and the expected time of next future occurrence (ADPC 2002).

Flood hazard mapping is an important step for 1) understanding the probable hazard situation, 2) planning development activities, and 3) supplementary decision making of recovery/reconstruction and prevention measures in an area. The identified hazard should therefore be easily interpreted into simple hazard maps which can be read and understood by both technical and non-technical individuals. There is, therefore, a need to flexibly generate images based on user-specific requirements, whether for individual or institutional purposes. Flood hazard maps normally are prepared based on specified flood frequencies or return periods, for example, 1:10 years, 1:25 years, 1:100 years, or to more extreme events such as the 1:1000 year return period for different scales[5].

[4] The probability of a 100-year flood occurring in any of the next 100 years is 0.636, closer to two-thirds.
[5] Information referred from Cities and Flooding 2012, p 71.

The identifiable flood hazards under such multiple scenarios (flood recurrence interval) should also be converted into digitalized data[6] be easily put into geographic information systems to dynamically process with other information such as vulnerability and susceptibility of an area so that the hazard information is used in order to further analyse disaster risks and impacts.

(2) Distinction of flood hazard assessment from flood risk assessment

Hazard assessment is distinct from risk assessment. The hazard maps are distinct from the risk maps accordingly. Definition of flood hazard assessment and flood risk assessment is presented in Sections 4.1 and 4.2. Methodology of flood hazard identification and mapping is presented in Chapter 5. Flood risk assessment is presented in Chapter 6.

2.2.2 Flood impacts

(1) Dynamic impacts of flooding

Excess water, as a consequence of flooding, in and of itself is not a problem. Rather, the impacts of flooding are imposed when the excess water interacts with natural and human-made environments in a negative sense, causing damage, death and disruption. The impacts of flooding on a rural agricultural area, urban industrial and commercial area and slum area will be very different. In the traditional farming in Asia the flood is a natural harnessed or endured for the long-term benefits for farmers, but for the urban dweller flooding is at worst a disaster which destroys all possessions. Impacts are also changing and dynamic due to development including urbanization. For example harness would be turned into an impact for farmers by transferring their traditional farming to modern farming. Impacts of flooding are also classified into direct impacts and indirect impacts.

(2) Direct and indirect impacts of flooding

The direct impacts of flooding will be imposed on primary receptors including people (risk to life and health), the urban and rural built environment, infrastructure, utilities, industrial, commercial and family assets, and farming areas. In cities and towns, flooding in housing and households, underground spaces, including subways, basement floors and utility facilities under the ground, is also typical. Fast flowing floodwaters are capable of washing away entire buildings and communities. Indirect effects include the loss of industrial or business processes.

Flood events can have a variety of impacts on businesses, ranging from direct physical impacts to indirect effects (loss of industrial or business processes including supply chains). Damage to premises, equipment and fittings; loss of stock; reduced customer visits and sales as well as disruption to business activities are among the common effects.

[6] Digitized flood hazard data can be easily converted into geographic information systems.

Box 2.1 Potential Consequences of Flooding-related Disruption

Specific guidance on the social, economic and environmental impacts of disruption to essential services is limited. The UK's Water Services Regulation Authority, known as Ofwat, provides a framework listing the following as potential consequences of flooding-related disruption of water infrastructure:

- Loss of state revenues due to non-functioning of the private sector
- Costs associated with state support for provision of emergency supplies if interruption is substantial
- Inconvenience of interruptions due to service loss
- Health risk due to contamination of water supply and the environment
- Extra clean-up costs due to wastewater mixing with flood water and entering property
- Environmental pollution due to wastewater mixing with flood water

Source: Ofwat 2009

The characteristics of a flood, including flood depth, duration and contaminants, will influence the extent of damage caused to a building. The speed of flooding can also determine the extent of the damage: flash flooding, for example, can completely destroy properties or cause irreparable structural damage. In a slow rise flood, static floodwater can also damage buildings.

(3) Indirect impacts and other effects of flooding

In addition there are indirect impacts caused by the complex interactions within the natural environment and the human use of resources. Such indirect impacts can be hard to immediately identify and to quantify the value. These indirect impacts can be subdivided into four major groups such as natural environment, human and social impacts (demographic changes, health impacts, human development impacts), economic and financial impacts (impact on long-term economic growth, impact on development goals, impact on livelihoods, business interruption) and political and institutional issues[7].

(4) Method of assessing impacts

The method of assessing flood impacts of flood vulnerability is presented in Chapter 6.

2.3 Establishing Qualified Flood Risk Assessment

Scientific and credible data is a basis for transparent and accountable governance. Qualified flood risk assessment build the basis of flood disaster management.

2.4 Regional Coordination of Risk Reduction

(1) ASEAN's regional collaboration in disaster risk reduction

Despite the growing understanding and acceptance of the importance of disaster risk reduction and increased disaster response capacities, disasters in particular the management and reduction of risk continue to pose a global challenge.

[7] Refer to further details in Section 2.3 and Section 2.4 of Cities and Flooding 2012.

There is now international acknowledgement that efforts to reduce disaster risks must be systematically integrated into policies, plans and programmes for sustainable development and poverty reduction, and supported through bilateral, regional and international cooperation, including partnerships. In order to meet the challenges ahead, accelerated efforts must be made to build the necessary capacities at the community and national levels to manage and reduce risk. Such an approach is to be recognized as an important element for the achievement of internationally agreed development goals, in particular in ASEAN.

The importance of promoting disaster risk reduction efforts on the international and regional levels as well as the national and local levels has been recognized in the past few years.

(2) Mission of flood risk assessment

The risk assessment constitutes the foundation of the strategic components, the core strategies and pillars that translate the spirit of AADMER and the principles of ASEAN in disaster management into concrete actions: Risk Assessment, Early Warning and Monitoring, Prevention and Mitigation, Preparedness and Response, and Recovery.

Events of hydro-meteorological origin constitute the large majority of disasters owing to the global climate change and progressive urbanization. A common guideline or standard for flood risk assessment is now anticipated in order to facilitate appropriate procedure or methodology for ASEAN’s collaborative work. Flood risk assessment also provides basic information for an regional business continuity plan and safety preparedness in industrial parks and special economic zones, which is anticipated to enhance sound/healthy competition in economic development.

The relationship of flood risk assessment in disaster management and regional business continuity plan is discussed in Section 4.3.

CHAPTER 3 CHALLENGES AND INITIATIVES

3.1 Challenges

3.1.1 Overview of policy and institutional response on flood risk assessment

(1) Flood Risk assessment, climate change, land use

International policy-oriented discussions on flood risk management approaches were held on November 30 and December 1, 2010 in Washington, D.C.[8] overviewed flood risk assessment, climate change, and land use change as one of the theme. The major issues and approaches concerned with flood risk assessment are listed below.

Major issues

1) Flood risk is defined for:

- Assessing flood risk involves the likelihood of a flood hazard occurring, the vulnerability of actions implemented to mitigate flood effects, and the consequences that result from that mitigated flood event,
- Understanding flood risk needs to identify, assess, and measure hazards, vulnerabilities and consequences,
- Managing flood risk must coordinate policies and actions with those who can affect the hazards, vulnerabilities, and consequences; must be integrated and synchronized.

2) Increasing concentration of the population in weather-sensitive areas will increase society's vulnerability to weather and water conditions.

3) Only the outreach and effectiveness of forecasts and early warnings based on scientific monitoring of meteorological and hydrological hazards can determine the success of any disaster preparedness planning.

4) Overall, need better understanding of causes and effects, integration of adaptation and mitigation plans, improvement of early warning systems, and adaptable protection plans for climate change.

5) Accurate forecast of future temperature and sea level are necessary for assessing future flood risk; however, predicting future climate is more difficult than understanding past.

Approaches

1) Transitioning from "flood protection" to "flood risk management" around the world.

2) U.S. learning from Hurricane Katrina, shifting to risk-informed, system-wide approaches:

- Modernizing Principles and Guidelines for water resources studies,
- National Flood Insurance Program Reform to ensure program efficiently and effectively meets needs of public,
- Regional Flood Risk Management Team in upper Mississippi coordinates federal, tribal, state, local governments' flood risk management initiatives.

3) The European Directive, DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007, establishes a legal framework with the overall goal to reduce adverse consequences of flooding to human health, environment,

[8] International Partnerships National Flood Risks Management Program, After-Event Report, International Management Approaches, International Policy-Oriented Discussions, 2011

cultural heritage, and economic activity. The directive requires the following by the member states:

- flood risk assessment to identify significant flood risk areas by 2011,
- flood hazard and flood risk map production by 2013,
- flood risk management plan must for all of the areas identified as being at a significant risk of flooding by 2015,

4) From 2005 to 2007, the Swedish government appointed a Commission to assess the national, regional, and local impacts of global climate change. Global climate change models were downscaled to regional and local conditions in Sweden to achieve the following goals:

- Map vulnerable areas,
- Estimate damages,
- Propose actions to mitigate vulnerabilities,
- Estimate costs of adaption and preventative measures.

5) We need to better understand perceptions and socio-economic costs to promote risk-wise behavior and development.

6) Paradigm shift from “providing safe level of protection” to “reducing risk to acceptable levels”; shift requires acceptance that absolute safety is impossible.

7) Preventative flood risk management is most cost-effective and can quickly show positive results.

8) Risk reduction can occur through spatial planning, such as in Slovenia:

- Integration of flood risk management into spatial planning,
- Integration of flood maps into spatial plans,

9) European Union Flood Risk Directive is changing legislation; proposed legislation for sharing responsibility for flood risk has provoked a variety of positive and negative reactions.

Box 3.1 The Flood Directive (2007/60/EC)

It applies to all kinds of floods (river, lakes, flash floods, urban floods, coastal floods, including storm surges and tsunamis), requires all of the EU territory Member States to approach flood risk management, and will be executed in a three stage process whereby:

By 2011 undertake a **preliminary flood risk assessment** of their river basins,

By 2013 develop **flood hazard maps** and **flood risk maps** for real flood damage risk areas,

By 2015 drawn up **flood risk management plans** for these zones.

Level of Risk and Information to be Identified by Flood Hazard and Risk Maps

A medium likely hood of flooding (at least a 1 in 100 year event) and extreme events or low likelihood events, and indicate expected water depths, the number of inhabitants potentially at risk, the economic activity and the environmental damage potential.

Flood Risk Management Plans

- to include measures to reduce the probability of flooding and its potential consequences,
- to address all phases of the flood risk management cycle but focus particularly on prevention, protection and preparedness.
- to leave much flexibility on objectives and measures to the Member States in view of subsidiarity.

Source: Adopted from The European Directive 2007/60/EC

(2) Defining standard, selecting measures, working with nature

The major issues and approaches for defining standard, selecting measures, working with nature are listed below.

Major Issues

1) In recent years, large events like Hurricane Katrina have impacted flood risk management policies. Some of the current flood safety policies are not enough and nations need to develop new safety standard for their flood defenses.
2) Similar to the shift in the standard for flood defenses, there has been a shift for a more holistic view of flood risk management where all nations are challenged by the following focusing on:
- Reducing risk,
- Eliminating risk,
- Sharing risk – insuring properties impacted,
- Managing risk,
- Accepting risk.
3) There has been a shift recently to move from just concentrating on probability to understanding both probability and consequences in a more holistic approach. In some nations, there is significant population behind some of the flood defenses and therefore, the consequences (populations impacted, impacts to the economy and building stock, etc.) of a failure or significant flood event are as important as understanding the probability.

Approaches

4) Clear arrangement should be made on the roles and responsibilities across all levels of government. In the Netherlands, there is a four layered approach with local (water boards), regional (provinces), national (Ministry of Infrastructure and Environment), and European Commission.
5) Like the United Kingdom, nations are looking to develop multiple strategies and adaption to manage flood risk. Legislation and policies drive certain behaviors but, they are also looking back to nature to help manage flood risk.

3.1.2 Challenges to flood risk assessment in ASEAN

In ASEAN various types of hazard maps have been produced. International organizations such as UNDP and the World Bank assist Cambodia, Laos, Philippines, Vietnam, etc. to produce multi-hazard maps with small scale. The purpose of these maps is primary policy making (refer to Tables 4.1 and 4.2). Those maps are not applicable to the purposes of flood management planning, preparedness and emergency actions and damage analysis. The same conditions are observed among the available flood hazard maps except some. The Mekong River Commission and the International Center for Water Hazard and Risk Management (ICHARM) have been producing flood vulnerability and risk maps, but their output is still at research level.

Production of flood hazard maps requires large input of cost, resources and time. Various challenges described below are expected to be overcome.

3.1.3 Challenge to share information

Sharing of basic information is prerequisite to produce and share common flood hazard, vulnerability and risk maps among the ASEAN countries. The basic information required to produce those maps are:

- Base map with scale of exceeding 1:50,000,
- Primal rainfall and discharge records for flood probability analysis, rainfall-runoff analysis, and runoff-inundation analysis,
- Regional socio-economic data for vulnerability analysis, and
- Buildings, infrastructure, assets, production value for exposure and risk analysis.

Topographic maps and meteor-hydrological data (rainfall, runoff, discharge) are not opened to the public under law in most of the ASEAN countries. Foreigners are not allowed to access to these maps and data. Only approved citizens are allowed to access to the topographic maps of large scale exceeding 1:50,000 and the original rainfall, runoff and discharge data. Other socio-economic data not published officially such as personal income, financial and fixed assets, production data, etc. are also not available due to limited resources in most of the ASEAN countries.

3.1.4 Challenge to materialize flood risk assessment

Food risk assessment is not well materialized yet in majority of the ASEAN countries. There are several reasons why flood hazard map has not been produced or not disclosed to the public are:

- Shortage of resources (financial, human, technical),
- Opposition by land owners and residents to disclose the maps to the public,
- Lack of public awareness of flood risk,
- Lack of legal and institutional arrangements, and
- Gap of needs for flood risk assessment among public, private and citizens.

3.2 Challenge to Develop Institutional Initiative

As briefed in Section 3.1 (1) various policies, initiatives and institutions have been internationally challenged to flood risk assessment. Institutional initiatives expected to develop before finalizing common flood assessment rules and guidelines for the ASEAN member states are:

- Development of social awareness consensus to produce and to disclose flood hazard maps in respective countries,
- Confirmation of basic conditions, maps and data to produce flood hazard, vulnerability, and risk maps,
- Institution to share basic maps and data to produce flood hazard, vulnerability and risk maps,
- Institution to establish an unified guideline or standard for risk assessment including relevant maps, and

- Third party verification system to assess quality and reliability of outputs of flood risk assessment[9].

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[9] Professor Kuniyoshi Takeuchi proposes to establish Flood Preparedness ISO in "Flood Disaster Preparedness Standard", Water, Environment, Energy and Society (WEES – 2009), New Delhi, 12-16 January 2009, Vol. 2, p 672 - 692

CHAPTER 4 FRAMEWORK OF METHODOLOGY: DEFINITION, PROCESS AND PURPOSE

4.1 Key Definitions

Definition of the three key factors of flood risk assessment is defined in the Guide as follows[10]:

Hazard: A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation;

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;

Risk: the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Practically risk is estimated as a product of probability (%) of a subject hazard x damage of the element at risk ($, death toll or other intangible value) by an event of hazard[11].

Where,

Probability: extent to which an event is likely to occur; Event: occurrence of a particular set of circumstances; and Impact: evaluated consequence of particular outcome[12.]

The other key definitions are listed in Table 4.4.

Advantage of applying the definitions of UNISDR 2004 is:

- It enables to facilitate common procedure and methodology,
- It enable to apply the results of risk assessment directly to practical purposes not only policy making but also flood disaster prevention and mitigation planning, cost benefit analysis and financial planning, and
- It enable to compare easily he results of risk assessment done in different places by the use of the same unit.

4.2 Process to Assess Flood Hazard, Vulnerability and Risk

4.2.1 Assessment Process

Flood risk assessment is the systematic approach to identify how flooding impacts the socio-economic and natural environment. The most common method for determining flood risk is to

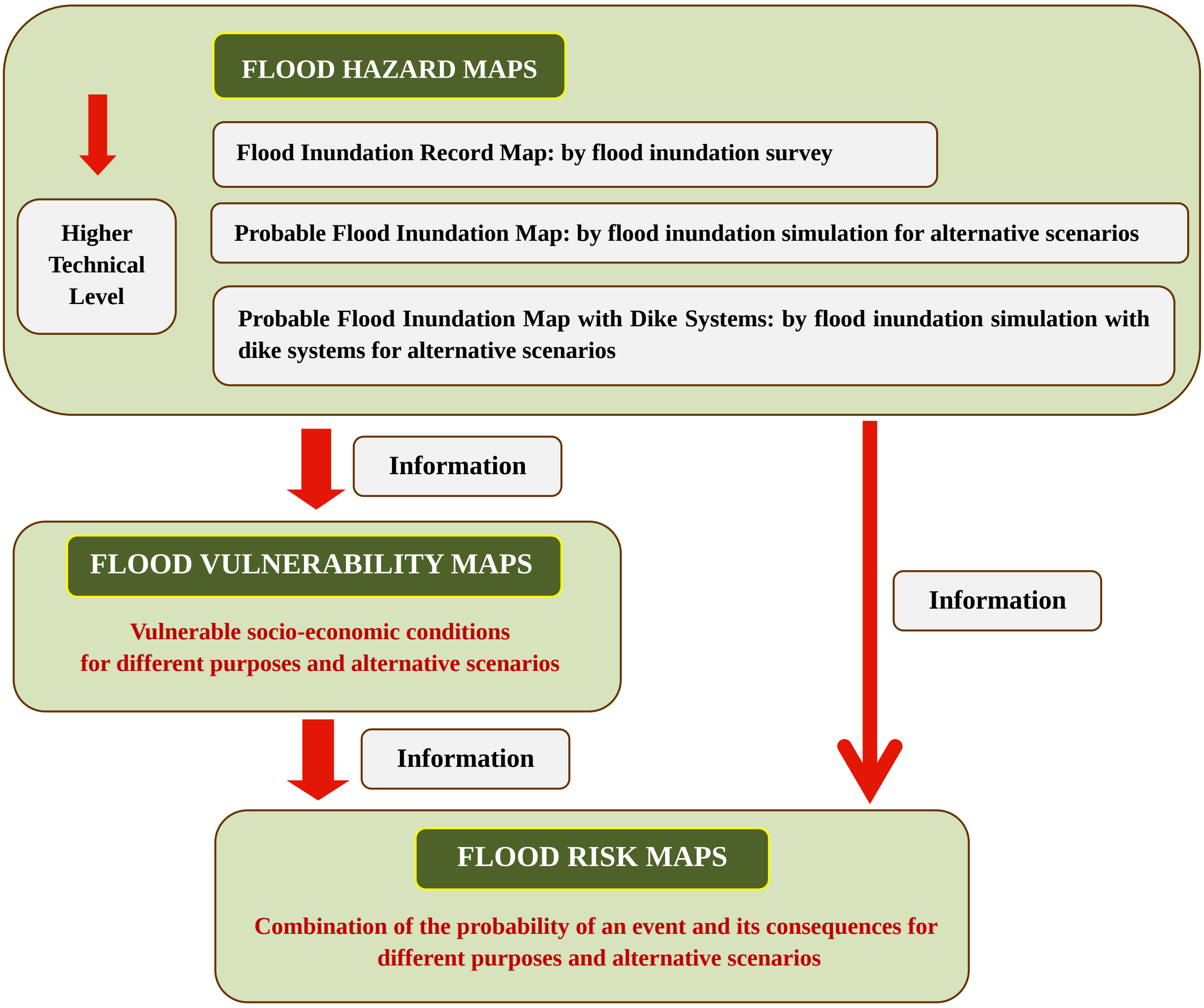
[10] Definitions of hazard, vulnerability and risk are adopted from Living with Risk – A global review of disaster reduction initiatives, ISDR 2004. Definition of risk is also referred to ISO/PAS 22399, First edition 2007-12-01, "Societal security-Guideline for incident preparedness and operational continuity management".

[11] The conventional notation, Risk = Hazards x Vulnerability (ISDR 2004) is not adopted because the dimension of risk is not captured accurately by this equation. The notation risk = Hazard x Exposure x Vulnerability is adopted. Risk is also defined as a Function (Hazards x Exposure x Vulnerability) by Associated Programme on Flood Management, World Metrological Organization, Urban Flood Risk Management, March 2008.

[12] Definitions of probability, event and impact are adopted from ISO/PAS 22399, 2007-12-01.

identify the probability of flooding and the consequences of flooding covering vulnerable areas, facilities and infrastructure. The key definitions including risk in Section 4.1 is applied to the Guide though risk is defined as a factor or index in some references.

A flood hazard assessment constitutes a basis of flood risk assessment. A well qualified hazard assessment procedure requires large amount of inputs (time, costs and other resources). Credible flood hazard assessment provide the basis for vulnerability and risk assessment, further followed by planning and implementation of flood disaster prevention and mitigation, as well as of responses. Figure 4.1 illustrate relationship between flood hazard, vulnerability and risk and their assessment process.



Source: JICA Study Team

Figure 4.1 Relations between Flood Hazard, Vulnerability, and Risk

Three different types of flood hazard identification are required for full flood hazard assessment: recorded flood hazards, simulated probable flood hazards, and simulated probable flood hazards with flood prevention systems. Probable flood hazard is estimated for multiple scenarios/return periods to use the results for different purposes and to identify a relationship between flood probability and hazard magnitude such as inundation area, depth, and velocity.

Recorded flood hazards are identified from the survey results of past flood inundation of one or several events. Probable flood hazards are identified by flood inundation simulation for multiple scenarios using rainfall and runoff records, a rainfall-runoff model, a runoff – inundation model and historic flood inundation records. Probable flood hazards with flood prevention facilities are identified by the same method considering effects of the existing and/or planned flood prevention facilities such as dike systems, drainage systems, retarding basins, etc.

4.2.2 Key Information for Assessment

The key information of the flood hazard identification is accurate topographic map or detailed data from Digital Terrain Model (DTM). The area-specific information, such as hydro meteorological record, rainfall-runoff coefficient parameters, carved elevations of flood marks, river basin morphology and detail topography of dyke and drainage systems, can also importantly supplement the implementation of hazard assessment to be reliable as much as possible.

The key information of the flood risk assessment is the location of the elements at risks and the vulnerability of those elements. The flood damages or losses can be estimated from the vulnerability information and the hazard identification. The damages are composed of direct physical damage (general infrastructures, essential facilities such as schools and hospitals, lifelines and transportation systems, and agricultural products and vehicles), direct economic and social losses, and indirect economic losses.

4.3 Purpose of Flood Risk Assessment

4.3.1 Purposes of flood risk assessment

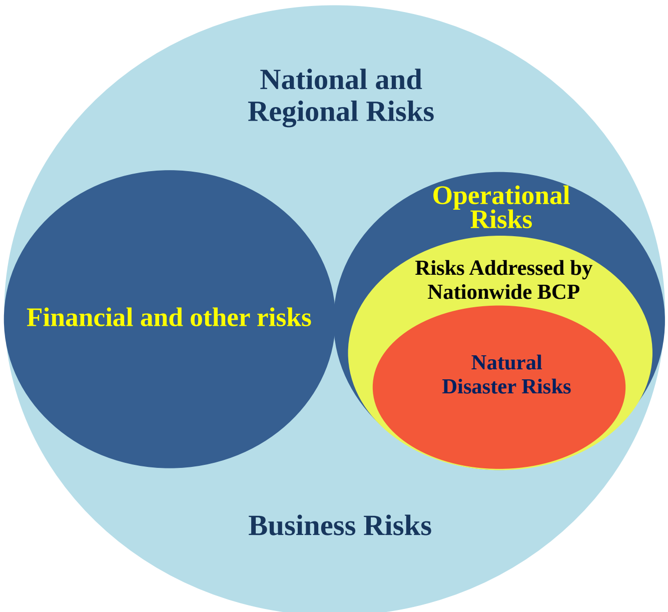
Flood risk information and results of risk assessment are used for different purposes from policy making, flood management planning, preparedness and emergency actions to damage analysis shown in Table 4.1.

Table 4.1 Purposes of Flood Risk Assessment and Corresponding Description

Purpose	Description
Policy Making	Formulation of national and regional development policy on strategic areas for disaster prevention, identification of model areas and budgetary arrangements; development and/or update of comprehensive plans, future land use maps, and zoning regulations
Flood Management Planning	Preparedness for emergency actions (evacuation and rescue) and relief actions; develop hazard mitigation projects; planning for continuity of operations plans, continuity of government plans, and emergency operations plans
Preparedness and Emergency Actions	Information for disaster mitigation and prevention planning, and river basin flood control master plan; re-evaluate and prioritize mitigation actions in local hazard mitigation plans; to communicate with property owners, business owners, and other citizens about flood risks
Damage Analysis	Damage analysis for investment on regional industrial clusters and insurance on factories, buildings and utilities; risk assessment on economic corridors such as roads, ports, and railways

4.3.2 Disaster management, regional BCP and flood risk assessment

A framework of national and regional risks are composed of risks of financial and other functions of government, operational risks of government and business risk as illustrated in Figure 4.2. The operational risks include risks addressed by nationwide business continuity plan (BCP). The operational risk of government broadly covers national and regional disaster management (refer to Box 4.1). Multi-disaster risk assessment provide basis of formulating national and regional disaster management or national and regional business continuity plan. In particular flood risk assessment provides the core information to the national and regional continuity plan in the regions where flood disasters are major disasters disrupting socio-economic activities and well beings.



