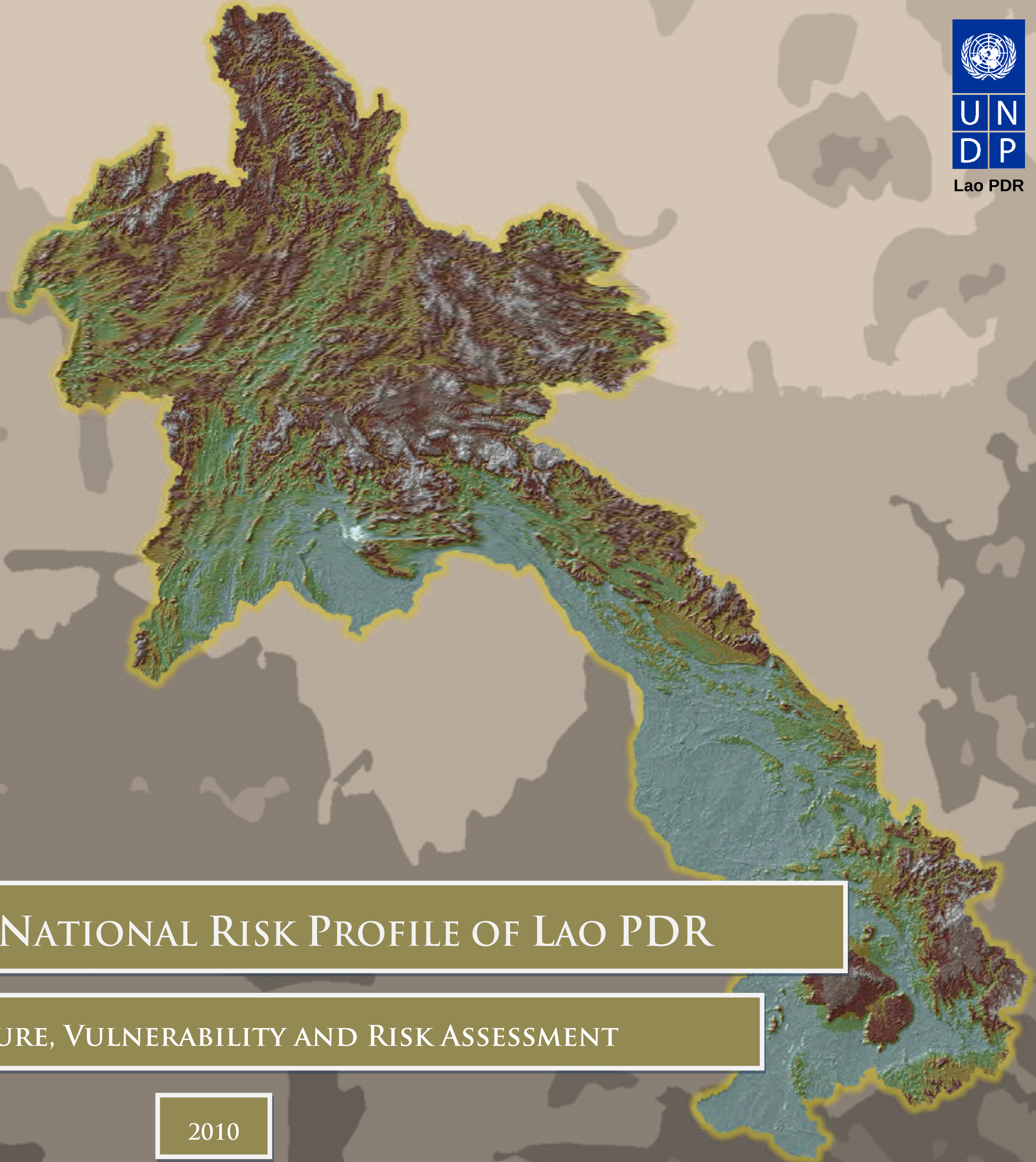

Developing a National Risk Profile of Lao PDR

Part 2: Exposure, Vulnerability and Risk Assessment

2010

A National Risk Profile of Lao PDR

2010

Prepared by

Asian Disaster Preparedness Center (ADPC),

In collaboration with

Public Work and Transport Institute (PTI) and National Disaster Management Office (NDMO)