Source: JICA Study Team

Figure 4.2 Framework of National and Regional Risks

The Civil Contingency Act 2004 of the United Kingdom repealed the Civil Defence Act 1948 and the Civil Defence Act (Northern Ireland) 1950 in the wake of the three events, the fuel protests of 2000 or natural threats like the mass flooding in 2000 and the outbreak of Foot and Mouth Disease in 2001. The Act establishes broadly a new definition for "emergency", and the role of local governments for emergency[13].

[13] The Act is divided into three parts: Part 1defines the obligations of certain organisations to prepare for various types of emergencies; Part 2 provides additional powers for the government to use in the event of a large scale emergency; and Part 3 provides supplementary legislation. An event or situation threatens damage to human welfare includes: loss of human life, illness, damage to property, disruption of a supply of money, food, water, energy or fuel, a system of communication, facilities for transport, or services relating to health.

Box 4.1: Typical Treasury Operational Risks

- Infrastructures and technology failures covering computer systems, power, telecommunications, data and physical records.
- Incidents where access to premises is denied, either through inaccessibility or building damage.
- Dependencies on third party key service providers such as the central and/or commercial banks, telecom and internet providers, and other outsourced operations, or resources failures from such incidents as a pandemic.
- Human errors or failures through lack of resources, skills, training, policies, procedures, delegations, code of conduct, and poor management.
- Failure to meet statutory, legal or contractual, human resources and other obligations including management objectives and reporting obligations.
- Natural and regional disasters covering incidents such as earthquake, tsunami, severe flooding, hurricane/typhoon, volcanic eruption, severe fires, landslides, and civil disturbance or terrorism

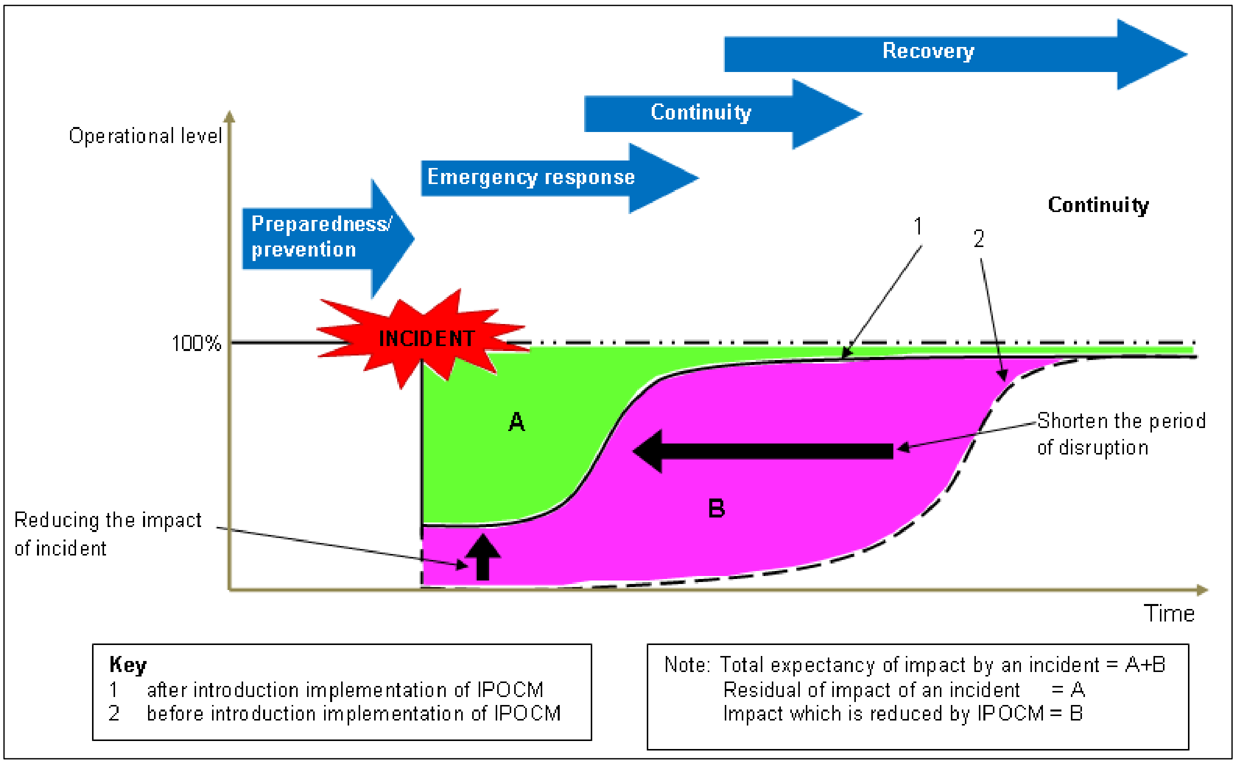
Source: International Monetary Fund, Technical Notes and Manuals, Operational Risk Management and Business Continuity Planning for Modern State Treasuries, Ian Storkey, November 2011, Box 1, p 4

4.3.3 National and regional business continuity plan

National and regional contingency plans are in preparation in ASEAN Member States. Business continuity plan (BCP) is applicable to individual private companies.

Incident preparedness and operational continuity plan (IPOCM) is the same concept as BCP according to ISO/PAS 2239. Figure 4.3 illustrates concept of IPOCM. It specifically illustrates that preparedness and prevention of disaster management, BCP or IPOCM are effective to reduce impacts (area B) by an event of incident in terms of damage and time for recovery. Flood hazard and risk maps provide the basic information for preparedness, prevention, continuity and recovery. Cost and resources used for risk assessment, preparedness and prevention is larger than part of the damage or loss which could be reduced by actions of preparedness and prevention (area B).

Regional business continuity plan (RBCP) is a regional or local contingency plan specific to business and commercial areas, which is part of a regional disaster management plan. RBCP deals with essential facilities, transportation systems and lifeline utility systems operated by both public and private sectors.



Source: Figure 1 of ISO/PAS 22399 Social Security – Guideline for incident preparedness and operational continuity management, first edition 2007-12-01. Note is supplemented by JICA Study Team

Figure 4.3 Concept of incident preparedness and IPOCM

4.3.4 Information for flood hazard, vulnerability and risk

Increase of risk of flood disaster due to rapid economic development and urbanization has been common issues of the ASEAN countries. The Study has identified high potential needs of flood risk assessment for different purposes. The 2011 flood disaster in the Chao Phraya River Basin, Thailand triggered a paradigm shift in the needs of flood risk assessment. Investment risk assessment on special economic zones (regional industrial clusters) and risk transfer including flood insurance system have attained high interests.

Table 4.2 and Table 4.3 shows example information required for those purposes in Section 4.3.1 and for national and local level and local and community level respectively.

Table 4.2 Requirement of Information for policy making and Flood Management Planning

Purpose	National	Local
Policy Making	Administrative boundaries, Inundation areas, water depth, Notation of flood risk class, Return period of flooding, Map scale: 1:100,000– 1,000,000	Administrative boundaries, Inundation areas, water depth, Notation of flood risk class, Return period of flooding, Map scale: 1:50,000–250,000
Flood Management Planning	Elevations of concerning points, Administrative boundaries, Inundation areas, water depth, flow velocity, return period, Notation of flood risk class or water depth, Land uses (agricultural, industrial, commercial, residential, forest, swamp), Dikes, dams, retarding ponds, drainages, pumping stations, Roads, railways, bridges, port, air port, power stations, water supply facilities, Map scale: 1:5,000-25,000 with contour lines	Elevations of concerning points, Administrative boundaries, Inundation areas, water depth, flow velocity, return period, Notation of flood risk class or water depth, Land uses (agricultural, industrial, commercial, public, forest, swamp, Dikes, dams, retarding ponds, urban drainages, Roads, railways, bridges, port, air port, power stations, water supply facilities, Map scale: 1:5,000-25,000 with contour lines

Table 4.3 Requirement of Information for Preparedness and Damage Analysis

Purpose	Local	Community
Preparedness and Emergency Actions	Elevations of concerning points, Administrative boundaries, Inundation areas, water depth, flow velocity, return period of flood, Dikes, flood posts, laud speaker posts, shelters, schools dams, retarding ponds, drainages, Roads, railways, bridges, Safe evacuation routes, Map scale: 1:5,000-15,000 with contour lines	Google map, Sketch map, Village or community boundaries, Inundation areas, water depth, flow velocity, return period of flood, Safe evacuation routes, Dikes, flood posts, laud speaker posts, shelters, schools, retarding ponds, drainages, ground water wells, Roads, railways, bridges, Map scale: 1:5,000-15,000 with contour lines
Damage Analysis	Elevations of concerning points, Administrative boundaries, Inundation areas, water depth, flow velocity, return period, Notation of flood risk class, Land uses (agricultural, industrial, commercial, residential, forest, swamp), Flood control level of dikes, dams, retarding ponds, drainages, pumping stations, Roads, railways, bridges, port, air port, power stations, water supply facilities, Population distribution, transport quantity of trunk main roads and ports, production turnover of industrial parks, Rainfall depth, geology and forestation for land slide risk assessment, Map scale: 1:5,000-25,000 with contour lines and spot elevations,	

Table 4.4 Definitions of Key Terms (1/5)

Acceptable risk: the level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions. Source: http://www.unisdr.org/we/inform/terminology
Adaptation: the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Source: http://www.unisdr.org/we/inform/terminology
Capacity: the combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals. Source: http://www.unisdr.org/we/inform/terminology
Capacity development: the process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions. Source: http://www.unisdr.org/we/inform/terminology
Climate change: (a) the Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability or its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use". (b) the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Source: http://www.unisdr.org/we/inform/terminology
Consequence: a result or effect, typically one that is unwelcome or unpleasant. Source: Oxford English Dictionary
Contingency planning: a management process that analyses specific potential events or emerging situations that might threaten society or the environment and establishes arrangements in advance to enable timely, effective and appropriate responses to such events and situations. Source: http://www.unisdr.org/we/inform/terminology
Crisis: any incident(s), human-caused or natural, that require(s) urgent attention and action to protect life, property, or environment. Source: ISO/PAS 22399 2007-12-01
Damage: physical harm that impairs the value, usefulness, or normal function of something. Source: Oxford English Dictionary
Disaster: event that causes great damage or loss. Source: ISO/PAS 22399 2007-12-01 a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. Source: http://www.unisdr.org/we/inform/terminology *A disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk.* Source: IDRD 2004
Disaster risk: the potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future period. Source: http://www.unisdr.org/we/inform/terminology
Disaster risk management: the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. Source: http://www.unisdr.org/we/inform/terminology
Disaster risk reduction: the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the casual factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events. Source: http://www.unisdr.org/we/inform/terminology

Table 4.4 Definitions of Key Terms (2/5)

Disruption: incident, whether anticipated (e.g. hurricane) or unanticipated (e.g. a blackout or earthquake) which disrupts the normal course of operations at an organization location. Note: a disruption can be caused by either positive or negative factors that will disrupt normal operations. Source: ISO/PAS 22399 2007-12-01
Early warning system: the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. Source: http://www.unisdr.org/we/inform/terminology
Emergency: sudden, urgent, usually unexpected occurrence or event requiring immediate action. Note: an emergency is usually a disruptive event or condition that can often be anticipated or prepared for but seldom exactly foreseen. Source: ISO/PAS 22399 2007-12-01
Emergency management: the organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps. Source: http://www.unisdr.org/we/inform/terminology
Event: occurrence of a particular set of circumstances. Source: ISO/PAS 22399 2007-12-01
Exposure: the sum total of human life and physical infrastructure at risk of loss resulting from the occurrence of a particular hazard or peril. Or in the context of an insurance contract, the total of insured assets (or the sum insured) at risk of loss resulting from the occurrence of the peril insured against at any one time. Source: NCRIM, 2008 People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Source: http://www.unisdr.org/we/inform/terminology
Flood: an overflowing or irruption of an great body of water over land in a built up area not usually submerged. Source: Oxford English Dictionary
Hazard: possible source of danger, or conditions physical or operational, that have a capacity to produce a particular type of adverse effects. Source: ISO/PAS 22399 2007-12-01 A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Source: NCRIM, 2008 *Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability.* Source: IDRD 2004 A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Source: http://www.unisdr.org/we/inform/terminology
Hydrometeorological hazard: process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Source: http://www.unisdr.org/we/inform/terminology
Impact: evaluated consequences of a particular outcome. Source: ISO/PAS 22399 2007-12-01
Impact analysis: process of analyzing all operational functions and the effect that an operational interruption might have upon them. Source: ISO/PAS 22399 2007-12-01
Incident: event that might be, or could lead to, an operational interruption, disruption, loss, emergency or crisis. Source: ISO/PAS 22399 2007-12-01
Incident management plan: clearly defined and documented plan of action for use at the time of an incident or disruption, typically covering the key personnel, resources, services and actions needed to implement the incident management process. Source: ISO/PAS 22399 2007-12-01
Incident preparedness: activities, programs, and systems developed and implemented prior to an incident that may be used to support and enhance mitigation of, response to, and recovery from disruptions, disasters, or emergencies. Source: ISO/PAS 22399 2007-12-01
Incident preparedness and operational continuity management IPOCM: systematic and coordinated activities and practices through which an organization optimally manages its risks, and the associated potential threats and impacts there from. Source: ISO/PAS 22399 2007-12-01

Table 4.4 Definitions of Key Terms (3/5)

Land-use planning: the process undertaken by public authorities to identify, evaluate and decide on different options for the use of land, including consideration of long term economic, social and environmental objectives and the implication for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses. Source: http://www.unisdr.org/we/inform/terminology
Mitigation: limitation of any negative consequence of a particular incident. Source: ISO/PAS 22399 2007-12-01 The lessening or limitation of the adverse impacts of hazards and related disasters. Source: http://www.unisdr.org/we/inform/terminology
Natural hazard: natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Source: http://www.unisdr.org/we/inform/terminology
Operational continuity OC: strategic and tactical capability, pre-approved by management, of an organization to plan for and respond to conditions, situations and events in order to continue operations at an acceptable predefined level. Note: operational continuity is the more general term for business continuity. It applies not only to for-profit companies, but organizations of all natures, such as non-governmental, public interest, and government organizations. Source: ISO/PAS 22399 2007-12-01
Operational continuity management OCM: holistic management process that identifies potential impacts that threaten an organization and provides a framework for building resilience with the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value-creating activities. Note: operational continuity management also involves the management of recovery or continuity in the event of an incident, as well as management of the management of the overall program through training, rehearsals, and reviews, to ensure the operational continuity plan stays current and up-to-date. Source: ISO/PAS 22399 2007-12-01
Operational continuity management program: ongoing management and governance process supported by top management and resourced to ensure that the necessary steps are taken to identify the impact of potential losses, maintain viable recovery strategies and plans, and ensure continuity of functions/products/services through exercising, rehearsal, testing, training, maintenance and assurance. Source: ISO/PAS 22399 2007-12-01
Operational continuity plan OCP: documented collection of procedures and information that is developed, compiled and maintained in readiness for use in an incident. Source: ISO/PAS 22399 2007-12-01
Organization: group of people and facilities with an arrangement of responsibilities, authorities and relationships. Note: an organization can be a government or public entity, company, cooperation, firm, enterprise, institution, charity, sole trade or association, or parts or combinations thereof. Source: ISO/PAS 22399 2007-12-01
Preparedness: the knowledge and capacities developed by government, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impact of likely, imminent or current hazard events or conditions. Source: http://www.unisdr.org/we/inform/terminology
Prevention: measures that enable an organization to avoid, preclude, or limit the impact of a disruption. Source: ISO/PAS 22399 2007-12-01 The outright avoidance of adverse impacts of hazards and related disasters. Source: http://www.unisdr.org/we/inform/terminology
Probability: extent to which an event is likely to occur. Source: ISO/PAS 22399 2007-12-01 Note 1: ISO 3534-1:1993, definition 1.1 gives the mathematical definition of probability as “a real number in the scale of 0 to 1 attached to a random event. It can be related to a long-run relative frequency of occurrence or to a degree of belief that an event will occur. For a high degree or belief, the probability is near 1.”
Public awareness: the extent of common knowledge about disaster risks, the factors that lead to disaster and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards. Source: http://www.unisdr.org/we/inform/terminology
Recovery: the restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors. Source: http://www.unisdr.org/we/inform/terminology

Table 4.4 Definitions of Key Terms (4/5)

Residual risk: risk remaining after risk treatment. Source: ISO/PAS 22399 2007-12-01 The risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. Source: http://www.unisdr.org/we/inform/terminology
Resilience: ability of an organization to resist being affected by an event. Source: ISO/PAS 22399 2007-12-01 The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Source: http://www.unisdr.org/we/inform/terminology
Response: the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Source: http://www.unisdr.org/we/inform/terminology
Risk: combination of the probability of an event and its consequences. Source: ISO/PAS 22399 2007-12-01 The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Source: IDRD 2004 Conventionally risk is expressed by the notation Risk = Hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability. Source: NCRIM, 2008 *Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes.* Source: IDRD 2004 The combination of the probability of an event and its negative consequences. Source: http://www.unisdr.org/we/inform/terminology
Risk assessment: overall process of risk identification, analysis and evaluation Note: risk assessment involves the process of identifying internal and external threats and vulnerabilities, identifying the likelihood of an event arising from such threats or vulnerabilities, defining critical functions necessary to continue the organization's operations, defining the controls in place necessary to reduce exposure, and evaluating the cost of such controls. Source: ISO/PAS 22399 2007-12-01 A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods, and the environment on which they depend. Source: NCRIM, 2008 and http://www.unisdr.org/we/inform/terminology
Risk assessment/analysis: *the process of conducting a risk assessment is based on a review of both the technical features of hazards such as their location, intensity, frequency and probability; and also the analysis of the physical, social, economic and environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios.* Source: IDRD 2004
Risk communication: exchange or sharing of information about risk between the decision-maker and other stakeholders. Source: ISO/PAS 22399 2007-12-01
Risk criteria: terms of reference by which the significant of risk is assessed. Source: ISO/PAS 22399 2007-12-01 Note: risk criteria can include associated cost and benefits, legal and statutory requirements, socio-economic and environmental aspects, the concerns of stakeholders, priorities and other inputs to the assessment. Source: ISO/IEC Guide 73
Risk management: coordinated activities to direct and control an organization with regard to risk. Source: NCRIM, 2008 The systematic approach and practice of managing uncertainty to minimize potential harm and loss. Source: http://www.unisdr.org/we/inform/terminology
Risk reduction: actions taken to lessen the probability, negative consequences, or both, associated with a risk. Source: ISO/IEC Guide 73

Table 4.4 Definitions of Key Terms (5/5)

Risk transfer: sharing with another party the burden of loss or benefit or gain, for a risk. Source: ISO/PAS 22399 2007-12-01 A contractual process whereby the burden of financial loss is shifted to another party, via the use of insurance or other financing instruments, in return for a payment or premium. Source: NCRIM, 2008 The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party. Source: http://www.unisdr.org/we/inform/terminology
Simulation exercise: test performed under conditions as close as practicable to real world conditions. Source: ISO/PAS 22399 2007-12-01
Socio-natural hazard: the phenomenon of increased occurrence of certain geophysical and hydrometeorological hazard events, such as landslides, flooding, land subsidence and drought, that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources. Source: http://www.unisdr.org/we/inform/terminology
Threat: potential cause of an unwanted incident, which may result in harm to individuals, a system or organization, the environment or the community. Source: ISO/PAS 22399 2007-12-01
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. Source: IDRD 2004

- IDRD 2004: Living with Risk – A global review of disaster reduction initiatives
- NCRIM 2008: 'Main Report' Natural Catastrophe Risk Insurance Mechanisms for Asia and the Pacific
- ISO/PAS 22399 2007-12-01: Societal Security-Guideline for Incident Preparedness and Operational Continuity Management.
- Oxford English Dictionary website: http://oxforddictionaries.com
- UNISDR website: http://www.unisdr.org/we/inform/terminology

CHAPTER 5 ASEESSMENT OF FLOOD HAZARD

5.1 Basic Conditions of Flood Hazard Identification

5.1.1 Basic conditions

Before actual identification of probable flood hazard, basic conditions should be studied based on inundation records and evacuation situations at the time of past floods, inundation risk areas and topography. The output of the flood hazard identification may be displayed on any Geographic Information System (GIS) or on printed maps.

The flood hazard information, by any means of GIS data or maps, is intended for floods that may occur in inundation risk areas that are designated by the relevant, national, state or provincial government in accordance with the disaster management law and then notified to the municipal governments concerned.

It is desirable that the flood hazard information covers the whole municipal district. However, it may cover only a limited area that contains inundation risk areas and evacuation sites if the inundation risk areas account for only a part of the municipal district. On the other hand, if an inundation risk area lies across multiple municipalities, the municipal governments concerned may need to jointly conduct flood hazard identification and mapping with relating municipalities in a wide area.

Flood Hazard Map, in some cases, is used for special purposes in local disaster management. Evacuation sites and routes, for instance in addition to the information of inundation risk areas and intensities, can be indicated on the hazard maps in a case that the flood hazard maps are used at the time of evacuation. Therefore, it is desirable to examine the indication method and the contents of information when deciding a form of flood hazard map. Table 5.1 shows the major forms of flood hazard map[14].

Table 5.1 Major Forms of Flood Hazard Map

Form	General description	Can cover the whole target area in a map
Printed map type	A0- to A1-size topographic map with related information added	- Can cover the whole target area in a map - Can contain only a limited amount of information
Pamphlet type	B5- to A4-size pamphlet map with related information added	- Difficult to cover the whole target area in a map - Can contain a large amount of information
Pamphlet + map	B5- to A4-size pamphlet with A0- to A1-size map inserted	- Can cover the whole target area in a map - Can contain a large amount of information

Source: Flood Hazard Mapping Manual in Japan, 2005, pp 12

5.1.2 Preparing a base map

If a topographic map which is used as a base map for flood hazard identification is old and does not sufficiently reflect the topography, house/road conditions, and secular changes, the

[14] Contents of sections 5.1 are referred from Flood Hazard Mapping Manual in Japan, June 2005, edited by Flood Control Division, River Bureau, Ministry of Land, Infrastructure and Transport (MLIT), translated by International Center for Water Hazard and Risk Management (ICHARM), p 12 - 14

base map must be revised. Note that procedure in accordance with the Survey Law may be required to use a map for the base map.

For specific use of emergency evacuation and rescue activities the map scale should be 1:10,000 to 1:15,000 because, with a scale smaller than this, each house and evacuation roads cannot be identified and therefore it is difficult to identify evacuation routes. It is preferable not to adopt a map scale of 1:25,000 to 1:50,000 unless unavoidable. The size standard of a base map is approximately A0 to A1 for map type form. However, A1 size is desirable because it is easier to use.

5.1.3 Computerization of the base map

The base map for flood hazard identification should be both a digital format data and printed paper. Printed maps shall be converted into electronic data to facilitate computerization and disclosure via internet and easily updating of hazard information. For this reason, municipal governments shall promote conversion of inundation risk area maps provided by the relevant national, provincial or local governments into electronic data and shall make use of such electronic data when conducting a flood hazard identification.

For specific use of emergency evacuation and rescue activities flood hazard maps are to be printed on paper because electric supply may not be available during emergency case.

5.2 Identification of Information for Flood Hazard Analysis

5.2.1 Information for hazard Indication

Information for flood hazard indication should be two kinds: general information, which in principle is required to be included in every flood hazard display or map; area-specific information, which needs to be decided whether to be included or not depending on respective local conditions[15].

(1) General information

There are various purposes to use flood hazard maps (Section 4.3.1). For specific use of preparedness, emergency evacuation and rescue activities flood hazard maps aim to prevent human loss in flooding. For that reason, it is important for the maps to be able to inform residents in an easy-to-understand way about inundation and evacuation. The minimum information related to evacuation and risk in flooding is referred as “general information". All flood hazard maps should include the general information listed in Table 5.2.

[15] Contents of section 5.2.1 are referred from Flood Hazard Mapping Manual in Japan, June 2005

Table 5.2 General Information for Flood Hazard Indication

Type of information	Content
Inundation risk area and types of damage	Designated areas, inundation depth, types of damage (Coloring for different inundation depths should follow that for inundation risk areas.)
Evacuation sites	Name, address, telephone number, etc. of evacuation facilities
Dangerous spots along evacuation routes	Mudslide hazard area, steep slope landslide hazard area, underpass, etc.
Ways to inform evacuation information including flood forecasting, etc	Communication routes/means for flood forecasting, water level information, evacuation order, evacuation instruction, etc.
Source of weather information, etc.	Name and address, website address, cell-phone website address, etc. of water level/precipitation stations

Source: Flood Hazard Mapping Manual in Japan, 2005, p 19

(2) Area – specific information

Area-specific information refers to information that is specific in the target area and is useful when residents evacuate. This kind of information is also helpful to promote residents' awareness of flood disasters in normal times. Whether each piece of area-specific information should be included in flood hazard mapping depends on the decision of the chiefs of local municipalities.

Information for evacuation

- Inundation information for other areas outside the inundation risk areas
- Evacuation zones
- Flood characteristics
- Evacuation tips
- Information regarding evacuation recommendation, etc.
- Information regarding underground spaces
- Information regarding facilities for disaster-vulnerable people
- Other

Information for disaster education

- Generation mechanism of flood disasters, topography and types of flood
- Information about possible risk of floods, types of damage, and past inundation
- Meteorological information
- Mental preparation for possible flood risks
- Other relevant information

5.2.2 Drafting standard for legend

(1) Significance of flood hazard

Drafting standard for legend or symbols will be necessary to help users of hazard maps understand and distinguish easily magnitude of hazard of distribution and to identify elements exposed to risk. Magnitude or degree of flood hazard is expressed by either inundation water depth, flow velocity or combination of water depth and flow velocity. Figure 5.1 illustrates an example of legend showing magnitude of hazard.

Range of water depth	Colour code by CMYK	Colour	Significance of hazard
below 0.5 m	Y50		Low
0 .5 to below 1.0 m	Y30, C10		Medium
1.0 to below 2.0 m	C20		High
2.0 to below 5.0 m	C40		Very High
5.0 m or higher	C20, M20		

Source: The range of water depth and colour is adopted from “Inundation Risk Area Mapping Manual” by MLIT River Bureau Flood Control Division, July 2001

Figure 5.1 Example Legend Showing Magnitude of Flood Hazard

(2) Topographic map information

Example legend for administrative boundaries, rivers, road, bridges, built-up area, contour lines, spot elevation, water body, etc is also introduced in Figure 5.2.

Source: Flood Hazard Map of Southern Leyte Province, Philippine Institute of Volcanology and Seismology

Figure 5.2 Example Legend for Topographic Information

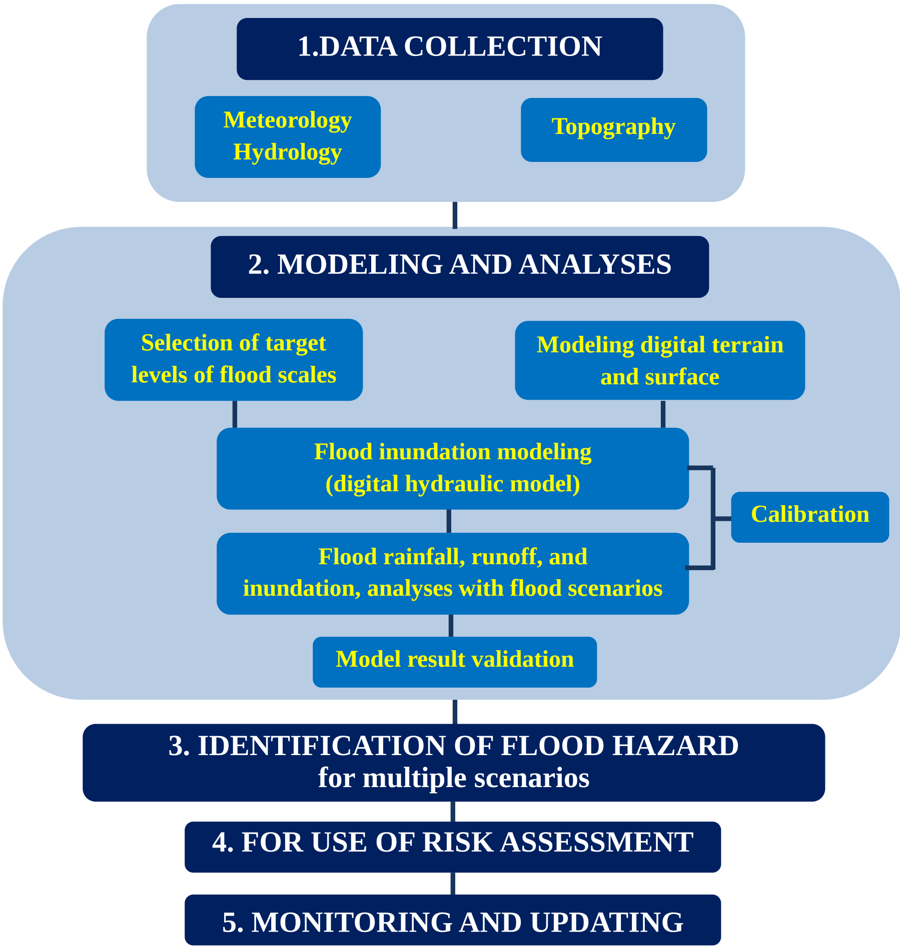
Refer to the flood hazard maps for evacuation and rescue in Japan in which general and area-specific information is presented, ANNEX: EXAMPLE HAZARD AND RISK MAPS, No. J1 and No. J2.

5.3 How to Identify Flood Hazard

5.3.1 Procedure to identify flood hazard

Identification of probable flood hazard is the first step towards flood risk assessment. The purpose is to better understand and communicate flood extent and flood characteristics such as water depth and velocity.

For accurate and qualified projection of flood hazard, selection of appropriate data, type of flood simulation model, schematization, proper parameterization, calibration and validation of results are all important steps. A step by step process for achieving this is illustrated in Figure 5.3.



Source: JICA Study team

Figure 5.3 Process to Identify Probable Flood Hazard

5.3.2 Data requirements for flood hazard assessment

For flood hazard assessment and production of flood hazard maps various type of data sets are required preferably with digitized format:

- Hydrological and meteorological data,
- Disaster data,
- Topographic map and data (Digital Terrain Model (DTM) [16] or paper topographic map),
- Hydraulic data (stream discharge, flood surface elevation),
- Flood plain topography (digitized flood boundaries, digital stream cross sections attributed with flood surface elevation, other flood plain maps).

[16] A DTM is digital representation of terrain features including elevation, slope, aspect, drainage and other terrain attributes. A DTM is one special case of the Digital Elevation Model (DEM) which is elevation of the earth surface. A DTM is usually made by an areal photographic survey or a ground survey. Conversion of DEM to DTM is possible but it is generally costly. Digital Elevation Model is a digital representation of surfaces of vegetation, buildings, lakes, the sea or the earth. It is necessary to mention always which surface is meant by using the DEM.

Those data are limited or not available depending on areas and countries. Cost of data acquisition is generally high.

Major international institution which provides some of these data is listed below[17].

(1) Hydro-meteorological data

Both qualitative and quantitative flood data can be used for either modelling or analysis. Quantitative data can be exemplified by hydro-meteorological data, while qualitative data can include descriptions of the type of areas affected, depth, and velocity. Data can be collected from the local municipality; governmental environment ministries and environmental agencies; weather and meteorological offices (local or regional); reports from the media and document archives; and through Participatory Rural Appraisal (PRA) tools. Hydrological data can be obtained from monitoring stations and gauging stations (where available), as well as satellite imageries (in real time or post-flood scenario) which can be obtained from national or international organizations involved in collection and storing of satellite images (for example the National Aeronautics and Space Administration (NASA), European Space Agency (ESA), and Indian Institute of Remote Sensing (IIRS). Photographs for post-flood analysis can be obtained either from the media or from local authorities.

(2) Archiving of disaster data of international institution

Major international institutions involved in collection and archiving of disaster data include: the Global Emergency Events Database (EM-DAT) supported by the Centre for Research on Epidemiology of Disaster (CRED); the World Health Organization (WHO); the Nat-Cat SERVICE provided by Munich Re; Relief Web supported by the UN Office for the Coordination of Humanitarian Affairs (UNOCHA); and the Global Disaster Information Network (GDIN). Most of the historical data from the international organizations are freely available, with the exception of real time hydro-meteorological data.

(3) Example of guidelines for ground surveys

The method of data capture and its quality determines the final products of hazard assessment. Guidelines are provided by the Federal Emergency Management Agency (FEMA 2003) regarding practical aspects of ground surveys and control points; measurement of hydraulic structures; photogrammetric mapping using aerial photographs and satellite imageries; use of LIDAR (Light Detection And Ranging) technology; and quality of spatial data sets, which are used as base maps for the production of final risk maps. There are similar guidelines for data capture standards.

(4) Hydraulic mapping

The most important element of any hydraulic mapping is the production of a Digital Terrain Model (DTM) which demands accurate elevation data. For production of flood hazard maps DTM is necessary but not a Digital Elevation Model (DEM). Techniques like

[17] Information of sub-sections (1) – (7) are adopted from Cities and Flooding, p 74-77

photogrammetry, LIDAR and SAR (Synthetic Aperture Radar) are used along with traditional topographic maps and surveying methods using DGPS (also known in this context as 'ground truthing'). They all have their limitations: data validation in larger areas, feasibility and cost effectiveness can become major issues. Remote sensing based methods are popularly used for generation of high resolution DTMs, but it should be kept in mind that errors resulting from data capture and data accumulation may still affect the accuracy of the final flood hazard maps.

(5) Flood plain topography

Floodplain topography is another important aspect of flood hazard assessment. Traditionally, topographic and bathymetric data were obtained from land surveying and bathymetric surveying, including technology such as Real Time Kinematic GPS (RTK-GPS) for coastal topographic measurement and underwater surveying. LIDAR technology is becoming increasingly popular for characterization of changing coastal topography worldwide. Techniques like SHOALS (Scanning Hydro-Graphic Operational Airborne LIDAR Survey) are useful in measuring both topography and bathymetry at the same time, thereby reducing the uncertainties in data due to time difference in data capture (Lillycrop et al. 1996). The most common technology for updating bathymetric data is called Multi Beam Eco-Sounder Surveying (MBES).

(6) Case of limited or no data

Areas with limited or no data face particular challenges. Both remote sensing and use of GIS techniques are especially useful solutions. These techniques can also be used in areas where physical accessibility is a problem. Satellite imagery, aerial photographs, and LIDAR technology can generate data in real time and both historical and hazard maps can be generated from them. Un-gauged catchments can be assessed using regional datasets such as flood frequency curves or regional regression equations (WMO 1999).

(7) Cost of data acquisition

The cost of data acquisition is always an issue of concern: purchasing expensive data and technologies like LIDAR and SAR must be set against the benefits of obtaining more accurate results for hazard analysis.

5.3.3 Probability of flood into hazard estimation

(1) Climatic and non-climatic factors causing flooding

Probable flood hazard is estimated for multiple scenarios/return periods to use the results for different purposes and to identify a relationship between flood probability and hazard magnitude such as inundation area, depth, and velocity.

Flood hazard is determined by conjunction of climatic and non-climatic factors that can potentially cause a flood: the magnitude of a fluvial flood will depend on physical factors such as intensity, volume and timing of precipitation. The antecedent conditions of the river and its drainage basin (such as the presence of snow and ice, soil type and whether this is saturated or unsaturated) will also have an impact on the development of the event, as will human-made factors such as the existence of dykes, dams and reservoirs, or the loss of permeability caused by urban expansion into floodplains[18].

(2) Estimation of flood hazards

Flood hazard is usually estimated in terms of a rainfall event or ‘design flood’ such as the 100 year flood. The estimation of flood probability or hazard combines statistics, climatology, meteorology, hydrology, hydraulic engineering, and geography. The standard approach described in Section 2.1(3) assumes that the flow data is sufficient to compute the design flood using statistical methods. In places where these data are not available because there are no gauges, or are of poor quality, other approaches are used. Data from a neighboring watercourse may be interpolated to the site of interest, or, if precipitation data are available, a design rainfall event can be computed, and a rainfall-runoff model used to estimate river flow. This is then fed into a hydraulic model that computes the depth and extent of the resulting flood. Finally, this information is combined with topographic, infrastructure, population and other geographic data in order to compute the flood hazard. Table 5.3 illustrates the range of model types used. The ‘generation’ denotes the level of sophistication inherent in the model, progressing from ‘first generation’ models including a number of simplified assumptions, through to the more advanced generations with fewer simplifying assumptions[19].

(3) Evaluation of return period of flooding

The annual maximum flood series is the maximum volume flow rate passing a particular location (typically a gauging station) during a storm event. This can be measured in m^3/sec and is calculated using the following formula:

$$Tr = (N+1)/ M$$

(where Tr = Return period of flooding (year); N= Total number of samples (number of recorded years); and M = Rank of flood event, according to order of highest flow).

Output from the return period calculations will enable users to understand the ‘probability’ of given flood events. If actual annual maximum discharge data is unavailable then approximation will be needed. But it must be recognized that this may lead to uncertainties within the model and thus in the end product[20].

[18] Adopted from Cities and Flooding 2012, p 71
[19] Adopted from Cities and Flooding 2012, p 72
[20] Adopted from Cities and Flooding 2012, p 79

Table 5.3 Types of Flood Models

Type of models	Useful in areas	Advantages	Disadvantages
First Generation with 2DH grid	Good for estimation of duration of flood, volume propagation, Useful in compact channels	Low to medium cost, simple calculation, low runtime (minutes to hours)	Does not give good results for vast areas or vast floodplains
Second Generation 1D/2D and 2D and Finite Elements models	Good for broad scale modeling, urban inundation, useful for compound channels	Medium to high cost, accuracy and run time (hours to days), can get outputs like percolation and seepage other than depth, velocity and volume	Broad scale application requires coarse grid otherwise the computational time becomes immense, high data demand
Third generation models	Good for showing breaching in 3D and flood propagation in 2D, useful for local predictions	High cost, accuracy, computation time (days) , flow velocity and flood boundaries accurately simulated	High run time, high demand for data, high cost
Erosion models Vellinga (1986)	Predicts final erosion profile based on wave height and storm surge water level	Can be used in coasts of different morphology	Does not include wave period
Komar et al (1999, 2001)	Predicts maximum erosion during an extreme event	Simplistic model	Does not take into account the storm duration
Sheach Model	Analytical more versatile	Estimation of cross shore transport rate in different shore zones	Demands high level of data, huge dataset
TIMOR3 and SWAN	Process based model, useful for short term	Detailed morpho-dynamic result	Not efficient to Calculate initial response

Source: Floodsite report T03-07-01 2008

5.3.4 Modeling flood scenario using digital hydraulic models

(1) Modelling flood scenarios

Available various flood models with varying degrees of simplification and applicability are listed in Table 5.3. Each has its own advantages and disadvantages, particularly in terms of the costs of the software and computer model runtime involved. Whichever one is chosen, schematization with the available input data, as above, is needed together with the boundary conditions for scenario generation according to the user’s requirements. Calibration of the model should then be performed followed by validation in order to get results closer to the reality (for example, by comparison with known flood extents in historic events in the locality).

Model outputs are obtained in the form of water depth, water velocity and extent of flooding for different return periods depending upon the model chosen. Depending on the nature of the flooding under consideration, the flood model adopted should ideally be the closest to the available resources, records and the existing conditions. Where the number of actual observations is limited, a process known as 'parameterization' of the inputs is needed in order to get the output as close as possible to the natural event. The details of this critical exercise vary according to the model used. Output can also be affected by the internal formula used by the model in performing the modeling process[21].

Box 5.1 Impacts by Depth and Flow Velocity of Floodwater

Generally speaking, the faster the velocity of the water the greater the damage, but the depth of floodwater is clearly another important factor in determining the scale of damage. It has been found that flood depths greater than 600 millimeters are more likely to result in structural damage to buildings. This relationship is normally demonstrated by a depth damage curve.

Flow velocity is presumed to be an important factor in the causation of flood damage, although hazard models rarely quantify its impact and its influence is therefore rarely taken into account. Some recent studies which have examined both water depth and flow velocity have concluded that the latter has a significant influence on structural damage, for example on roads, but only a minor influence on monetary losses and business interruption (Kreibich et al. 2009). However, it has also been recommended that if the other impact factor, water depth, is less than two meters then flow velocity alone is not a suitable consideration for estimating monetary loss in flood damage modeling and assessment.

Source: U.S. Army Corps of Engineers (USACE).1988. Tests of Materials and Systems for Flood Proofing Structures. Washington, DC: Army Corps of Engineers.

(2) Open source software

Most of the models and software used for flood hazard assessment are quite expensive to buy and are not freely available to the public. Due to their high price they are an impractical consideration for many developing nations. Therefore there is a need for high quality open source software which will be able to serve these highly sophisticated models to the extent that they can provide a general idea of the areas under threat.

Some of the open source software freely available for analysis and visualization purposes is as follows:

- Flow map designed by Utrecht University in the Netherlands is specifically designed to display flow data and works under Windows platform.
- GRASS is the most popular and well known open source software application which has raster and vector processing systems with data management and spatial modeling system. It works with Windows, Macintosh, Linux, Sun-Solaris, HO-Ux platforms.
- gvSIG is another GIS software application written in Java and works in Windows, Macintosh and Linux platforms.
- Ilwis is a multi-functionality GIS and Remote sensing software which has the capacity of model building. Regular updates are available for this software.

[21] Adopted from Cities and Flooding 2012, p 79 - 80

- Quantum GIS is a GIS software which works with Windows, Macintosh, Linux and Unix.
- SPRING is a GIS and Remote sensing image processing software with an object oriented model facility. It has the capacity of working with Windows, Linux, Unix and Macintosh.
- uDig GIS is yet another open source desktop application which allows viewing of local shape files and also remote editing spatial database geometries.
- KOSMO is a popular desktop application which provides a nice graphic user interface with applications of spatial database editing and analysis functions.
- iRIC (International River Interface Cooperative) is a river flow and riverbed variation analysis software package which combines the functionality of MD_SWMS, developed by the USGS (U.S. Geological Survey) and RIC-Nays, developed by the Foundation of Hokkaido River Disaster Prevention Research Center. The iRIC software consists of three functions: preprocessor**,** postprocessor, and solver**.** iRIC Software, iRIC Project: http://i-ric.org/en/

Interactive visualization tools are:

- Showing sea level rise: http://globalfl oodmap.org/South Africa
- Global Archive map of extreme flood events (1985-2002):

http://floodobservatory.colorado.edu/Archives/GlobalArchiveMap.html

A major step taken by Deltares, a leading research institute based in the Netherlands, is to release specific modules of the Delft 3D model (FLOW, Morphology and Waves) as open source to bring experts all over the world together to share their knowledge and expertise. It is a robust, stable, flexible and easy to use model which is internationally recognized. For more information please see the following link: http://oss.deltares.nl/web/opendelft3d/home.

(3) Model result validation and uncertainty involved

Validation of results by means of surveying, also known as ‘ground truthing’ of the model, is extremely important to ascertain the quality of the model output. Additional validation, using actual event data, provides another way of testing how appropriately the hazard model has performed. Both the above checking processes are required in order to improve the precision of the model outputs and thereby the usefulness of the final map product[22].

It is observable that uncertainty exists in every stage of hazard assessment. Uncertainty exists in every stage of data accumulation, model selection, input parameters, operational and manual handling of the model till the final output is obtained. Each element contributes to the uncertainty in accuracy of the final output. Therefore it is necessary to consider the impact that uncertainty has on the output of a model and is essential to reduce it as much as possible[23].

[22] Adopted from Cities and Flooding 2012, p 80
[23] Contents of section 5.3.5 are adopted from Cities and Flooding 2012, p 80

5.3.5 Flood maps prepared and distributed to users

Model outputs can be exported in a variety of GIS formats (raster or vector) which can then be used to generate maps, thereby translating the model results into a user-friendly format. Hazard maps in different formats are helpful for different kind of users (in terms of scales, size, the amount of information, and the level of generalization). The appropriate software will permit outputs to be tailor-made in order to adhere to specific user requirements. Those flood hazard maps in different format shall be delivered to the relevant stakeholders including representatives of local residents depending on respective purposes and needs through the relevant local government offices.

5.3.6 Monitoring and regular updating of Flood Hazards

Identified Flood hazard information must be updated regularly with both field information (for example, major building developments or road construction that significantly alter the terrain) as well as other relevant data, such as any changes in the peak recorded flows from gauging stations following extreme events. Monitoring of the flood hazard in use is also required to be revised (for example, where data from actual events following model calculation are found to exceed the predictions)[24].

[24] Adopted from Cities and Flooding 2012, p 82

CHAPTER 6 ASSESSMENT OF VULNERABILITY AND RISK

6.1 Characteristics of Flood Vulnerability and Disaster Risk

6.1.1 Issues in assessing flood vulnerability and risk

(1) Hazard assessment to risk assessment

According to the United Nations Department of Humanitarian Affairs (UNDHA) the concept of risk assessment involves the survey of a real or potential disaster in order to estimate the actual or expected damage for making recommendations for prevention, preparedness and response (UNDHA 1992). This essentially consists of evaluation of risk in terms of expected loss of lives, people injured, property damaged and businesses disrupted. Based on the definitions in Section 4.1, risk is the product of hazard, exposure and vulnerability and can be mathematically expressed for a given flood event in a particular area and reference time period. In Chapter 6 this definition of risk is applied to risk assessment.

Flood hazard assessment is explained in Chapter 5 as part of flood risk assessment. Vulnerability assessments are mainly based on the depth of flood water and they are further used for risk analysis and evaluating the economic and other damages. One of main purposes of flood risk assessment is to provide a sound basis for the planning and allocation of funds and other resources. Evaluation of hazard and vulnerability assessment should proceed as parallel activities so that results combined are comparable. For example, several cities, agricultural lands or industrial parks may be equally vulnerable, but those could have very different exposure to the hazard, depending on their elevation. The main problem in doing so is the availability of organized data, especially in developing countries, and the cost and effort needed to acquire data.

The basic steps involved in a flood risk assessment process are:

- Hazard estimation with reference to location, level of severity and the probability of event occurrence
- Estimation of exposure of elements at risk
- Estimation of vulnerability or damage
- Estimation of risk by integrating hazard, exposure and vulnerability or integrating probability and damage

(2) Accuracy of damage records

In most cases risk assessments are performed based on direct damages. Indirect damages, also known as ‘second order’ effects, are often ignored leading to underestimation of the total cost of flood damage. It can be difficult to get appropriate data for indirect damage assessment, the main problems being measuring accurately the ripple effects on the economy and impacts on infrastructure and communication disruption. In addition, historical data do not disaggregate the total loss into direct and indirect losses. To perform a comprehensive risk assessment, it is necessary to reduce the difference between actual and estimated damage assessment, integration of primary and secondary sources of damage assessment and risk evaluation[25].

(3) Cascading impacts in multiple hazards areas

In areas of multiple hazards the risk is sometimes cascading in nature. Flooding leaves a large amount of debris in its way, disrupting normal drainage and transportation systems. It may also cause fires and electrical short circuits, leading to more damage and destruction. Salt water contamination in coastal regions can also affects water supply lines, as well as contributing to the rate of deterioration of property and other assets.

In addition to raw sewage spills and debris, flood water may also contain toxic materials, leading to pollution of the local environment. There are occasions when a landslide or earthquake causes flooding: this is particularly true in multi hazard areas where one disaster leads to another, resulting in a much greater incidence of damage and destruction[26].

(4) Transition of hazard, impacts and vulnerability

Changes in impacts from flooding may result from changes in the hazard, changes in the exposure of populations and their assets, or changes in the vulnerability of the exposed populations and assets.

6.1.2 Types and purpose of assessing vulnerability and risk

(1) Type of vulnerability

The different types of vulnerability and the factors affecting their rate of exposure are shown in Table 6.1.

Table 6.1 Types of Vulnerability and the Factors Affecting Their Rate of Exposure

Types of Vulnerability	Exposure Factors
Individual or household vulnerability	Education, age, gender, race, income, past disaster experience
Social vulnerability	Poverty, race, isolation, lack of social security services
Institutional Vulnerability	Ineffective policies, unorganized and non-committed public and private institutions
Economic Vulnerability	Financial insecurity, GDP, sources of national income and funds for disaster prevention and mitigation
Physical Vulnerability	Location of settlement, material of building, maintenance, forecasting and warning system
Environmental Vulnerability	Poor environmental practices, unprecedented population growth and migration
System Vulnerability	Utility service for the community, health services, resilient system
Place Vulnerability	Mitigation and social fabric

Source: Cities and Flooding 2011, Table 2.3, p173

To measure vulnerability at different scales, hazard researchers have used numerous strongly correlated variables, such as the physical, social, economic, and political condition of the area

[25] Adopted from Cities and Flooding 2012, p 170
[26] Adopted from Cities and Flooding 2012, p 171

of occurrence. Some of the major factors which increase vulnerability to urban flooding, especially in developing countries, are: poverty, poor housing and living conditions, lack of preparedness and management of flood defenses, increasing population, development of squatter settlements in hazard prone regions, poor maintenance of drainage structures, lack of awareness among the general population, and limitations in early warning systems[27].

(2) Purpose of vulnerability assessment

Vulnerability assessment is carried out in order to identify the most vulnerable sections of the society. Undertaking a vulnerability assessment requires consideration of: the location of the area, resources under threat (both population and physical elements), level of technology available, lead time for warning, and the perceptions of residents regarding hazard awareness (ADPC 2005). Mapping vulnerability can help the policy makers and managers to identify the areas of highest susceptibility and impact, in order to reduce vulnerability and enhance capacity building, by concentrating efforts in those locations[28].

(3) Purpose of flood risk assessment

To understand the potential impact on a community and the appropriate response, flood risk assessment is an invaluable tool: they provide the foundation upon which a well-planned risk management strategy can be built. They assist decision makers to make cost benefit assessments, to prioritize spending, to direct emergency assistance and to design and implement mitigation activities of all kinds. Risk assessment is also necessary for financial planning and insurance purposes.

In order to quantify flood risk completely, it is necessary to estimate the expected losses from potential future flood events, based on the best understanding of impacts. Most risk assessments will start with an assessment of losses due to physical direct damage using a stage damage function and asset database[29].

6.1.3 Characteristics of flood vulnerability and risk maps

(1) Location, elements at risk, land use, flood scale, vulnerability

Vulnerability maps are based on two major factors: the location of the elements at risks (buildings, roads, bridges, settlements critical infrastructure and utilities); and the vulnerability of those elements to different aspects of flooding (flood height, duration, sediment concentration, velocity of water, impulse and level of pollution). Development of vulnerability curves, or stage-damage curves, can be plotted based on different classes of land use, to specify their values in relation to the magnitude of flooding (Smith 1994)[30].

Vulnerability can be expressed as the degree of loss (susceptibility) resulting from occurrence of a natural phenomenon on a scale of 0 to 1, where 0 indicates no vulnerability and 1 is the

[27] Adopted from Cities and Flooding 2012, p 174
[28] Adopted from Cities and Flooding 2012, p 174
[29] Adopted from Cities and Flooding 2012, p 172
[30] Adopted from Cities and Flooding 2012, p 175

highest level of vulnerability. This helps in prioritization of mitigation activities (refer to Section 6.2 (1)).