With the support of

UNDP Lao PDR Country Office

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CONTRIBUTORS

Organization	Name	Designation
Asian Disaster Preparedness Center, Bangkok	MNSI Arambepola	Team Leader(Project), Director ADPC, Bangkok
	Amit Kumar	Project Manager (Project), Senior Project Manager, ADPC, Bangkok
	Anggraini Dewi	GIS Specialist, ADPC, Bangkok
	Kittiphong Phongsapan	GIS Researcher, ADPC, Bangkok
	Khondoker Golam Tawhid	Regional and National Training Coordinator, ADPC, Bangkok
	Rendy Dwi Katiko	Ex. GIS and Geologist Specialist, ADPC Bangkok
	Amin Budiarjo	Ex. GIS and Database Specialist, ADPC, Bangkok
	Sisira Kumara	Senior Project Manager, ADPC, Bangkok
	Thanongdeth Insisiengmay	Program Manager, ADPC, Vientiane, Lao PDR
	Phitsamai khammanivong	Project Assistant, ADPC, Lao PDR
Public Works and Transport Institute, Lao PDR	Saykham Thammanosouth	Director, Planning and cooperation division, PTI, Lao PDR
	Phouthala Souksakhone	Dy. Director , Planning and cooperation division, PTI, Lao PDR
	Bouvanh Luangsay	Deputy Director of Housing and Town Planning Division, PTI, Lao PDR
UNDP Lao PDR	Chikako Kodama	Chief, Crisis Prevention and recovery Unit, UNDP Lao PDR
	Viratsamay Visonnavong	Programme Analyst, UNDP Lao PDR

Name	Designation / organization
Aphone Inthalangsy	Officer, National Geographic Dept, Government of Lao PDR
Bounphakone Phongphichit	Institute of Water Resources & Environment
Bounpheng	Program Officer, Care Laos
Bounseuk Inthapatha	Chief, Hydrological Division, Water Resources and Environment Administration, Department of Meteorology and Hydrology, Government of Lao PDR
Bountheung Menavilay	Lao Red Cross
Bourvanch Luangsaly	Deputy Director, PTI
Chanthangso Oudomdeth	Public works and Transport Institute
Emma	Consultant, Save The Children, Australia, Lao PDR
Huon Rath	GIS Specialist, Technical Support Division, Mekong River Commission, Vientiane Lao PDR
Inpong Homsombath	Dy. Director, Geo Information Division, Ministry of Energy and Mines, Department of Geology, Government of Lao PDR
Inthawa Sayyaseng	Public works and Transport Institute
Jauraman Potty	Senior Scientist, RIMES, Bangkok, Thailand
Kamal P. Budhathoki	Senior Divisional Meteorologist, Department of Hydrology and Meteorology, Ministry of Environment , Science and Technology, Government of Nepal
Keodokmay Paseuth	Department of Water Resources , WREA
Ketsana xaiyasane	Technical, Lao National Mekong Committee
Khammai Vongsathiane	Department of Irrigation
Khammoungkhoun	Information Officer, National Regulatory Authority For UXO
KWD Nandalal	Professor, Department of Civil Engineering, University of Peradeniya, Sri Lanka
Kyaw	Head of Project, World Food Program, Lao PDR
Matthew	Country Director, Save The Children, Australia, Lao PDR
Noun Phommixai	Vice Director, Cartography Division, National Geography Department, Prime Minister’s Office, Government of Lao PDR
Pangkham Thikeo	Department of Statistics
Pasith Dethphommathep	Director General, National Disaster Management Office, Government of Lao PDR
Phonepaseuth	Dy. Chief, Planning and Cooperation Division, National Program Coordinator, Department of Water Resources, Lao National Mekong Committee, Water Resource and Environment Administration, Vientiane, Lao PDR
Phonesavanh	NDMO, Government of Lao PDR
Phonesavanh Phengsida	Director, Cabinet Division, Public Works and Transport Institute, Vientiane Lao PDR
Phonesavanh Phengsida	Public Works and Transport Institute