(2) Stage damage curve

The stage damage curves can be developed in two different ways: either from the actual damage survey from an event, or based upon a hypothetical scenario of an event. The data for the stage damage function are normally obtained from existing inventories, such as cadastral maps, land use maps and information from land valuation or registration offices. Information on the materials used to construct buildings is required, as well as an indication of the condition (whether in a good state of repair, for example). Obtaining such detailed data on an individual level is quite difficult in many cases, especially in countries with weak asset data systems. The survey is conducted based on the value of different classes and a potential valuation curve or stage damage curve is prepared[31].

(3) Vulnerability map

A flood vulnerability map can be prepared based on the information prepared by a method described in sub-sections (1) and (2) using GIS software to assign values per pixel for the entire affected area. The map will then indicate the level of vulnerability that each land use type is exposed to, based on their indicative values from the stage-damage curves.

Flood management in an area can be made highly effective by means of vulnerability zoning, in which areas classified from higher to lower levels of vulnerability. This further helps in the proposition of flood defense mechanisms, effective flood control measures, evacuation planning and flood warning. Table 6.2 summarizes the methods that can be used for vulnerability at different scales of interest, from national down to local[32].

Table 6.2 Vulnerability Assessment Methods at Different Scales

Serial Number	**Methods**	**Remarks**
A	**National level**	
1	Disaster Risk index by BCPR-UNDP	Based on historical vulnerability, for example mortality and level of damage; simple and straightforward
2	Hot spot model by World Bank	Calculated to get vulnerability coefficients; based on disaster related mortality and losses
3	Composite vulnerability index for small island states	This method is event specific.
4	Small island states: natural disaster vulnerability indicator	Uses five specific indicators of vulnerability; representation via scale of 1-4, (1 being of highest vulnerability and 4 the lowest)
B	Megacity level	
1	Mega city level vulnerability assessment by Munich Re	It is important for understanding the level of vulnerability of the existing infrastructures and population; does not take into account historical disasters

[31] Adopted from Cities and Flooding 2012, p 176
[32] Adopted from Cities and Flooding 2012, p 176

Serial Number	Methods	Remarks
C	Local Scale	
1	Vulnerability assessment at local level	Data acquired from local offices at municipal level, questionnaires and national archives, where available; several factors are used to assess vulnerability
2	Household sector approach	Effective for high magnitude event; surveys individual households to gather data about their level of vulnerability
3	Vulnerability at community level	This approach provides a comparative vulnerability analysis between communities in an area; data is primarily collected through questionnaire surveying and interviews
4	Normalizing vulnerability and risk community comparison	Vulnerability is accessed at town and city level by integrating data from aggregation of parameters at this level
5	Holistic approach	Method combines the approach as represented by exposure rate, social fragility and lack of resilience measures; easy to apply in cities but needs specific survey to gather information

Source: Adopted from Villagran de Leon 2006 (Cities and Flooding 2012, p 178)

6.2 Mapping process of flood vulnerability and risks

(1) Workflow of flood vulnerability and risk mapping

Flood risk mapping is a process representing a spatial integration of the hazard, exposure and the level of vulnerability. Risk information can provide overall view of risks by combining effectively probable flood damage with flood hazard. Figure 6.1 illustrates the process of flood vulnerability and risk mapping on the basis of the flood hazard information produced by a method described in Chapter 5.

Flood hazard information, such as flood inundation area, nature of flooding (depth, flow velocity, probability, etc), together with the vulnerability data such as topographic information (elevation, rivers, roads, major buildings, etc), land use and specific elements at risk required for a specific purpose, can provide fundamental data required to conduct flood risk mapping.

In this process vulnerability (susceptibility or resilience) is assessed by a specific survey or conversion from damage records: vulnerability = damage of the elements at risk ÷ total value of the elements at risk. Value of damage ($, death toll, etc) is assessed by a specific survey of damage-stage curve or it is estimated from available value of vulnerability: damage = vulnerability x exposure.

Risk is product of probability of a hazard event and damage of the elements at risk by an event of hazard or product of probability of a hazard, vulnerability and exposure. Definition and key indicator of vulnerability and risk is summarized in Table 6.3.

Table 6.3 Factors Required to Estimate Flood Risk

Factor	Definition	Key Indicator
A. Hazards	Potentially damaging event of flooding	Water depth (mainly), water velocity, inundation period
B. Vulnerability	Conditions determined by physical, social factors to the impact of flood hazard	Susceptibility or Resilience; 0 (no) to 1 (highest) or B = E ÷ D
C. Probability of hazard	Extent to which an event is likely occur	Return period, probability of occurrence; 0 (no occurrence) to 1 (100% occurrence)
D. Value of the elements at risk (or exposure)	Aggregate value of assets, operational indirect products, intangible assets of the elements at risk	Monetary value ($), death toll, etc
E. Damage of the elements at risk by an event of hazard	Aggregate value of direct and indirect damages to the elements impacted by an event of flooding	Damage ($, death toll, etc) = B x D or Value of damage measured by surveys
F. Risk	Combination of the probability of an event (%) and its consequences ($, death toll)	Risk = C x E or C x B x D

Source: JICA Study Team

Box 6.1 Example Vulnerability Map in Tokyo

Responsibility of Local Governments: In Japan municipal governments are required to produce flood hazard maps by the Flood Fighting Act 2005, but flood vulnerability and risk maps are not required. On the other hand prefectural and specified local governments are required by the Disaster Countermeasures Basic Act 1961 (latest amendment December 2011) to produce earthquake hazard and vulnerability maps. Earthquake risk maps are not required.

Report on Earthquake Regional Risk Survey by Tokyo Metropolitan Government 2008: The report provides three types of vulnerability maps and the basic data used and outputs of analysis: Risk rank of building collapse, Risk rank of building firing, and Overall risk ranking. All municipalities and villages of 5,099 are assessed and classified into 5 group of regional risk rank. Risk rank (vulnerability) of each municipality or village is measured in terms of number of buildings at risk of collapse/ha, number of building at risk of firing/ha, and aggregate risk rank of building collapse and firing respectively for risk rank of building collapse, risk rank of firing, and overall risk rank. Municipalities or villages assessed with higher rank are exposed to high impact of a specified earthquake event. Various factors are considered to evaluate respective vulnerabilities.

Regional Risk Rank	Range of Rank of municipalities or villages	Color of Legend
5	1 - 84	
4	85 - 367	
3	368 – 1,174	
2	1,175 – 2,707	
1	2,798 – 5,099	

Source: JICA study Team

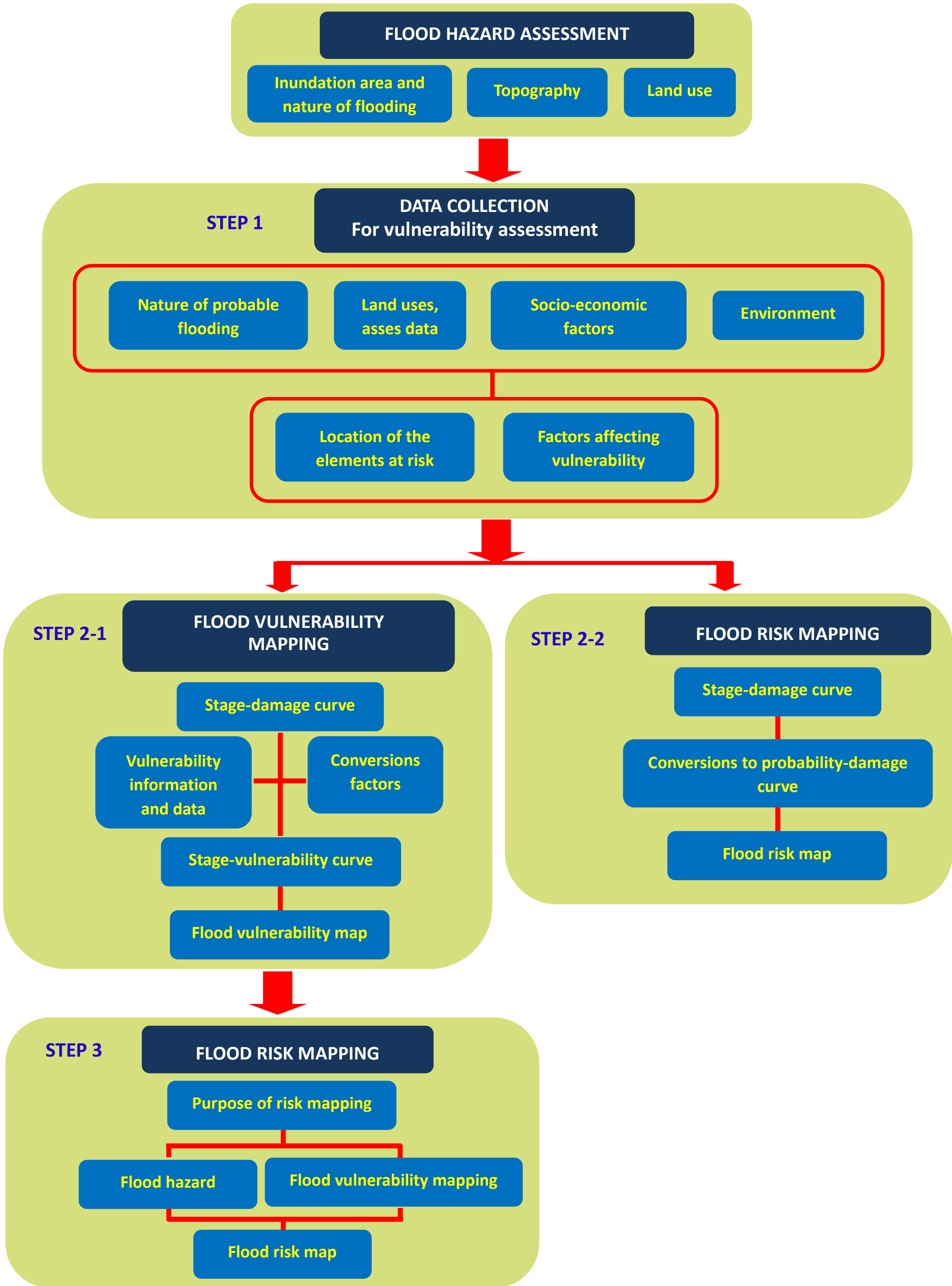


Figure 6.1 Process of Flood Vulnerability and Risk Mapping

Step 1 Data Collection

Supplemental data collection is required to design specifically for vulnerability and risk assessment. The data collection survey covers quantitative nature of probable flooding (for a specific purpose to use), land uses, asset data (buildings, infrastructure, utilities, etc), and factors affecting vulnerability.

Step 2-1 Flood vulnerability mapping

A stage (floodwater depth) - damage curve (or a stage-damage function), which gives a relation between inundation depth and flood damage, is required for each different class of land use. The stage-damage curve provides a base for flood vulnerability assessment. The stage-vulnerability curves are produced by an independent survey or by converting the stage-damage curve by the use of conversion factors with reference to available socio-economic information and data.

For the stage-damage or stage-vulnerability curve, stage is a parameter to define a level of flood scale (magnitude with an exceeding probability or return period): a higher stage indicates a larger flood magnitude, a longer return period or a less probability of occurrence as shown in Figure 6.2.

A flood vulnerability map is produced for a specific magnitude of flood by aggregating the stage-vulnerability curves and hazard information considering its purpose of use.

Step 2-2 or Step 3 Flood risk mapping

A flood risk map is produced either by the use of a stage-damage curve (step 2-2) or by the use of available flood vulnerability maps combined with flood hazard maps (step 3). A stage-damage curve is produced by the use of flood damage survey results with different magnitude of flooding. Once a probability-damage curve is produced from the stage-damage curve, flood risk maps for different occurrence probability are produced by aggregating specific probable damages (both direct and indirect) and appropriate risk information depending on their purpose.

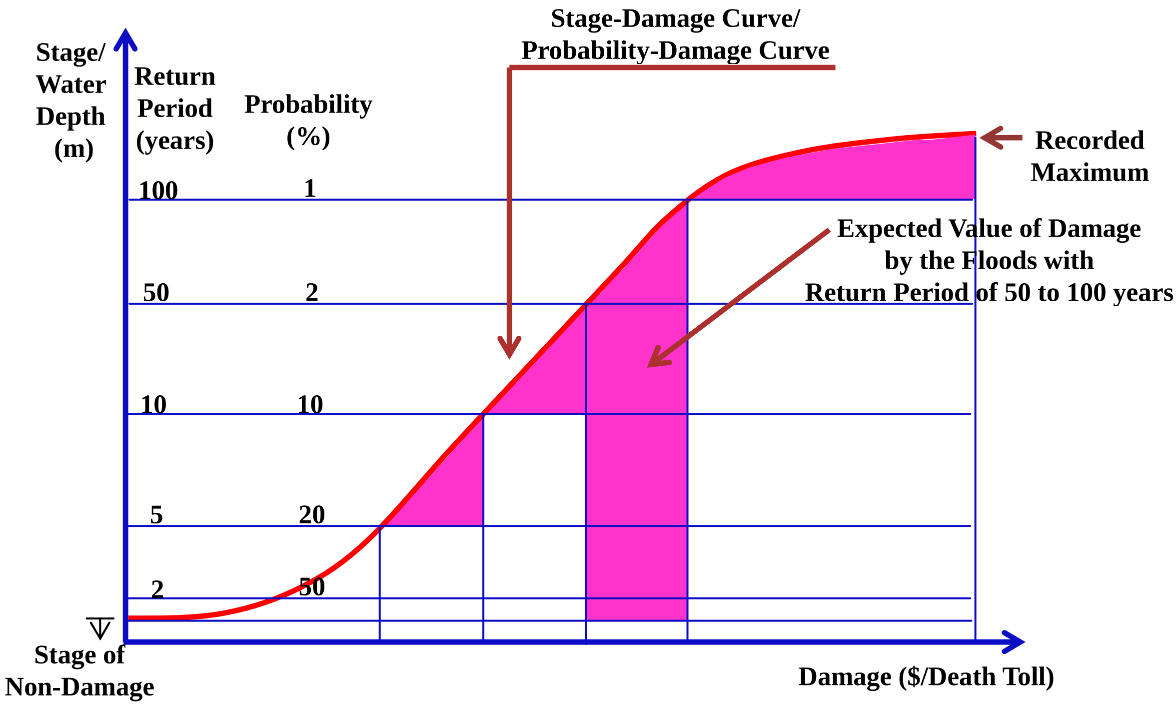
(2) Dynamic nature of flood risk map

Areas at risk of flooding can be dynamic in nature. With a changing level of development, the nature and degree of risk also changes. Flood risk increases mainly because of an increased level of exposure of the elements under threat.

Continuous updating and monitoring of probable risks is most important for proper flood risk management.

(3) Consideration for flood risk mapping

Risk evaluation is the basis for the design of methods to prevent, mitigate and reduce damages from natural disasters. Although there are several available methods for assessment of risk, it has been observed that in many cases societies prefer to set arbitrary standards as the basis for risk mitigation. Without a clear and detailed evaluation of risk, those with responsibility for planning will have inadequate information for allocation of resources for mitigation purposes. This makes it more important to have a standard method for preparation of flood maps as a utility tool for the decision makers (Cities and Flooding 2012, p 181). Table 6.4 below presents key issues for flood risk mapping.



Source: JICA Study Team

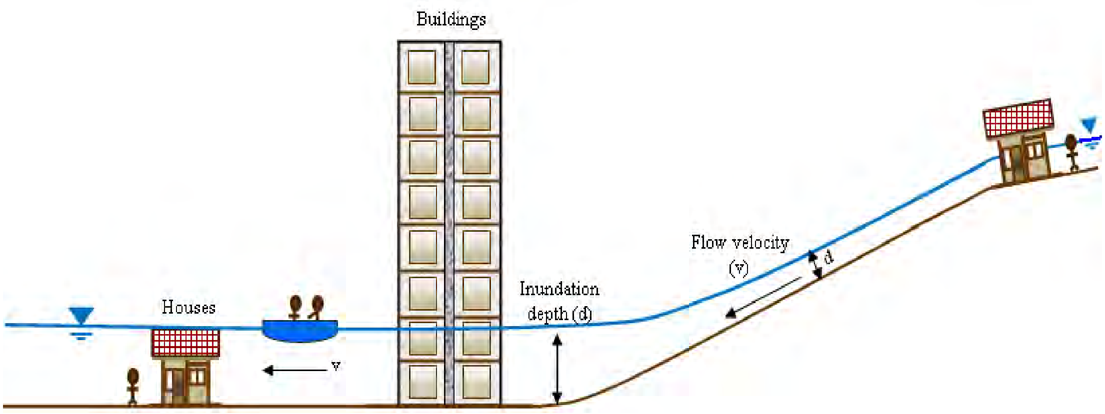
Figure 6.2 Stage-Damage Curve/Probability-Damage Curve

(4) Example flood hazard, vulnerability and risk maps

Example flood hazard, vulnerability and risk maps are presented in ANNEX. Nos. J1 and J2 maps are flood hazard maps specifically produced for evacuation and rescue activities in Japan. Nos. 1 to 10 maps are examples of deterministic flood hazard maps produced in some ASEAN Member States. No. 11 map is a nationwide flood vulnerability map in USA in which vulnerability is expressed in terms of average number of extreme high flow days. Nos. 12 and 13 maps are example outputs of flood risk assessment made in Lao PDR. Nos. 14 and 15 maps are example flood risk maps produced by FEMA, USA. In No.15 map flood risk is noted with a chance of risk (%) and expected loss (US million dollars). Nos. 16 and 17 maps are detailed flood insurance rate maps produced by FEMA, USA in which potential flood inundation areas are noted with zones classified for insurance rate.

Box 6.2 Hazard-Damage-Risk-Relationship

Case of Flood



Impact of flood hazard (I_f) = f (d,v)

Value of elements at risk (V_r): $, value of intangible assets, death toll, etc.

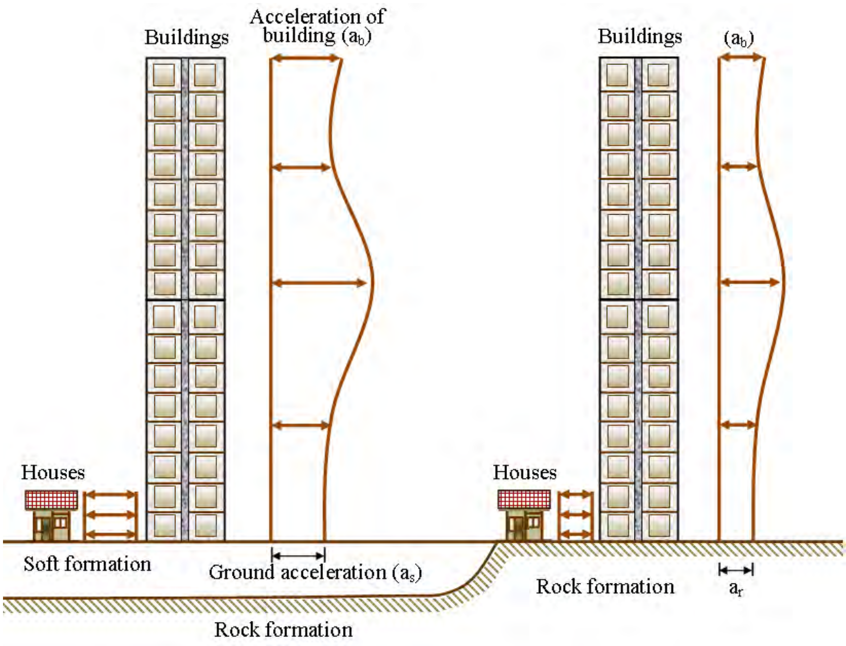
Probability of flood occurrence (P_f): %

Vulnerability to flood (V_f) = Suscepability (S_f)

Flood damage (D_f) = f (d, v) x V_r x V_f

Flood risk = D_f x P_f

Case of Earthquake



Impact of earthquake hazard (I_e) = f (a_s, a_r)

Value of elements at risk (V_r)

Probability of earthquake occurrence (P_e): %

Vulnerability to earthquake (V_e) = Suscepability (S_e)

Earthquake damage (D_e) = f (a_s, a_r) x V_r x V_e

Earthquake risk = D_e x P_e

Source: JICA Study Team

Table 6.4 Consideration for Flood Risk Mapping: Actions & Outputs

Actions	Considerations/operations	Outputs/benefits
Data Collection and Integration	Actual event data, historical data, socio-economic and physical data Sources: local municipalities, regional or national data archives, international organizations like WMO, EM-DAT, existing vulnerability curves for different countries Field Surveying Hypothetical scenario generation for modeling vulnerability	Output in the form of database Important for integration of data from different sources and for future vulnerability analysis of the elements at risk
Generation of stage damage functions or vulnerability curves	Depth of flood water for different return periods Value of the elements at risk depending on their location, condition, material of construction, number of floors, and existence of cellars Extracting data by graphically representing the percentage of damage of the elements at risk to depth of flood water due to lack of resilience and adaptive capacity	Vulnerability curves are important for identifying the level of damage that has been (or can be caused by) different water depths
Conversions of depth-damage-curves to vulnerability maps	Importing data to GIS software (Arc GIS (ESRI), ILWIS (Integrated Land And Water Information System; open source), GRASS (Geographic Resource Analysis Support System; open source) Map classifications based on high, medium and low vulnerability	Conversion of results to an accessible, visual format as maps Essential for illustration of zones of high, medium and low vulnerability for action prioritization
Using vulnerability maps for risk assessment	Integration of hazard maps and vulnerability maps to produce risk maps	Output is in the form of maps showing high, medium and low risk areas Utility tool for decision making to local, regional, national and global authorities

Source: Cities and Flooding 2012, Table 2.5, p 182

6.3 Flood Damage Estimation

6.3.1 Process of flood damage estimation

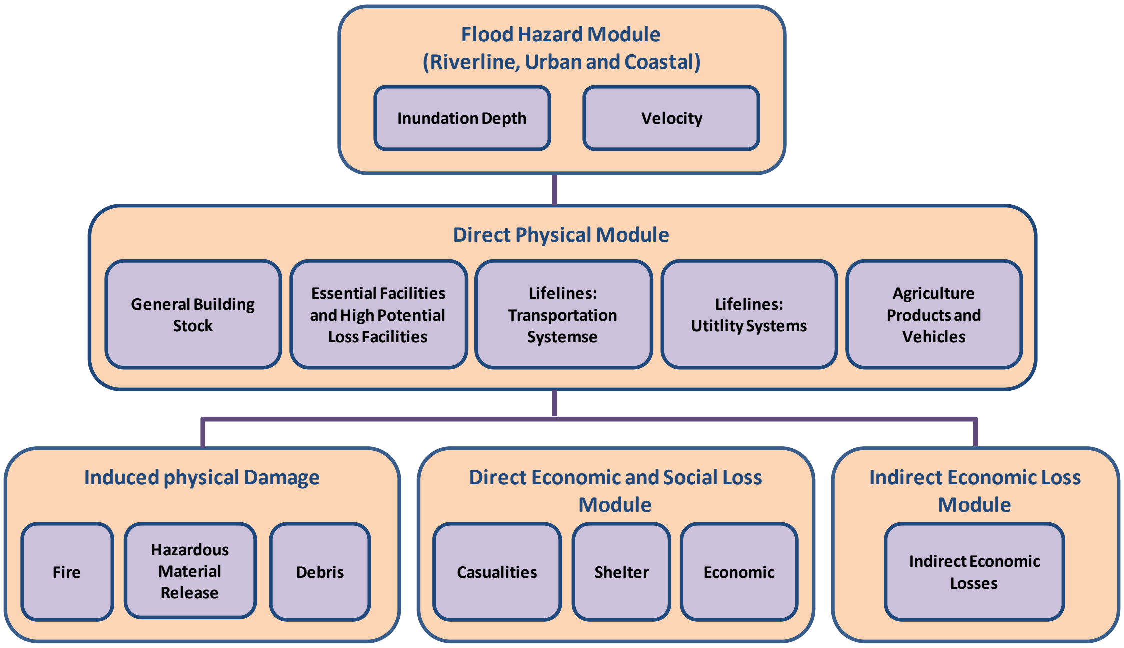
The flood damage or loss estimation analysis will be composed of the following interrelated components:

- Inventory Data
- Flood Hazard
- Direct Physical Damage
- Induced Physical Damage
- Economic and Social Impacts

An important requirement for estimating losses from floods is the identification and valuation of the building stock, infrastructure, and population exposed to flood hazard i.e., an inventory. Consequently, a comprehensive inventory in estimating losses is required.

Depending on the expertise of the professionals concerned, production of flood risk maps requires to operate with minimal interface and data, at least to have Geographic Information System (GIS) such as ArcGIS version 9.3.1 with SP1 and the associated extension Spatial Analyst in order to perform flood hazard and loss estimation.

Figure 6.3 illustrates the database module necessary for flood damage estimation and flood risk assessment. Section 2.1 for floods and Section 2.1 for flood hazard are to be referred for flood hazard assessment.



Source: JICA Study Team

Figure 6.3 Data Base Module for Flood Risk Assessment

6.3.2 Inventory and Standardization for flood damage estimation

Flood damage or loss estimation requires adequate standardization for data collection, process and analysis covering:

1. Inventory data collection based on census block areas or site specific data collection,
2. Using database maps of terrain elevations (DTM),
3. Classifying occupancy of buildings and facilities,
4. Classifying building structure type,
5. Developing building damage functions,
6. Grouping, ranking and analyzing lifelines,
7. Using technical terminology,

8. Providing output.

The inventory data serves as the default when the flood damage estimation is required. Additionally, the national data for essential facilities, high potential loss facilities, selected transportation and lifeline systems, demographics, agriculture, and vehicles are also necessary. The inventory data is required to estimate damage and the direct economic losses for some elements (i.e., the general building stock) or the associated impact to functionality for essential facilities.