Name	Designation / organization
Phouangphanh	National Geographic Dept, Government of Lao PDR
Phouangphanh Souvannabouth	General Manger, Green Gold consulting Company, Vientiane, Lao PDR
Prasith Dethpomathed	Director, Social Welfare Dept
Savanhsiri Yangnuvong	Department of Agriculture and Forestry
Sikhay S. Siribounma	Head, Science and Technology Division, National Geography Department, Prime Minister's office, Government of Lao PDR
Singthong Pathoummady	Director, Division of Meteorological Network, earthquake Monitoring and Telecommunication, Department of Meteorology and Hydrology, Vientiane, Lao PDR
Sisomvang Vilayphong	Dy. Director, National Disaster Management Office, Government of Lao PDR
Sivixay Thammalangsy	Ministry of Health
Somchit Chershourthor	Public works and Transport Institute
Somhack	Deputy Head, Lao Red Cross
Somlith Lithsana	Office of Climate Change of WREA
Sommay Syhavong	Department of Education
Somphith	Dept of Energy Promotion and Development, Government of Lao PDR
Sompong Boonprasert	Senior Hydrologist, Technical Support Division, Mekong River Commission, Vientiane. Lao PDR
somsanouk keobounsan	Internship, SAVE THE CHILDREN, AUSTRALIA
Synouk Thilavong	FSS, National University of Laos
Thenekham Thongbon	Public Works and Transport Institute, Vientiane Lao PDR
Thenekham Thongbonh	Dy. Director General, Public Works Department, Ministry of Pubic works and Transport, Government of Lao PDR
Thepphathai Phanka	Public works and Transport Institute
Thipphachane	National Regulatory Authority-UXO
Thongdom Chanthala	Public works and Transport Institute
Tran Van Tuan	Program Coordinator, Information and Knowledge Management Programme, Mekong River Commission, Vientiane, Lao PDR
Vanhdy Douangmala	Department of Hydrology and Meteorology
Virany Sengtianthr	Director, Remote Sensing Center-RSC, Water Resource and Environment Research Institute-WERI, Vientiane, LaoPDR

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The project team extends their greatest thanks to its project partner, the Public Works and Transport Institute (PTI), Lao PDR, for providing all the technical and administrative support needed to complete the project. This mutual technical cooperation and collaboration has rendered immense benefit to the project outcomes, as well as furthering institutions in building their professional capacity.

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PREFACE

It is my great honor to present this report on "Developing the National Risk Profile of Lao PDR". This report received overwhelming support from the Government of Lao PDR and was produced in close collaboration with a number of national focal, technical and scientific agencies related to disaster risk reduction. The methodology used for this report was developed following rigorous discussion and consultation with all leading national government and non-governmental agencies. This report was financially supported by the United Nations Development Programme (UNDP) based in Lao PDR; technical advice and support was provided by the GRIP unit of BCPR of UNDP, Geneva.

This report highlights the regional experiences intrinsic to the work of the Asian Disaster Preparedness Center (ADPC) and the Public Works and Transport Institute (PTI) in disaster risk assessment and mapping in the region. The project objectives include mapping out all hazard prone areas (based on historic disaster events), identifying and assessing the exposure, vulnerability and risk of people, property, critical facilities, infrastructure and economic activities in those hazards prone areas; and creating preliminary national multi-hazard profiles, in terms of the type of hazard and affected sectors, so as to identify the risk priorities for the national disaster risk reduction strategies.

Upon fulfilling the objectives of this report, the project team produced a two-part report. Part one covers an overview of the project, a description of the baseline data, and hazard assessment and mapping for earthquakes, floods, drought, landslides, epidemics and diseases, UXO and storms hazards at the national level. Thus, part one results in the development of a multi-hazard risk map for Lao PDR. Part two of this report discusses the methodology for exposure, vulnerability and risk assessment for various hazards. In addition, part two recommends necessary intervention strategies for disaster risk reduction. The recommendations are segmented into eight sections: policy; institutional mandates and institutional development; hazard, vulnerability and risk assessment; multi-hazard early warning systems; preparedness and response plans; the integration of disaster risk reduction into development planning; community-based disaster risk management; and public awareness, education and training.

I hope that this report will prove to be useful to the National Disaster Management Office (NDMO), the Government of Lao PDR, the Water Resources and Environment Institute (WERI), the Department of Meteorology and Hydrology, the Lao National Mekong Committee (LNMC), the National Geographic Department, Department of Planning (DoP), the Ministry of Agriculture and Forestry (MAF), the Department of Planning, the Ministry of Health and others through its provision of sectorally-based disaster management planning. This report is formatted in a user-friendly manner such that all disciplines are able to apply the information and recommendations provided in this report for the safe and sustainable development of each respective sector. The ultimate goal is for the two volumes within this report to serve as a practical guide for disaster managers, as well as to enable them to use the information provided effectively for the benefit of the millions of people living in disaster prone areas of Lao PDR.

I would like to extend my sincere gratitude to the Government of Lao PDR, UNDP Lao PDR, the national stakeholders involved and the project partners for their partnership, consultation, support and advice.