The general building stock includes residential, commercial, industrial, agricultural, religious, government and education buildings. Damage is estimated in percent and is weighted by the area of inundation at a given depth for a given census block. The entire composition of the general building stock within a given census block is assumed to be evenly distributed throughout the block. The inventory information necessary for determining a given percent damage for the inundated area is given by relationships between the specific occupancy classifications and the building types. Unit area occupancy table is the table from which all the other tables are based.

Box 6.3 Example of Inventory Databases (Earthquake and Flood Module)

Inventory data for loss estimation are available based on census block for the citizens of the USA.

General Building Stock Occupancy Square Footage Building Type- Occupancy **Essential Facilities** Medical Care Facilities Emergency Operation Centers Schools **High Potential Loss Facilities** Dams **Nuclear Power Facilities** Military Installations Transportation System Highway Segments Highway Bridges Highway Tunnels Railway Track Segments Railway Bridges Railway Tunnels Railway Facilities Light Rail Track Segments Light Rail Bridges Light Rail Tunnels Light Rail Facilities Bus Facilities	Ports and Harbors Facilities Ferry Facilities Airports Facilities Airports Runways **Utility System** Potable Water Pipeline Segments Potable Water Facilities Potable Water Distribution Lines Waste Water Pipeline Segments Waste Water Facilities Waste Water Distribution Lines Oil Pipelines Segments Oil Systems Facilities Natural Gas Pipelines Segments Natural Gas Facilities Natural Gas Distribution Lines Electric Power Facilities Electric Power Distribution Lines Communication Facilities Communication Distribution Cables **Hazardous Materials Facilities** **Population Inventory**

Source: Edited from Hazus-MH User's Manual, Department of Homeland Security, Federal Emergency management Agency, Mitigation Division, Washington, D.C.

CHAPTER 7 APPLICATION OF FLOOD RISK ASSESSMENT

7.1 How to Apply Flood Risk Assessment

7.1.1 Application of flood risk assessment

Flood risk information and results of risk assessment can be used for different purposes, from policy making, flood management planning, preparedness and emergency actions to damage analysis as shown in Table 4.1 in Section 4.3.1. However accuracy and nature of outputs is different depending on type of assessment and degree of accuracy and reliability. Application of those outputs must be carefully determined considering adequate purpose and accuracy of outputs.

Outputs of flood hazard assessment, flood vulnerability assessment and flood risk assessment are clearly different according to the respective definitions. For example hazard is defined as a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or property damage, while risk is defined as the probability of harmful consequences, or expected losses resulting from interactions between natural or human-induced hazards and vulnerable conditions (see details in Section 4.1).

Main outputs of flood hazard are flood inundation depth and flow velocity for different scenarios (probability of flood). Main outputs of flood vulnerability are susceptibility of communities or damage ratios of assets against corresponding flood hazard level. Main outputs of flood risk are expected damages or loss against corresponding flood hazard level. The relationship between flood hazard, flood vulnerability and flood risk and flood inundation depth is called respectively as stage-probability curve, stage-vulnerability curve, or stage-damage/risk curve (refer to Section 6.2).

For policy making and planning of disaster prevention, mitigation and preparedness outputs of flood hazard assessment are sufficient, but risk assessment covering expected damages is required to execute cost benefit analysis for implementation of structural measures which require high public investment.

Reliable and accurate flood hazard assessment or a flood hazard map is a key to execute accurate flood risk assessment. Investors or insurance companies are able to estimate the total value of the elements at risk, vulnerability and probable damage to the elements at risk if reliable and accurate flood hazard maps are available. It takes cost and time to produce credible and accurate regional flood hazard maps applicable to investment risk assessment or to produce a flood insurance rate map (refer to flood insurance rate maps of Nos. 16 and 17 of Annex Example Hazard and Risk Maps).

7.1.2 Regional BCP

A regional business continuity plan (RBCP), which shows quantitatively a potential risk of public services of a region and their recovery plan, is require in case of a catastrophic flood event. A RBCP provides measures to start and continue operation of the essential facilities, transportation systems and lifeline utility systems which provide services to the region's communities and factories after an event of flood disaster. Essential facilities are schools, police stations, fire stations, medical facilities, and emergency operation centers. Transportation systems are highways, railways, light railway, bus, ports and harbors, ferries, airport systems. Lifeline utility systems are portable water systems, wastewater, oil, natural gas, electric power, communication systems.

In case of a catastrophic flood event, access roads to the subject industrial park, port facilities, and communication facilities could be disrupted, and water supply, electricity supply and communication could be failed resulting failure of carriage of goods, services and workers, and production of factories. This risk is not able to be managed by individuals or a group of factory managers and investors in an industrial park only. Both individual business risk assessment and regional business risk assessment are required for investment risk assessment to a factory in an industrial park.

7.2 Institutional Arrangement for Flood Risk Transfer

The Hyogo Framework for Action (HFA) highlighted the importance of (i) promoting the development of financial and risk sharing mechanisms, particularly insurance and reinsurance against disasters; (ii) encouraging the establishment of public–private partnerships to better engage the private sector in disaster risk reduction activities; encourage the private sector to foster a culture of disaster prevention, putting greater emphasis on, and allocating resources to pre-disaster activities such as risk assessments and early warning systems; and (iii) developing and promoting alternative and innovative financial instruments to address disaster risk.

It will be necessary for ASEAN to facilitate flood insurance mechanisms as part of catastrophic flood risk transfer mechanisms. One path toward sustainable flood risk–transfer mechanism is to establish an initiative for public–private partnerships (PPP) where possible. The PPPs can serve as platforms for market-based risk transfer solutions.

Development of credible and accurate flood hazard maps, regional business continuity plans (RBCPs) and business continuity plans (BCPs) for individual companies will reduce a premium of flood insurance, where flood reinsurance companies could reduce their business risk in flood insurance. Flood hazard assessment, RBCPs, RBCs and flood reinsurance are a set of mechanism of flood risk transfer, where role of national and local governments, insurance companies, and insurers are to be defined clearly.

As an example Federal Emergency Management Agency (FEMA, USA) has provided present National Flood Insurance Program (NFIP) since 1973[33]. NFIP sells both individuals and enterprises flood insurances, but it requires municipal governments to provide qualified flood control measures under the law. Its re-insurance is guaranteed by the federal government.

[33] FEMA, National Flood Insurance Program, Flood Insurance Manual, May 2005

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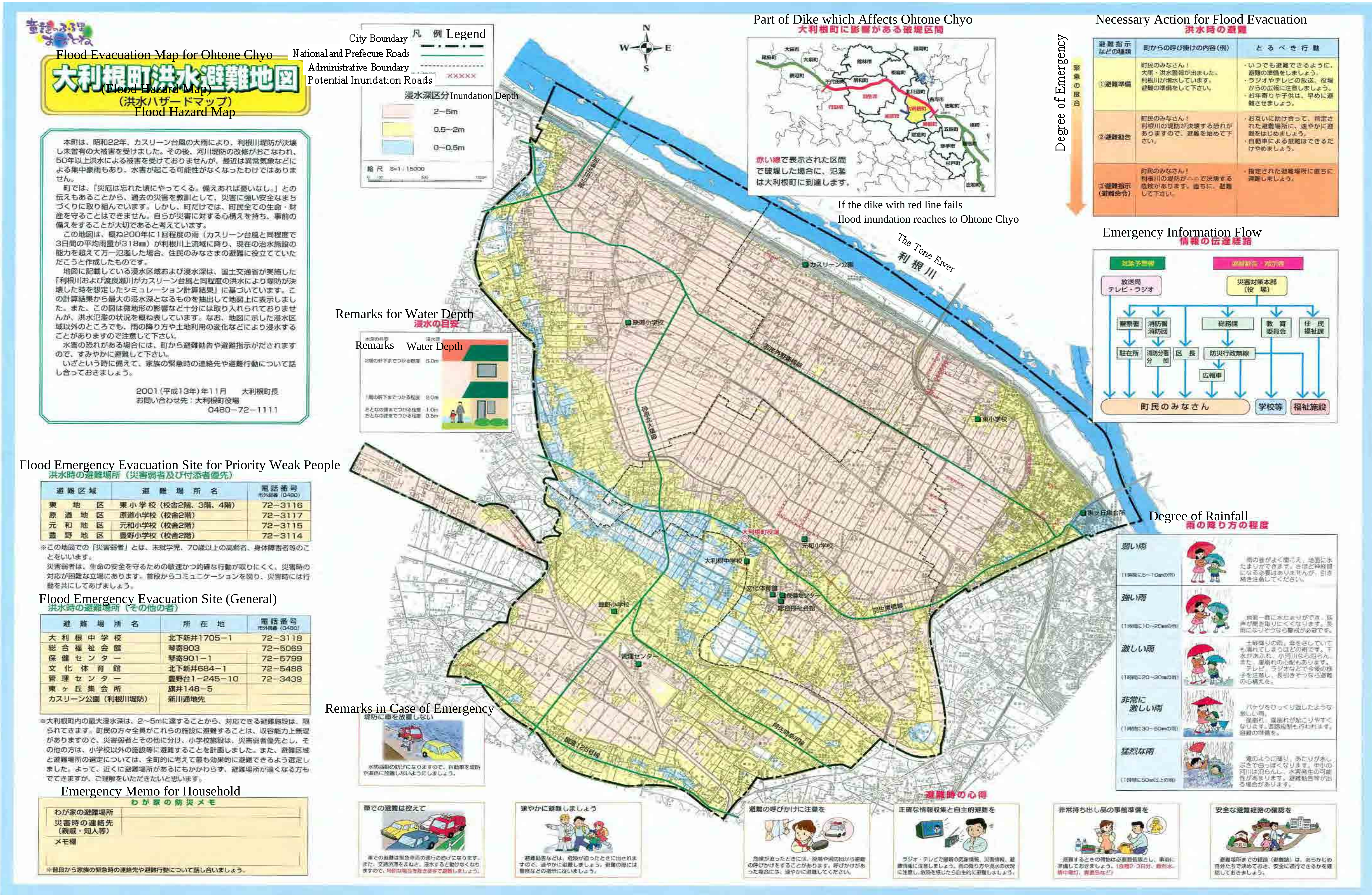
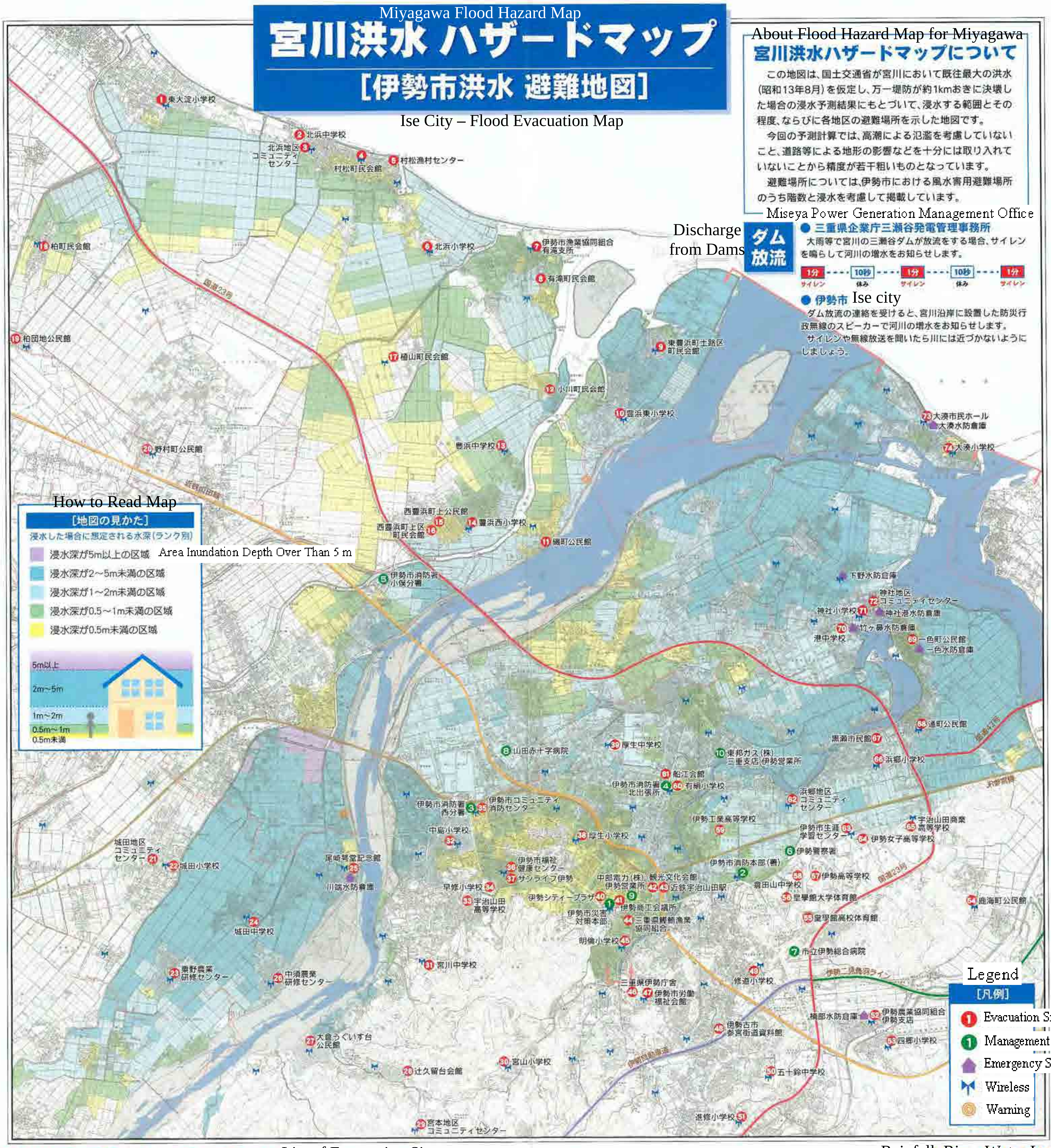
ANNEX: EXAMPLE FLOOD HAZARD AND RISK MAPS

No.	Title
J1	Example Flood Hazard Map in Japan: Flood Evacuation Map for Ohtone Chyo, Japan
J2	Example Flood Hazard Map in Japan: Miyagawa Flood Hazard Map, Japan
1	Example Flood Hazard Map: Maluku Province, Indonesia
2	Example Flood Hazard Map: Solo and Mungkung River, Indonesia
3	Example Flood Hazard Map: Solo River, Indonesia
4	Example Flood Inundation Map: Ciliwung-Cisadane River Territory, Indonesia
5	Example Flood Inundation Map: DKI Jakarta in Year 2002 and 2007, Indonesia
6	Example Flood Prone Map: BBWS Ciliwung-Cisadane River Territory, Indonesia
7	Example Flood Hazard Map: Philippines
8	Example Flood Hazard Map: Lao PDR-1
9	Example Flood Hazard Map: Lao PDR-2
10	Example Flood Hazard Map: Cambodia
11	Example Flood Vulnerability Map: NRDC USA
12	Example Output of Flood Risk Assessment: Lao PDR-1
13	Example Output of Flood Risk Assessment: Lao PDR-2
14	Example Flood Risk Map: FEMA USA-1
15	Example Flood Risk Map: FEMA USA-2
16	Example Flood Insurance Rate Map: FEMA USA-1
17	Example Flood Insurance Rate Map: FEMA USA-2



No. J1 EXAMPLE FLOOD HAZARD MAP IN JAPAN: Flood Evacuation Map for Ohtone Chyo, Japan



●避難場所一覧表（ハザードマップ該当分） List of Evacuation Sites

名称	所在地	電話番号
1 東大淀小学校	東大淀町351	37-2143
2 北浜中学校	東大淀町15	37-2142
3 北浜地区コミュニティセンター	村松町3-1	37-2026
4 村松町民会館	村松町4011-1	37-2938
5 村松漁村センター	村松町3859-2	37-2101
6 北浜小学校	村松町3292	37-2127
7 伊勢市漁業協同組合有滝支所	有滝町2021	37-2050
8 有滝町民会館	有滝町2638	37-3114
9 東豊浜町土路区町民会館	東豊浜町1089	37-2501
10 豊浜東小学校	東豊浜町299	37-2156
11 磯町公民館	磯町964-1	37-0896
12 小川町民会館	西豊浜町3657-3	37-1908
13 豊浜中学校	西豊浜町2736	37-2137
14 豊浜西小学校	西豊浜町1779	37-2202
15 西豊浜町上公民館	西豊浜町45-1	37-0401
16 西豊浜町上区町民会館	西豊浜町40	—
17 植山町民会館	植山町486	37-1099
18 柏町民会館	柏町528	37-0436
19 柏団地公民館	柏町760	—
20 野村町公民館	野村町5566-1	37-4802
21 城田地区コミュニティセンター	上地町1809-1	22-3638
22 城田小学校	上地町1478	22-3641

名称	所在地	電話番号
23 粟野農業研修センター	粟野町1235-1	22-4673
24 城田中学校	粟野町777	25-5978
25 尾崎咢堂記念館	川端町97-2	22-3198
26 中須農業研修センター	中須町1699	23-6523
27 大倉うぐいす台公民館	大倉町1553-61	—
28 辻久留台会館	辻久留町545-155	—
29 宮本地区コミュニティセンター	前山町355-4	22-2232
30 宮山小学校	旭町349	28-2540
31 宮川中学校	二俣4丁目5-3	28-3702
32 中島小学校	二俣1丁目2-17	28-2766
33 宇治山田高等学校	浦口3丁目13-1	28-7158
34 早修小学校	常磐3丁目10-19	28-2765
35 伊勢市コミュニティ消防センター	常磐1丁目17-12	28-2939
36 伊勢市福祉健康センター	八日市場町13-1	27-2425
37 サンライフ伊勢	八日市場町13-13	28-1266
38 厚生小学校	一志町1-4	28-2185
39 厚生中学校	一之木5丁目5-3	28-3703
40 伊勢シティープラザ	岩渕1丁目2-29	24-2751
41 伊勢商工会議所	岩渕1丁目7-17	25-5151
42 観光文化会館	岩渕1丁目13-15	28-5105
43 近鉄宇治山田駅	岩渕2丁目1-43	28-2767
44 三重県鰹鮪漁業協同組合	岡本1丁目7-9	25-1255

名称	所在地	電話番号
45 明倫小学校	岡本1丁目18-21	28-2721
46 三重県伊勢庁舎	勢田町622	27-5115
47 伊勢市労働福祉会館	勢田町628-3	25-5686
48 伊勢古市参宮街道資料館	中之町69	22-8410
49 修道小学校	久世戸町5	28-2764
50 五十鈴中学校	中村町458	22-2929
51 進修小学校	宇治浦田2丁目16-43	22-2427
52 伊勢農業協同組合伊勢支店	楠部町乙581-1	22-3377
53 四郷小学校	楠部町2484	22-3397
54 鹿海町公民館	鹿海町994-1	25-0455
55 皇學館高校体育館	楠部町138	22-0205
56 皇學館大学体育館	神田久志本町1704	22-0201
57 伊勢高等学校	神田久志本町1703-1	22-0281
58 倉田山中学校	神田久志本町1645	22-2198
59 伊勢工業高等学校	神久2丁目7-18	23-2234
60 有緝小学校	船江2丁目2-5	28-2450
61 船江会館	船江1丁目5-44	23-3090
62 浜郷地区コミュニティセンター	黒瀬町48	22-4880
63 伊勢市生涯学習センター	黒瀬町562-12	21-0900
64 伊勢女子高等学校	黒瀬町562-13	22-4155
65 宇治山田商業高等学校	黒瀬町1193	22-1101
66 浜郷小学校	黒瀬町1648	22-3701

名称	所在地	電話番号
67 黒瀬市民館	黒瀬町1180	25-7535
68 通町公民館	通町1339	24-2073
69 一色町公民館	一色町1681	24-3692
70 港中学校	竹ヶ鼻町100	36-4684
71 神社小学校	神社港294	36-4666
72 神社地区コミュニティセンター	神社港262-1	36-4651
73 大湊市民ホール	大湊町783-11	36-4534
74 大湊小学校	大湊町1118-194	36-4564

●緊急連絡先 Emergency Phone Number

名称	所在地	電話番号
1 伊勢市防災交通課（災害対策本部）	岩渕1丁目7-29	21-5523
2 伊勢市消防本部（署）	神田久志本町1436-1	25-1261
3 伊勢市消防署西分署	常磐1丁目17-12	28-2939
4 伊勢市消防署北出張所	船江2丁目1-10	28-2094
5 伊勢市消防署小俣分署	度会郡小俣町元町13	37-4446
6 伊勢警察署	神田久志本町1481-3	20-0110
7 市立伊勢総合病院	楠部町3038	23-5111
8 山田赤十字病院	度会郡御薗村高向810	28-2171
9 中部電力(株)伊勢営業所	岩渕1丁目9-24	28-2134
10 東邦ガス(株) 三重支店伊勢営業所	船江2丁目27-43	28-9101
— NTT西日本 113お客様センター	津市丸之内28-38	113

●雨量・河川水位情報 Rainfall, River Water Level

川の防災情報（三重県）

内容 Available Information

県内の雨量、河川水位などの情報をリアルタイムで提供

アドレス Address

ホームページ
http://mie.river.go.jp/

i-mode
http://i-mie.river.go.jp/

［浸水予測について］ About Inundation Projection

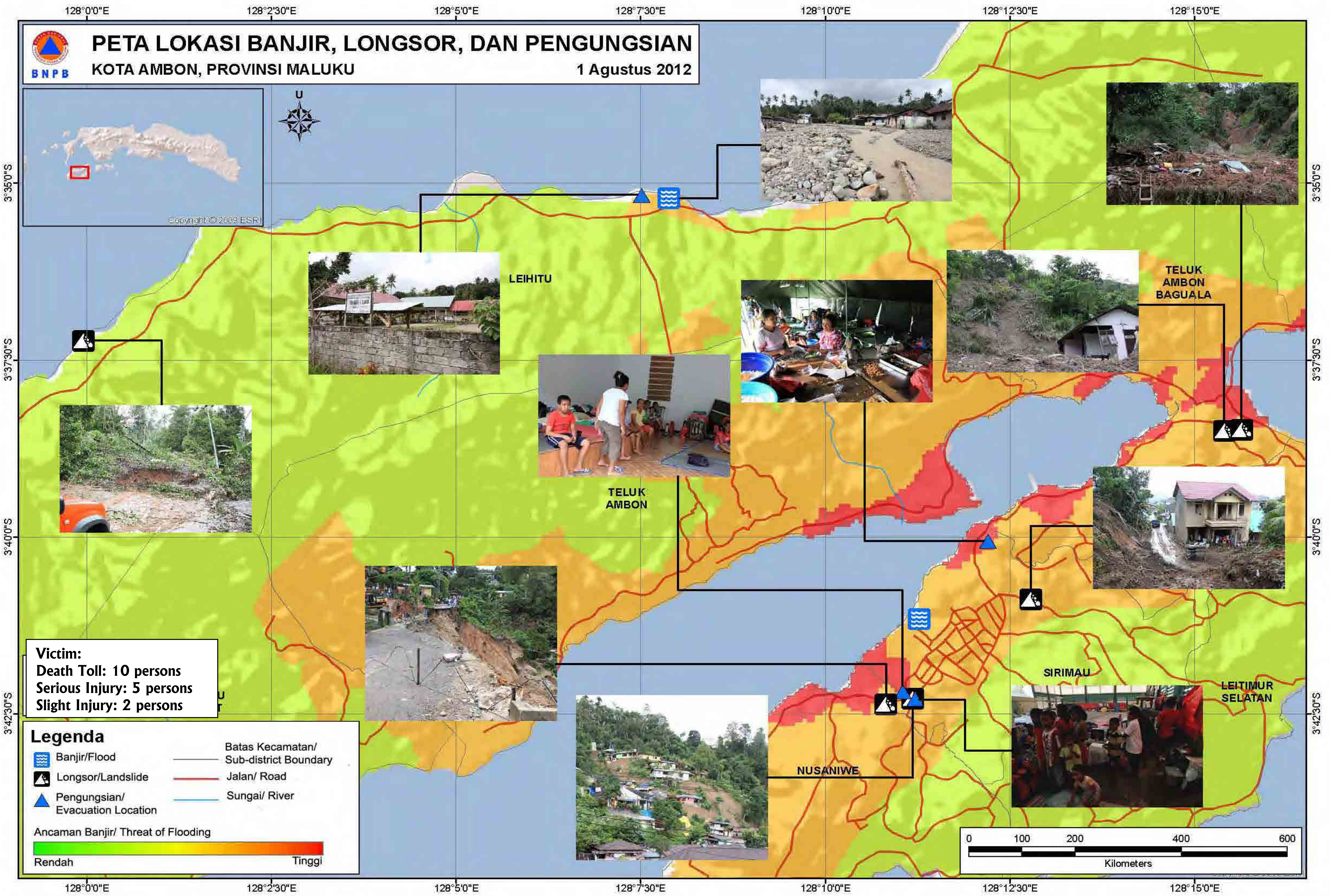
お問合せ先
国土交通省
三重河川国道事務所
調査第一課
☎(059)229-2216