Bangkok, November 2010

Dr. Bhichit Rattakul

Executive Director, ADPC

ABBREVIATION

ACD	Asian Cooperation Dialogue
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
ATC	Applied Technology Council
CAgM	Commission for Agriculture Meteorology
CBDRM	Community-based disaster risk management
CBOs	Community Based Organizations
CRED	Centre for Research on the Epidemiology of Disasters
CTG	Consultation Technical Group
DD Ratio	Depth Damage Ratio
DEM	Digital Elevation Model
DM	Disaster Management
DMG	Department of Mines and Geology
DMH	Department of Meteorology and Hydrology
DoA	Department of Agriculture
DoG	Department of Geology
DoP	Department of Planning
DPM	Disaster Probability Matrix
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DVI	Disaster victim Identification
EA	Exposure Assessment
EOC	Emergency Operations Centre
EVRA	Exposure, Vulnerability and Risk Assessment
EW	Early Warning
EWS(s)	Early Warning System(s)
FAO	Food and Agriculture Organization
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GESI	Global Earthquake Safety Initiative
GIS	Geographic Information System
GRID	Global Resource Information Database
HAZUS	Hazard US
HECRAS	Hydraulic Engineering Centers River Analysis System
HVRA	Hazard, Vulnerability and Risk Assessment
ICS	Incident Command System
JTWC	Joint Typhoon Warning Center
Lao PDR	Lao People's Democratic Republic
LDS	Lao Department of Statistics
LNMC	Lao National Mekong Committee
MAF	Ministry of Agriculture and Forestry
MC	Municipal Councils
MEM	Ministry of Energy and Mines
MIH	Ministry of Industry and Handicraft
MMI	Modified Mercalli Intensity
MPI	Ministry of Planning and Investment
NAFRI	National Agricultural and Forestry Research Institute
NCDC	National Climatic Data Center
NDMA	National Disaster Management Acts
NDMC	National Disaster Management Committee
NDMC	National Drought Mitigation Centre
NDMO	National Disaster Management Office
NDMP	National Disaster Management Plan
NGD	National Geography Department
NGO(s)	Non-Governmental Organization(s)
NOAA	National Oceanic Atmospheric Administration
NRA	National Regulation Authority
NSC	National Statistic Center
NTA	National Tourism Authority
OCHA	Office for the Coordination of Humanitarian Affairs
PTI	Public Work and Transport Institute
RADIUS	Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters
RCC	Reinforced Cement Concrete
SOP	Standard Operating Procedure
SPI	Standard Precipitation Index
TMD	Thai Meteorological Department
TWG	Technical Working Group
UC	Urban Councils
UNDP	United Nations Development Programme
UN-ISDR	United Nations – International Strategy for Disaster Reduction
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
US	United States
USACE	United States Army Corps Engineering
USGS	United States Geological Survey
UXO(s)	Unexploded Ordnance(s)
VA	Vulnerability Assessment
VRA	Vulnerability Risk Assessment
WMO	World Meteorological Organization
WREA	Water Resources and Environment Administration
WREI	Water Resources and Environment Institute

EXECUTIVE SUMMARY

Background

Lao PDR has witnessed several major natural disasters in the last two centuries. These hazard events pose a severe threat to national development processes. The national government is committed to take the necessary measures to avert these threats impacting on the country's development process. In line with this commitment, the Government of Lao PDR's National Disaster Management Office (NDMO) initiated the process of developing a national hazard and risk profile for the country. The project was financially supported by the United Nations Development Programme (UNDP), Lao PDR. The project was implemented by the Asian Disaster Preparedness Center (ADPC) and Public Works and Transport Institute (PTI), Lao PDR. The project was largely implemented by consultation and coordination with all focal government departments including the Department of Meteorology and Hydrology (DMH), Water Resources and Environment Administration (WREA), Lao National Mekong Committee (LNMC), National Geographic Department, Department of Planning (DoP), Ministry of Agriculture and Forestry (MAF), Ministry of Health, Department of Agriculture and other non-governmental agencies. The project process was further coordinated with several focal agencies, departments and institutions.

Project Objectives

The project objectives included mapping out all hazard-prone areas based on historic disaster events, identifying and assessing the exposure, vulnerability and risk of people, property, critical facilities, infrastructure and economic activities to those hazards prone areas and creating preliminary national multi-hazard profiles in terms of hazards and sectors to identify priorities for national disaster risk reduction (DRR) strategies.

Project Methodology

The methodology has been compartmentalized into several sections. The project methodology incorporated data collected from existing hazard and vulnerability studies, risk assessment reports, disaster databases, the national economic assets database, and so on. In addition, hazard mapping was carried out by modeling earthquakes, floods, landslides, epidemics, unexploded ordnances (UXOs), storms and droughts. The vulnerability functions of various assets were characterized with respect to each hazard, as well as the estimation of associated risks. Lastly, national DRR recommendations were developed. The methodology is presented in flowchart 1.