［避難場所について］ About Evacuation Sites

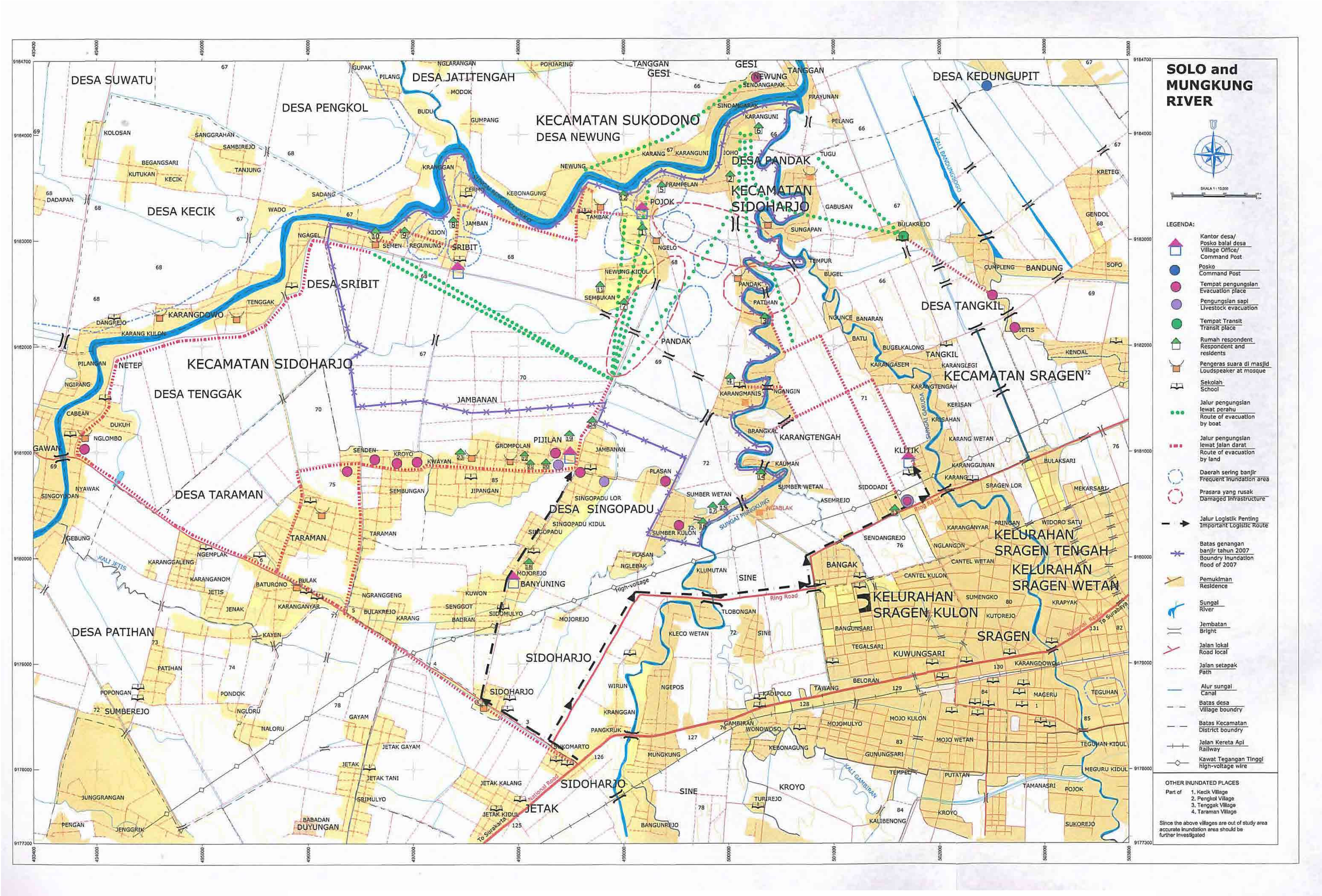
お問合せ先
伊勢市役所
総務部防災交通課
☎21－5523

平成16年3月作成

NO. J2 EXAMPLE FLOOD HAZARD MAP IN JAPAN: Miyagama Flood Hazard Map, Japan

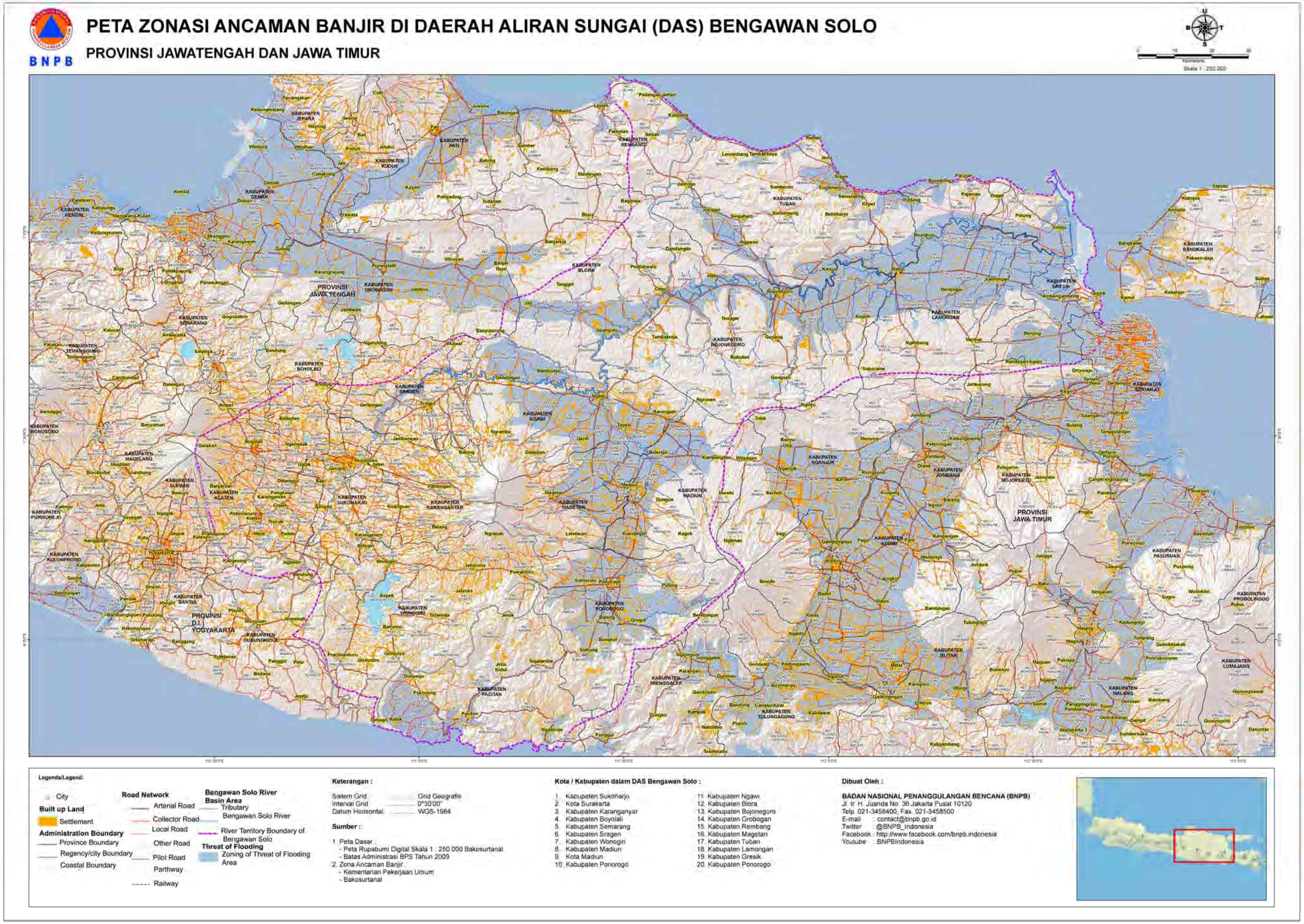


No. 1 EXAMPLE FLOOD HAZARD MAP: Maluku Province, INDONESIA
PURPOSE: Identification of Inundation Areas and Landslide Areas, Evacuation Routes and Location

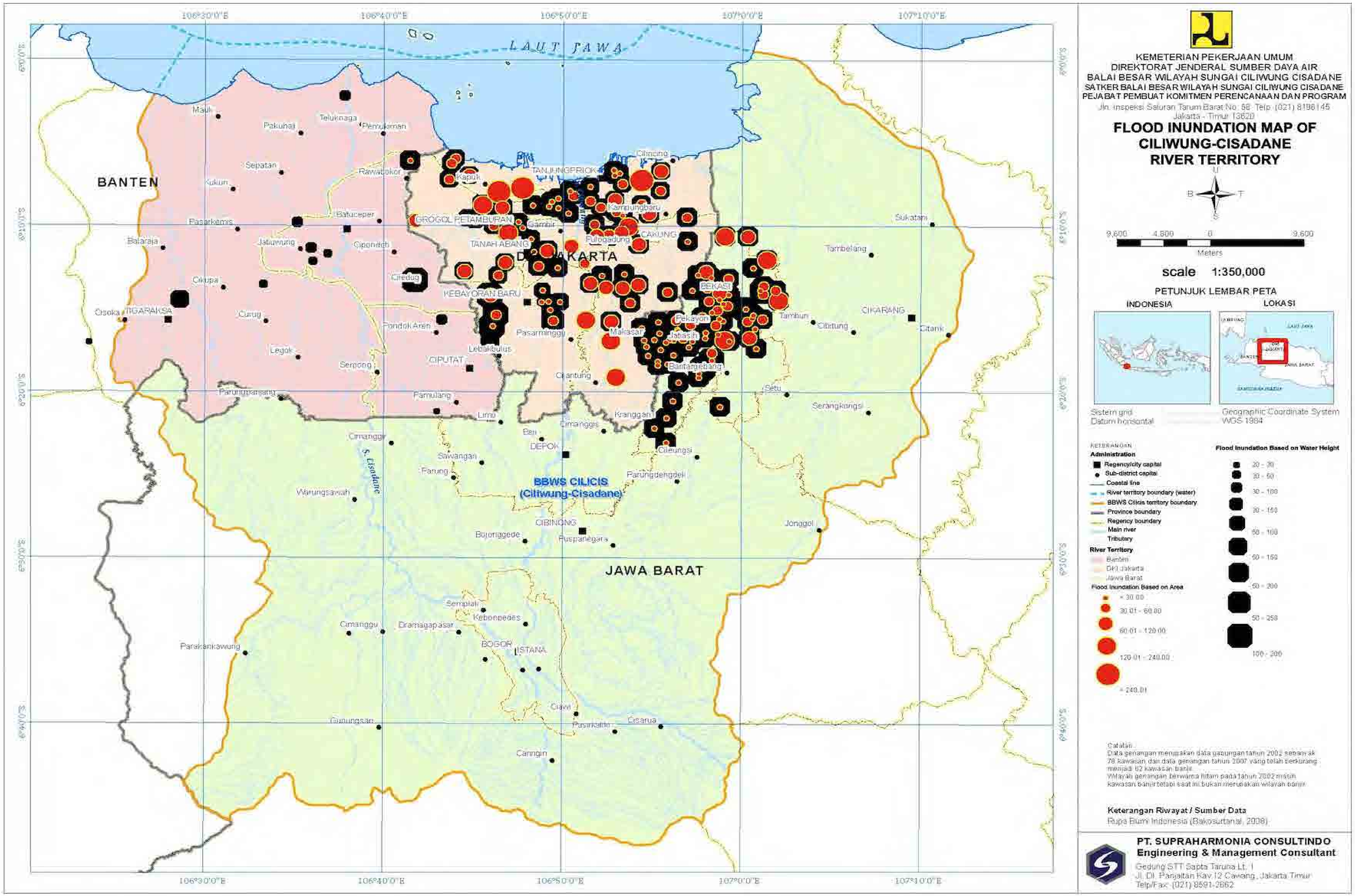


No. 2 EXAMPLE FLOOD HAZARD MAP: Solo and Mungkung River, Indonesia

PURPOSE: Identification of Inundation Areas and Vulnerable Facilities Evacuation Rates and Location

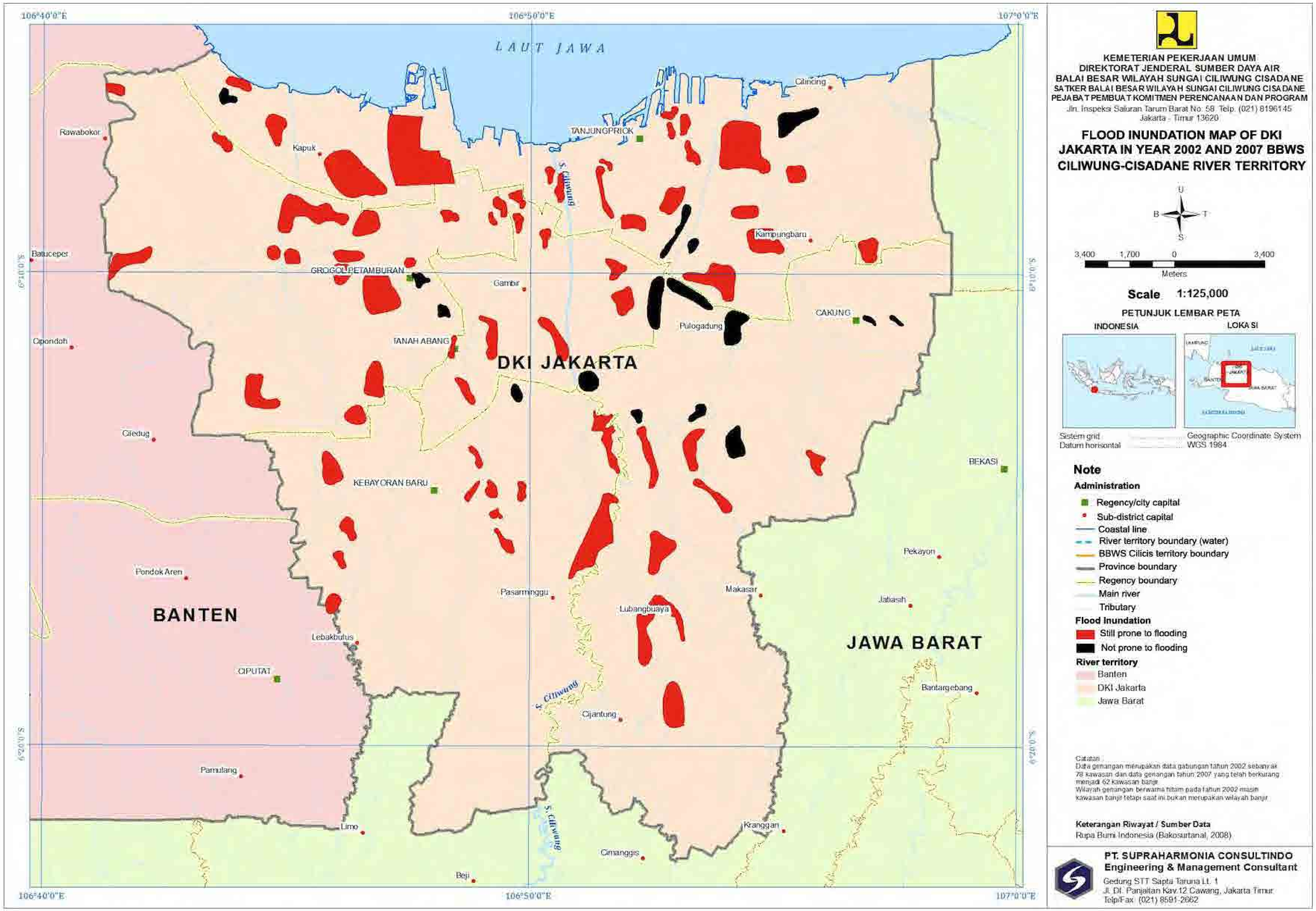


No. 3 EXAMPLE FLOOD HAZARD MAP: Solo River, Indonesia
PURPOSE: Identification of Regional Inundation Areas



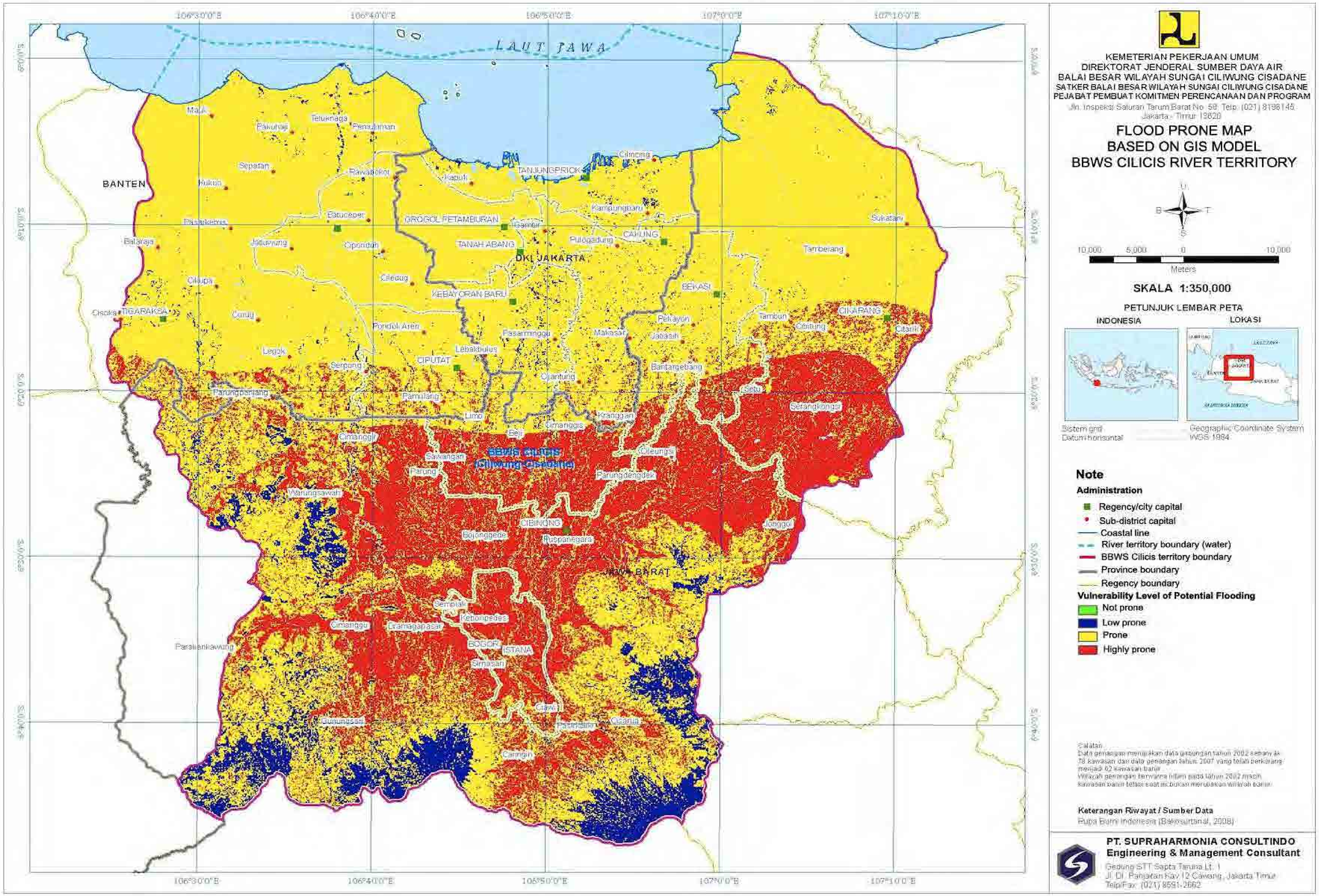
Source: Draft Final Report of Study for Flood Prone Area Mapping in Ciliwung-Cisadane River Territory

No. 4 EXAMPLE FLOOD HAZARD MAP: Flood Inundation Map of Ciliwung-Cisadane River Territory, Indonesia



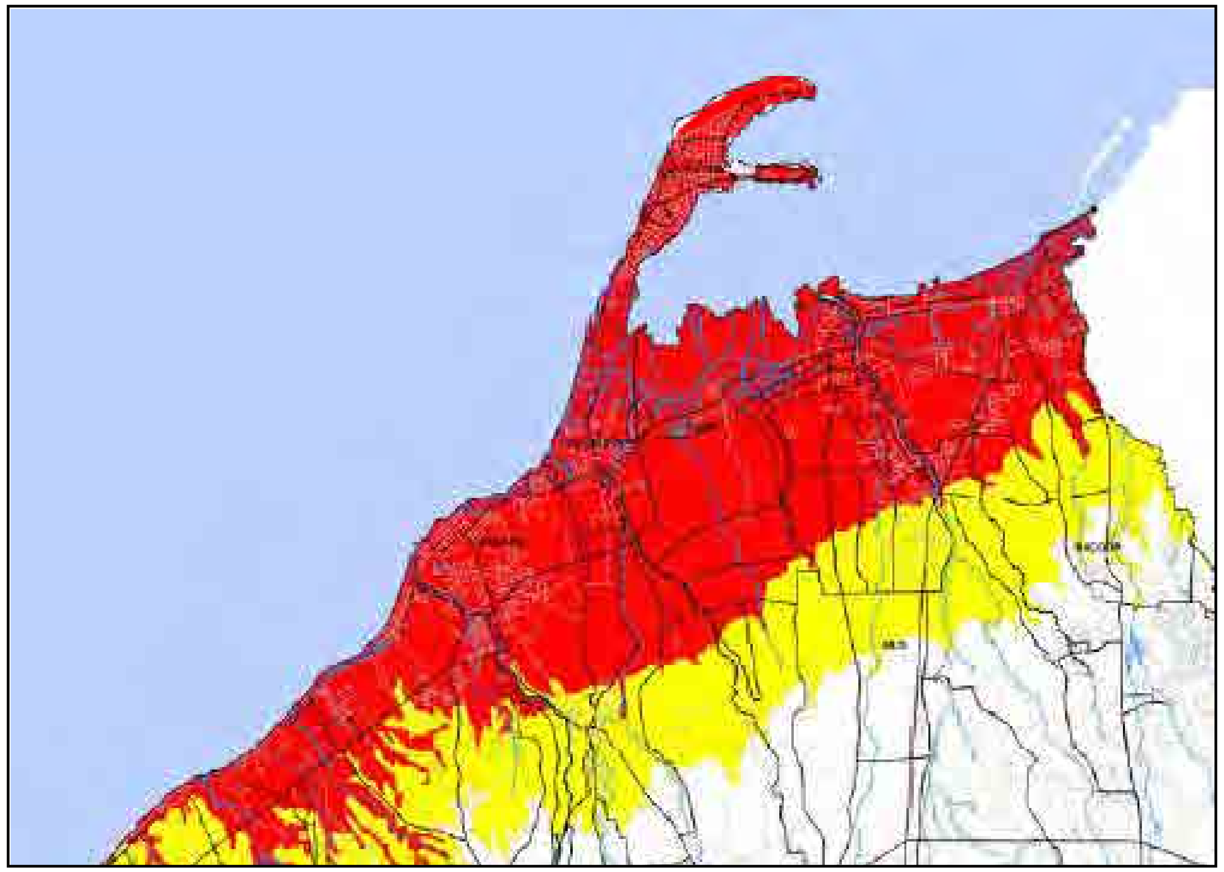
Source: Draft Final Report of Study for Flood Prone Area Mapping of Ciliwung-Cisadane River Territory

No. 5 EXAMPLE FLOOD HAZARD MAP: Flood Inundation Map of DKI Jakarta in Year 2002 and 2007 BBWS Ciliwung-Cisadane River Territory, Indonesia

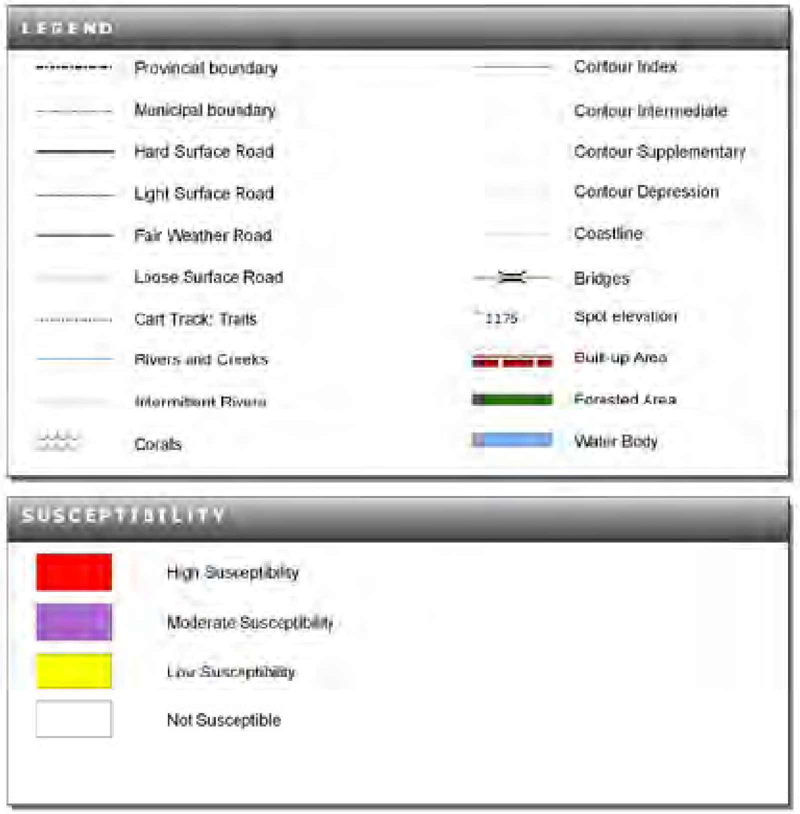


Source: Draft Final Report of Study for Mapping of Flood Prone Area in Ciliwung-Cisadane River Territory

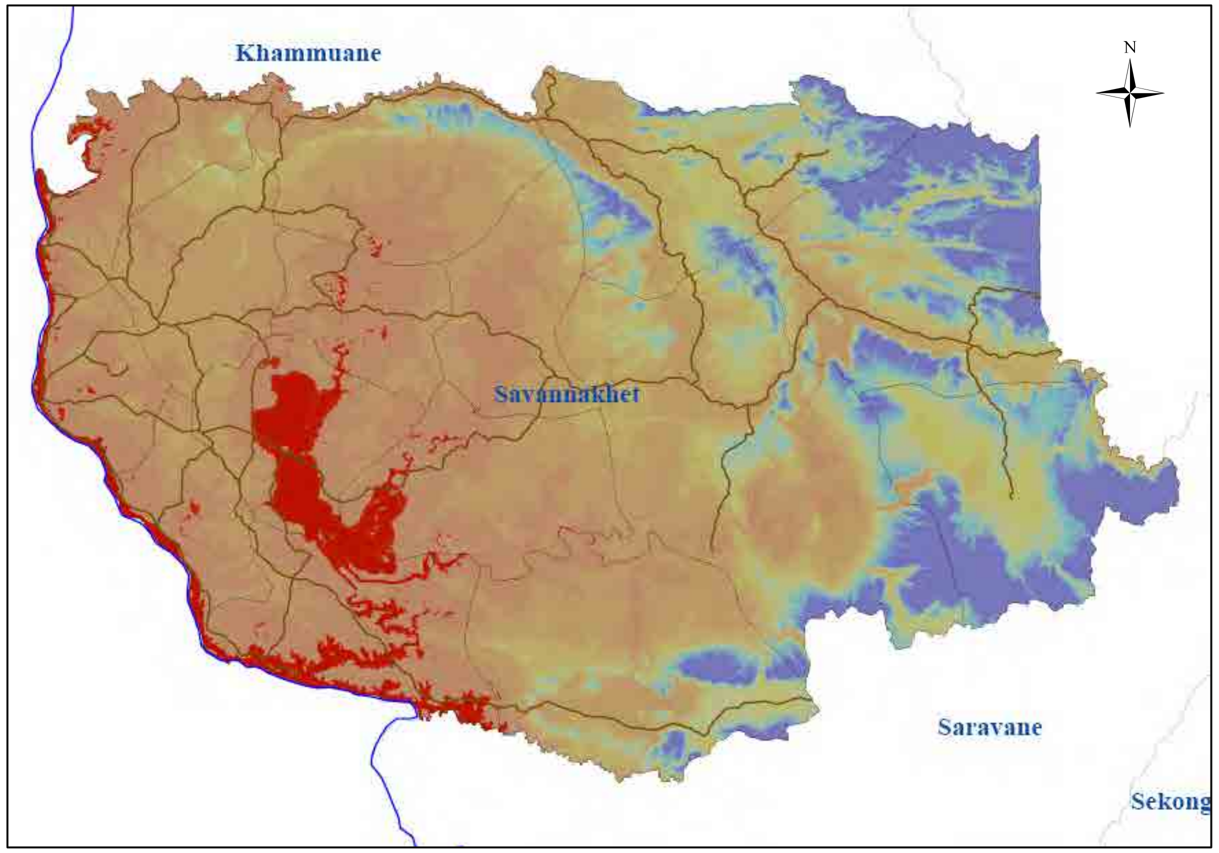
No. 6 EXAMPLE FLOOD HAZARD MAP: Flood Prone Map Based on GIS Model BBWS Ciliwung-Cisadane River Territory, Indonesia



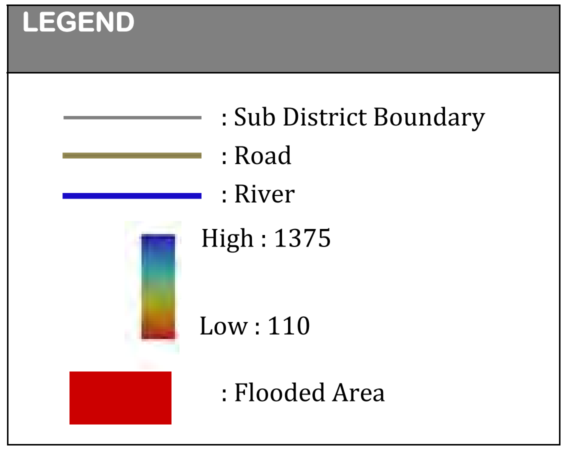
Source: Flood Hazard Map of Cavite Province, Philippines, Scale 1:60,000



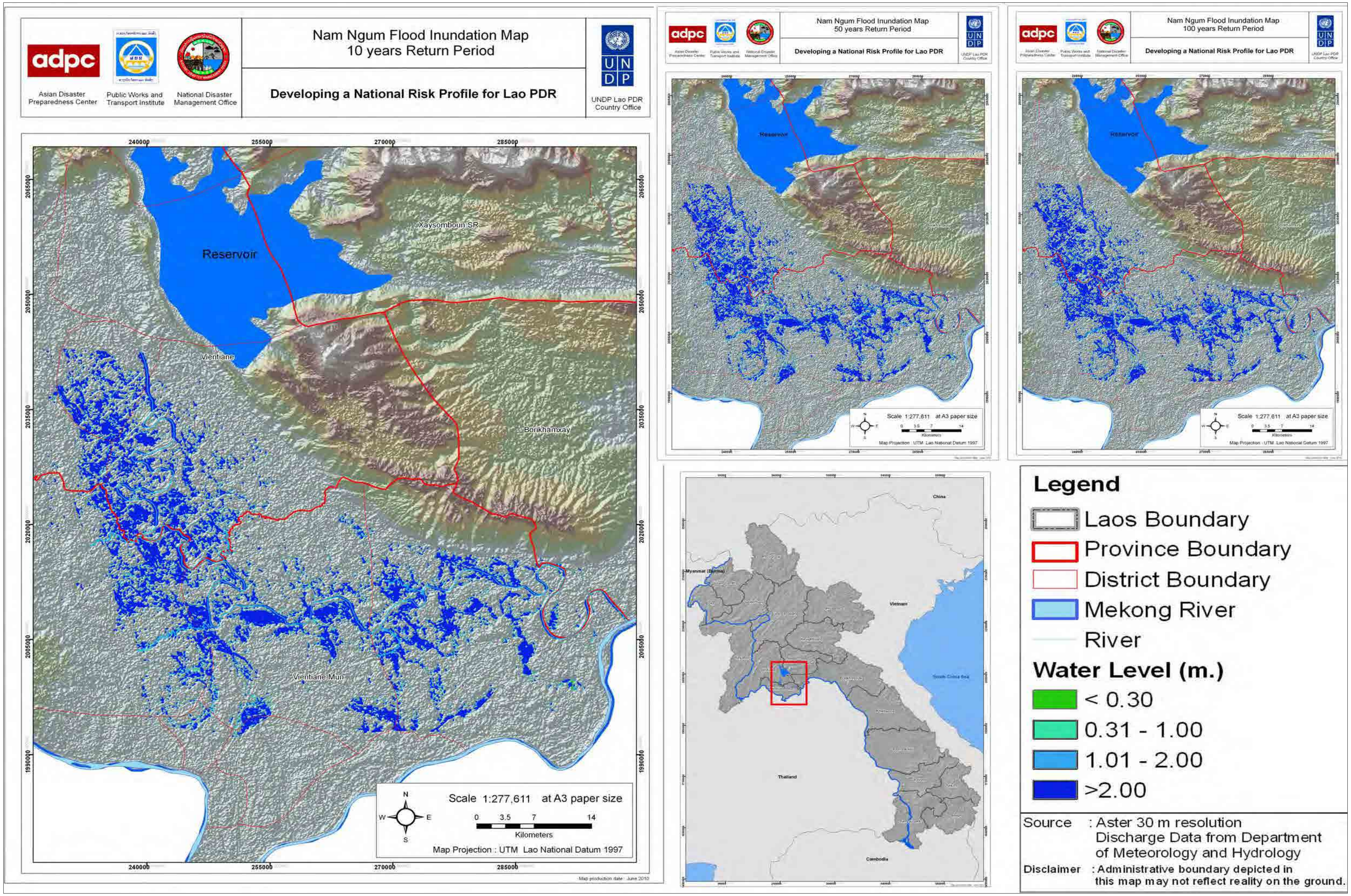
No. 7 EXAMPLE FLOOD HAZARD MAP: Philippines
PURPOSE: Identification of Regional Flood Hazard Areas



Source: Flood Hazard Map of Savannaketh Province, Lao PDR, Scale 1:400,000

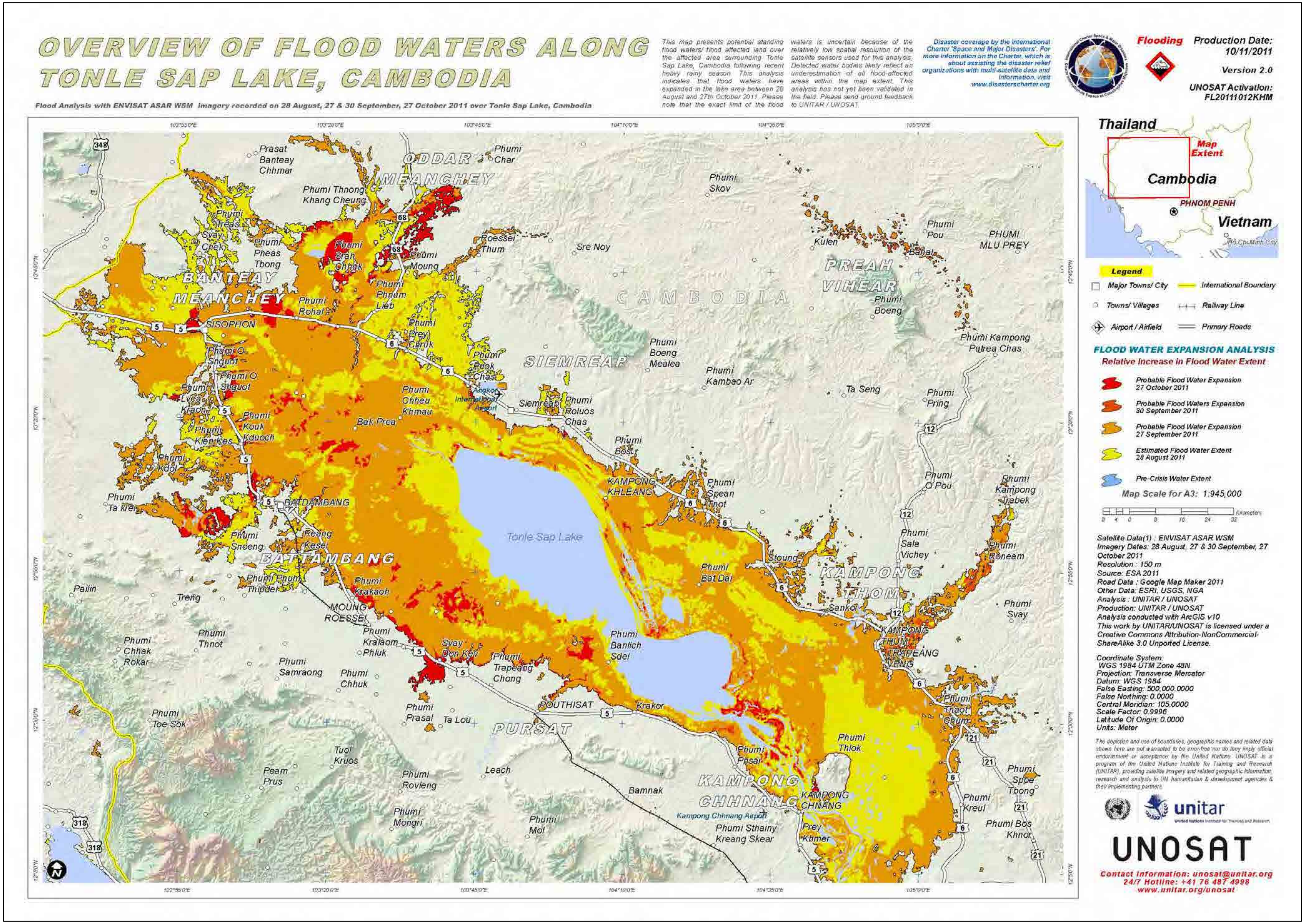


No. 8 EXAMPLE FLOOD HAZARD MAP: Lao PDR-1
PURPOSE: Identification of Regional Flood Hazard Areas

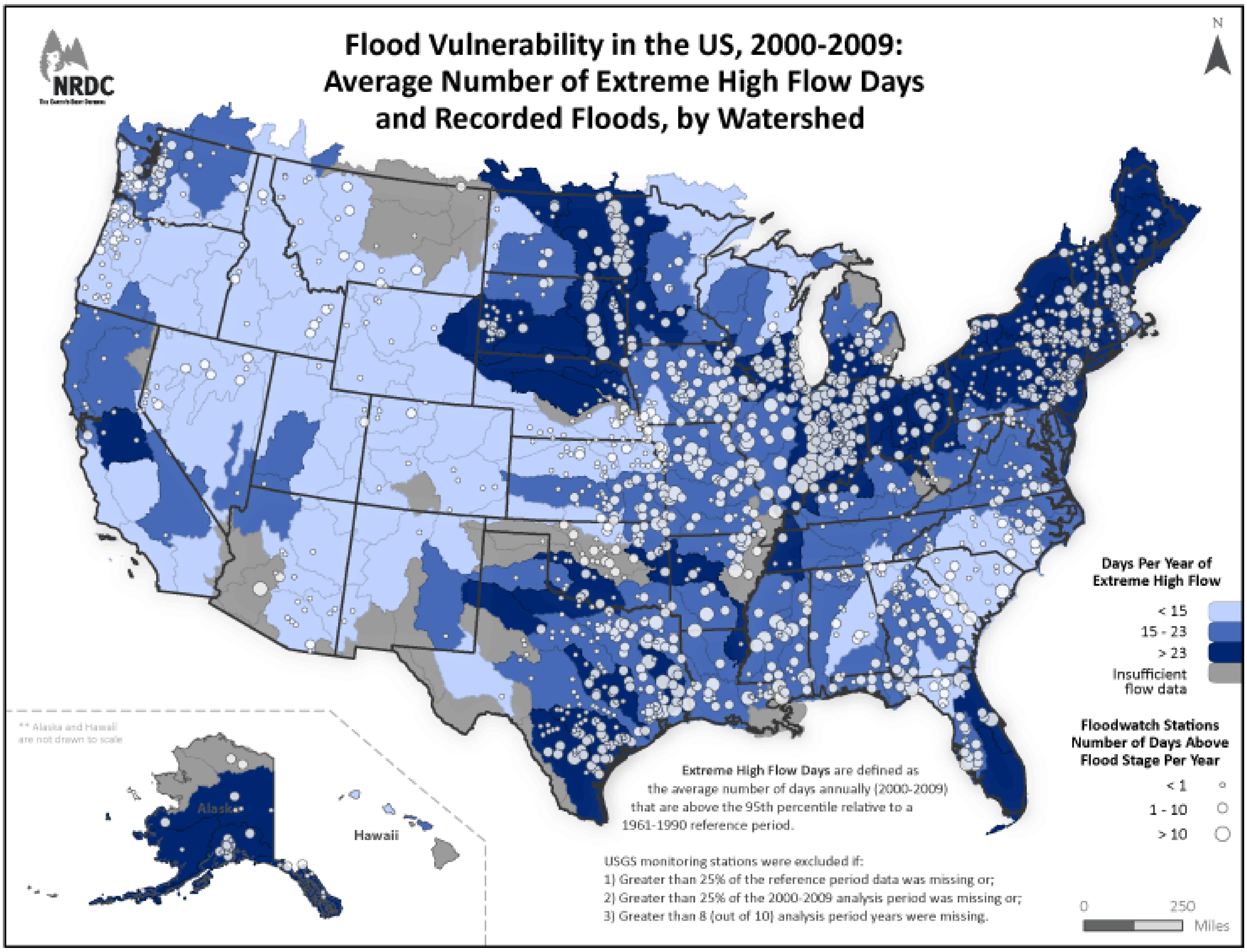


Source: Developing National Risk Profile of Lao PDR, Part-1: Hazard Assessment, November 2010
Asian Disaster Preparedness Center (ADPC), UNDP Lao-PDR Country Office

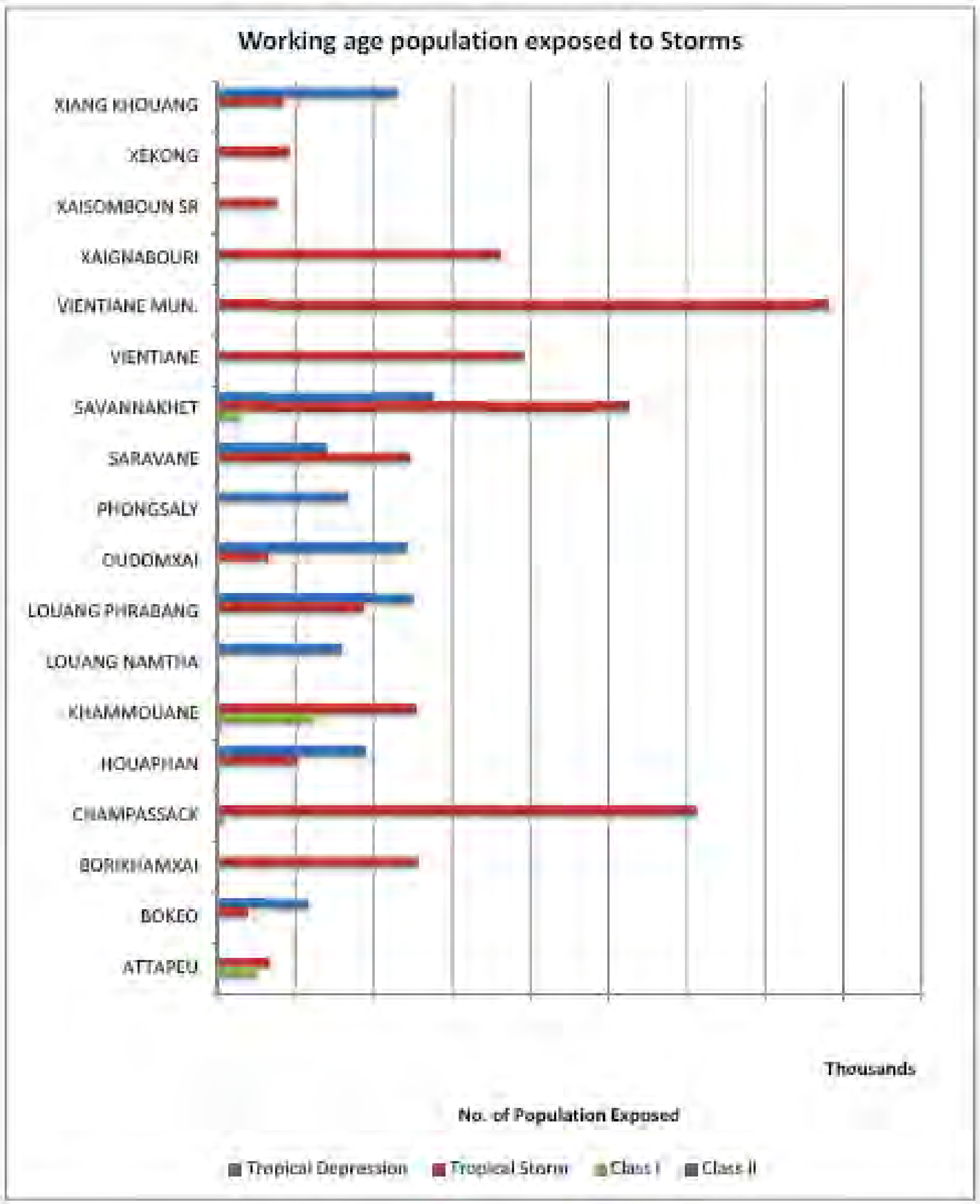
No. 9 EXAMPLE FLOOD HAZARD MAP: Lao PDR-2
PURPOSE: Identification of Regional Flood Hazard Areas

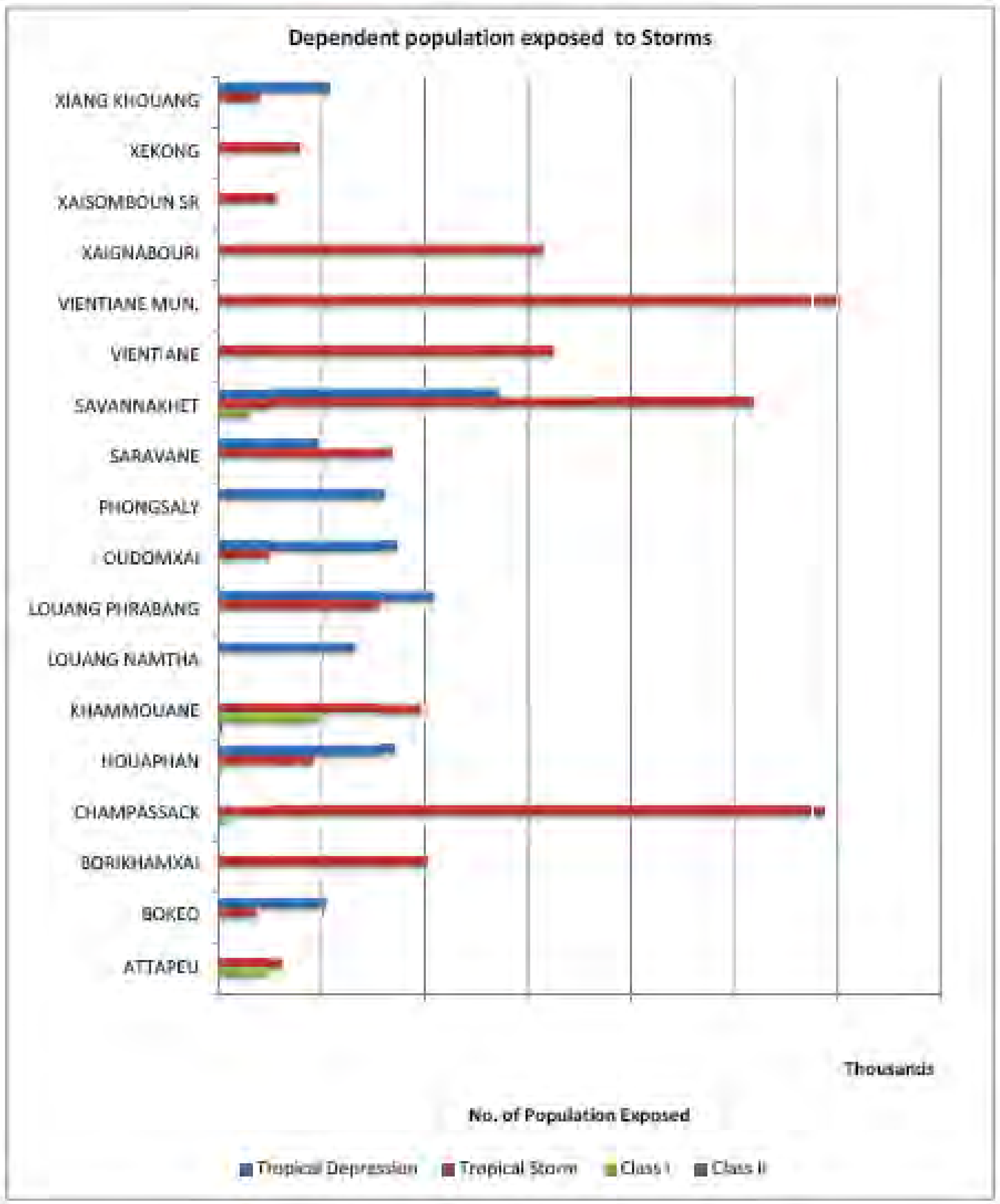


No. 10 EXAMPLE FLOOD HAZARD MAP: Tonle Sap Lake, Cambodia
PURPOSE: Identification of Regional Flood Hazard Areas



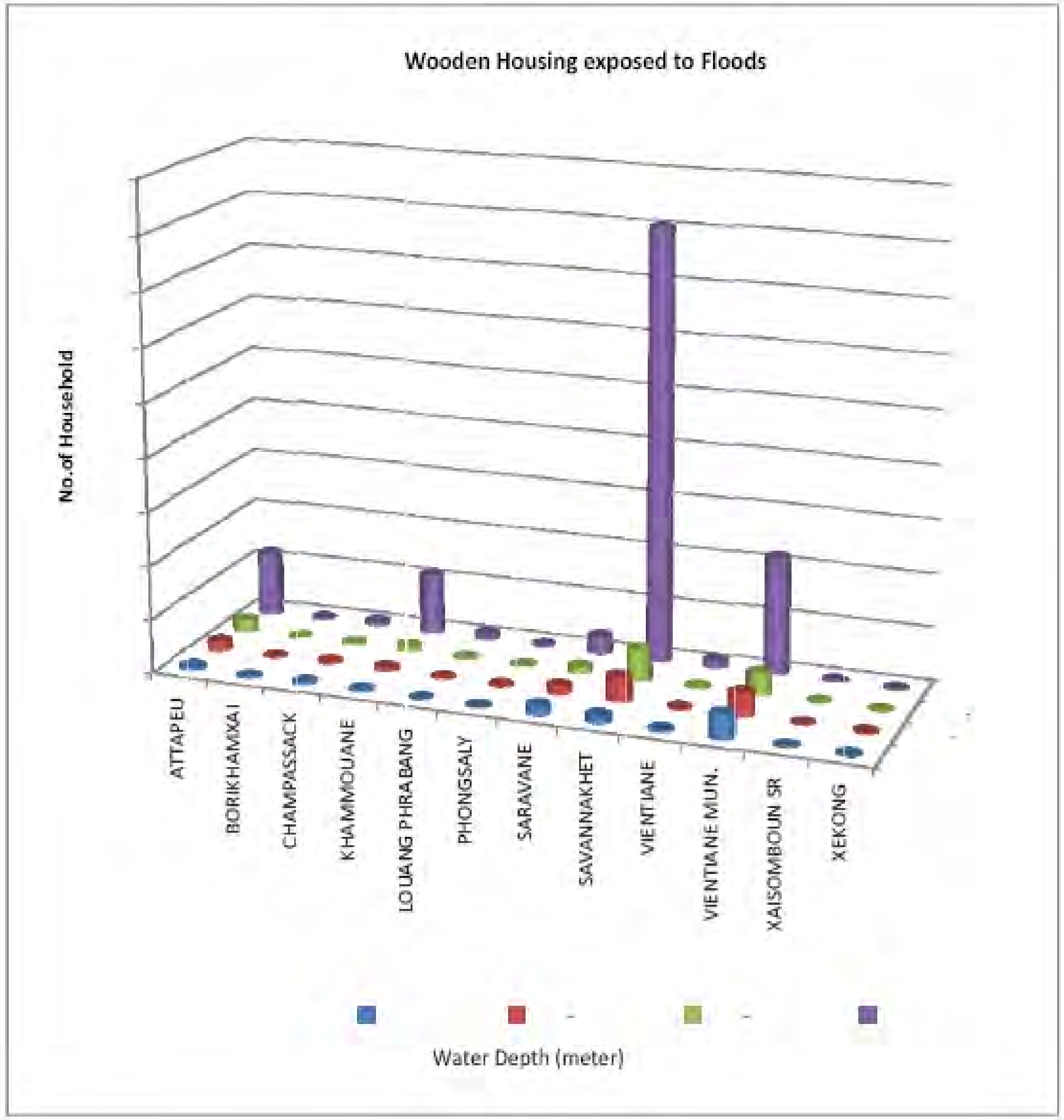
No. 11 EXAMPLE FLOOD VULNERABILITY MAP: USA

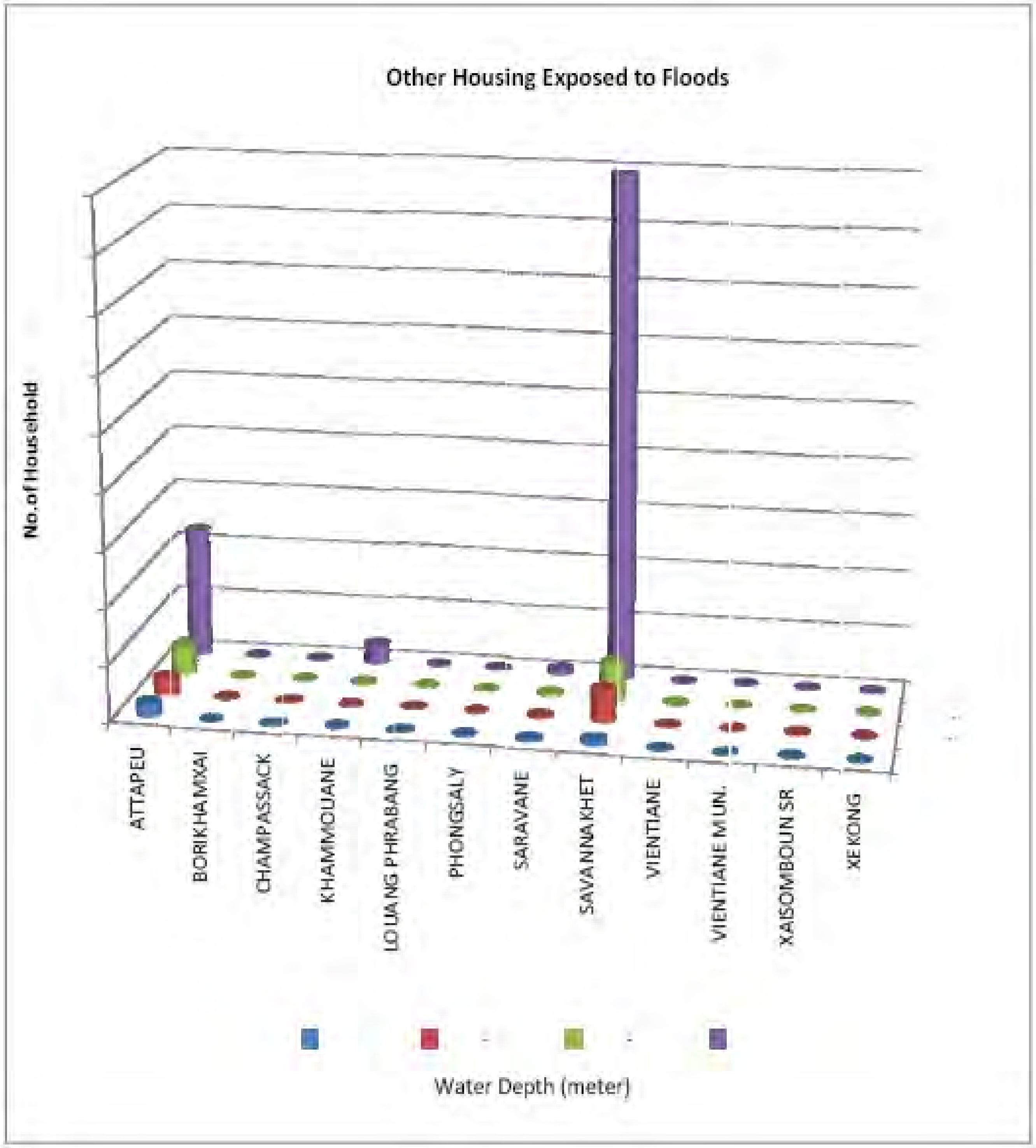




Source: ADPC November 2010, Part 2

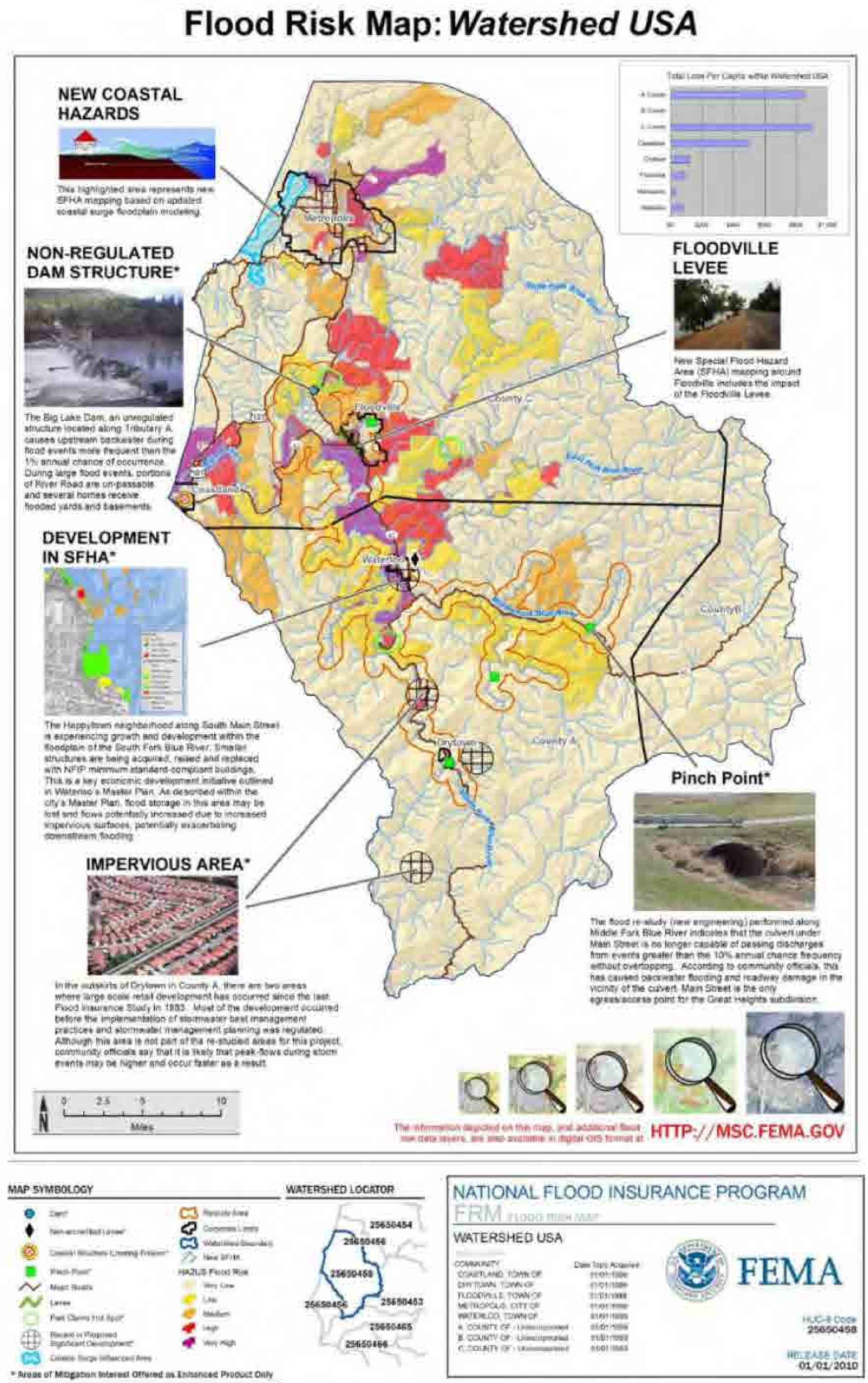
No. 12 EXAMPLE OUTPUT OF FLOOD RISK ASSESSMENT: Lao PDR-1





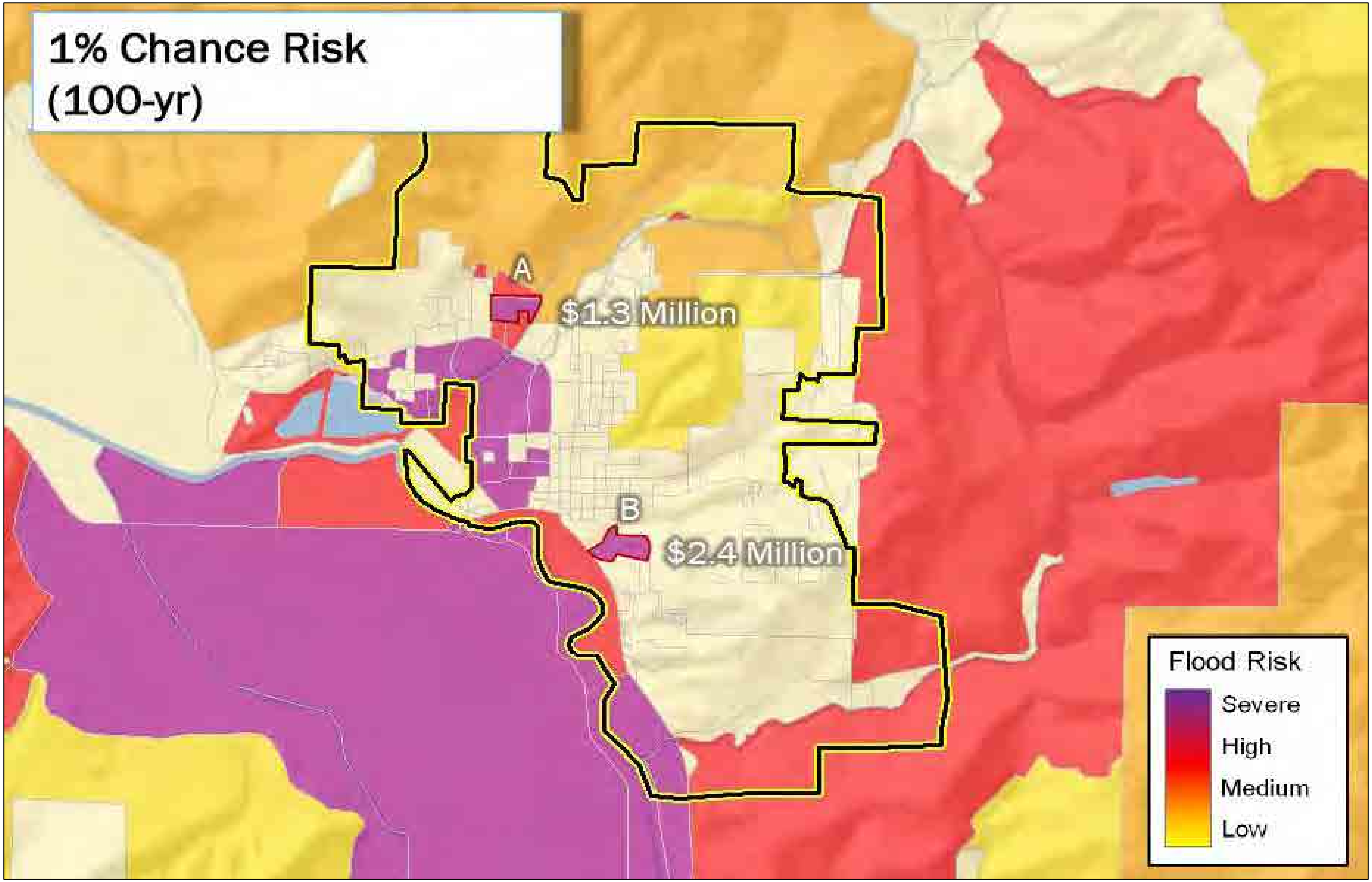
Source: ADPC November 2010, Part 2

No. 13 EXAMPLE OUTPUT OF FLOOD RISK ASSESSMENT: Lao PDR-2



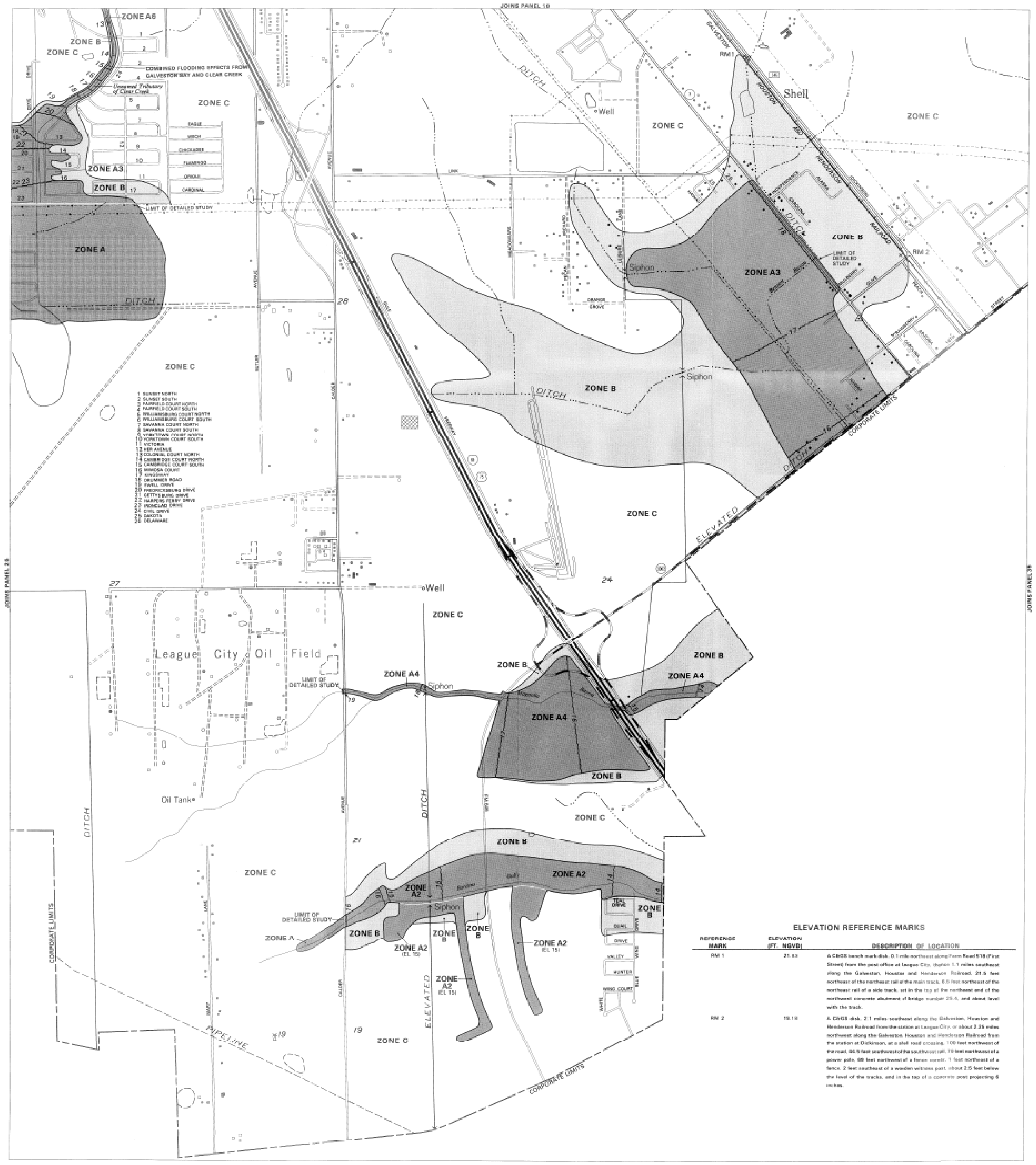
Source: Draft – Watershed USA Flood Risk Report

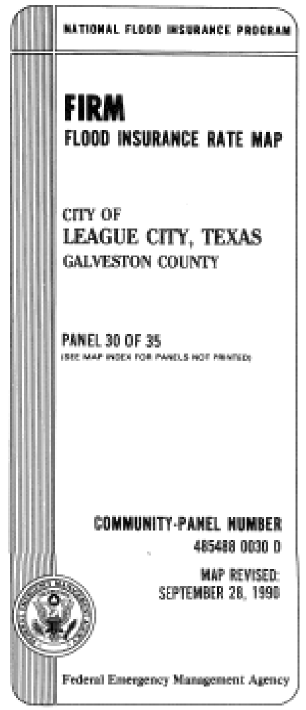
No. 14 EXAMPLE FLOOD RISK MAP: FEMA USA-1



Source: Flood Map Modernization and Risk MAP Update,
Briefing to Flood Mapping Coalition, October 2010, FEMA

No. 15 EXAMPLE FLOOD RISK MAP: FEMA USA-2





KEY TO MAP

500-Year Flood Boundary	ZONE B
100-Year Flood Boundary	
Zone Designations*	ZONE A1 / ZONE A5
100-Year Flood Boundary	
500-Year Flood Boundary	ZONE B
Base Flood Elevation Line With Elevation In Feet**	513
Base Flood Elevation in Feet Where Uniform Within Zone**	(EL 987)
Elevation Reference Mark	RM7×
Zone D Boundary	
River Mile	•M1.5
Undeveloped Coastal Barriers	

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
AO	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
'1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

This map is for use in administering the National Flood Insurance Program; it does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size, or all planimetric features outside Special Flood Hazard Areas. The community map repository should be consulted for possible updated flood hazard information prior to use of this map for property purchase or construction purposes.

Coastal base flood elevations apply only landward of 0.0 NGVD, and include the effects of wave action; these elevations may also differ significantly from those developed by the National Weather Service for hurricane evacuation planning.

Areas of special flood hazard (100-year flood) include Zones A, A1-A30, AH, AO, A99, V, and V1-V30.

Certain areas not in Special Flood Hazard Areas may be protected by flood control structures.

For adjoining map panels see separately printed Map Index.

No. 16 EXAMPLE FLOOD INSURANCE RATE MAP: FEMA USA-1
PURPOSE: Zone Designation for Insurance

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

The **projection** used in the preparation of this map was South Carolina State Plane, Zone FIPSZONE 3900. The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit their website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was derived from multiple sources. This information was compiled from the U.S. Geological Survey, 1989 and 2009, National Geodetic Survey, 2009, and U.S. Census Bureau, 2008. Additional information was photogrammetrically compiled at a scale of 1:12,000 from U.S. Geological Survey aerial photography dated 2006.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

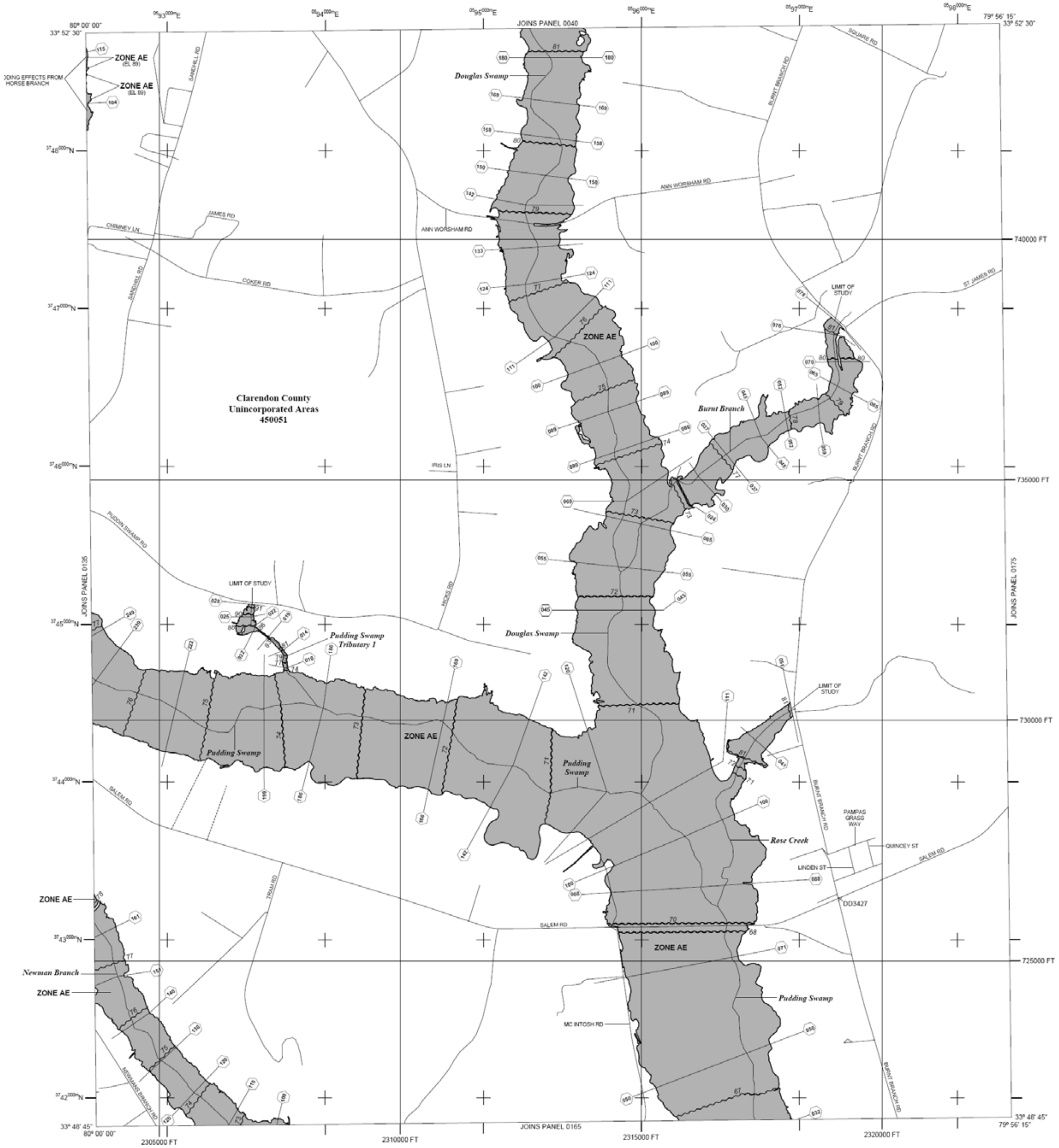
For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map**, how to order products or the National Flood Insurance Program in general, please call the **FEMA Map Information eXchange (FMIX)** at **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.

DNR

This digital Flood Insurance Rate Map (FIRM) was produced through a unique cooperative partnership between the State of South Carolina and the Federal Emergency Management Agency (FEMA). The State of South Carolina has implemented a long-term approach of floodplain management to decrease the costs associated with flooding. This is demonstrated by the State's commitment to map floodplain areas at the local level. As a part of this effort, the State of South Carolina has joined in a Cooperating Technical State agreement with FEMA to produce and maintain this digital FIRM.

http://www.dnr.state.sc.us/



No. 17 EXAMPLE FLOOD INSURANCE RATE MAP: FEMA USA-2
PURPOSE: Zone Designation for Insurance

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain boundary

Floodway boundary

Zone D Boundary

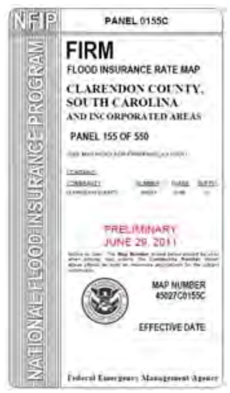
CBRS and OPA Boundary

Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A —— A	Cross section line
23 - - - - - 23	Transect line
	Culvert, Flume, Penstock or Aqueduct
	Road or Railroad Bridge
	Footbridge
97° 07' 30", 32° 22' 30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
4276000m E	1000-meter Universal Transverse Mercator grid values, zone 17
600000 FT	5000-foot grid ticks: South Carolina State Plane coordinate system, (FIPSZONE 3900), Lambert Conformal Conic Projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile



MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

300 0 300 600 METERS