The project began by studying a number of past disasters and their impacts in Lao PDR. Thanks to a strong national commitment to alleviate disaster suffering, the impacts of several types of disasters are reducing daily. Despite this, impending threats of major disasters will continue to exist in the future. There are several important sectors which govern the national growth of Lao PDR on which disasters can have serious impacts. It is thus necessary to assess such impacts on these identified sectors. Key sectors such as housing, health, education, transportation, agriculture and power are considered in this report. There remain, however, several other important sectors in Lao PDR which could not be considered in this project due to time constraints and the unavailability of data.

The hazard assessment and hazard mapping has been carried out for earthquakes, floods, landslides, droughts, UXOs, storms and epidemics. Well-established scientific tools and techniques have been used to assess the hazards and mapping accordingly. For earthquakes, hazard mapping is done for 250-year return periods. For flooding, the most flood-prone rivers and catchments are considered in the flood hazard assessment. The flood hazard mapping presents flood severity in terms of inundation depth and area with respect to 10-year, 25-year, 50-year and 100-year return periods. The landslide hazard mapping is carried out considering rainfall as a triggering factor. Landslide-prone areas are classified as low, moderate and high-prone areas. The drought hazard mapping consisted of an analysis for the whole of Lao PDR using the Standard Precipitation Index (SPI). Drought hazards were classified into moderate, severe and extreme conditions. Hazard assessment and mapping is conducted for several epidemics and diseases including ten diseases: Acute Bloody Diarrhea, Acute Respiratory Tract Infection, Acute Watery Diarrhea, Dengue Fever, Dengue Hemorrhagic Fever, Food Poisoning, Hepatitis, Malaria, Measles and Typhoid Fever. UXO hazard-prone areas have been mapped based on the UXO Regulatory Authority database. The storm mapping is developed based on historical storm data, with a 10-year, 20-year, 30-year and 50-year return period.

The hazard assessment concludes with multi-hazard assessment and mapping based on a specific hazard severity scenario. The multi-hazard mapping process reveals that Khamuane province is prone to six hazards and Luang Prabhang, Saravane and Vientiane are prone to five types of natural and human-induced hazards. The district level multi-hazard assessment shows that out of 141 districts in Lao PDR, 56 percent are epidemic-prone, 34.7 percent are flood-prone, 29.8 percent are earthquake-prone, 19.1 percent are landslide-prone, 4.9 percent are storm-prone and 4.9 percent are UXO-prone districts.

The next component of the report is the exposure, vulnerability and risk assessment. This is essential in policy-making, planning and strategy development. Each hazard has specific impacts on particular sectors. For example, earthquakes largely impact on the population, housing, education, health and infrastructure sectors. Floods largely impact on the agriculture, housing, population, education and health sectors, whilst droughts largely affect the agriculture sector. Landslides typically occur in hilly areas and primarily affect the road and transport sector. At the national scale, the damage caused by landslides is negligible in comparison to that caused by earthquakes, floods, storms and droughts. These four disasters impact on a larger geographical scale, covering almost all parts of the topography of Lao PDR. In light of this fact, only these disasters are considered for detailed exposure, vulnerability and risk assessment.

Finally, the project provides recommendations for DRR based on the completed pragmatic and scientific analyses. The recommendations are segmented into eight sections namely policy; institutional mandates and institutional development; hazard, vulnerability and risk assessment; multi-hazard early warning systems; preparedness and response plans; the integration of DRR into development planning; community-based disaster risk management (DRM); and public awareness, education and training. Each section considers the geographic locations where projects should be implemented, the associated activities and expected outcomes of these projects, as well as the ministries, departments and agencies responsible for project implementation.

Applications of the Project Report

- At present, several agencies have carried out risk assessments for various parts of Lao PDR at different scales. This study has developed a comprehensive risk assessment profile for the whole of Lao PDR at the Provincial level. It will serve to enhance the qualitative and quantitative aspects of work previously conducted by other agencies.
- Tools for physical vulnerability assessments of various assets at the provincial level have been developed. These will aid in the identification of the most vulnerable sectors and the measures necessary to reduce disaster impacts.
- The study will bring out existing gaps in DRR strategies. In addition, it will recommend measures to build decision-making capacities.
- The report will be a useful tool in mainstreaming DRR into various sectors at all levels.
- The assessment will help provincial and regional decision-makers, policy-makers and development agencies in preparing DRR planning.
- Based on the outcomes of the study, Lao PDR's government may take actions toward capacity building for DRR.
- The study developed a robust methodology for hazard, vulnerability and risk assessments in close collaboration with national technical departments and agencies. These models may now be replicated in other countries and regions.
- Ideally, the study will encourage the financial support of international organizations for measures and actions that will reduce the risk associated with natural hazards in Lao PDR.

Report Chapter Organization

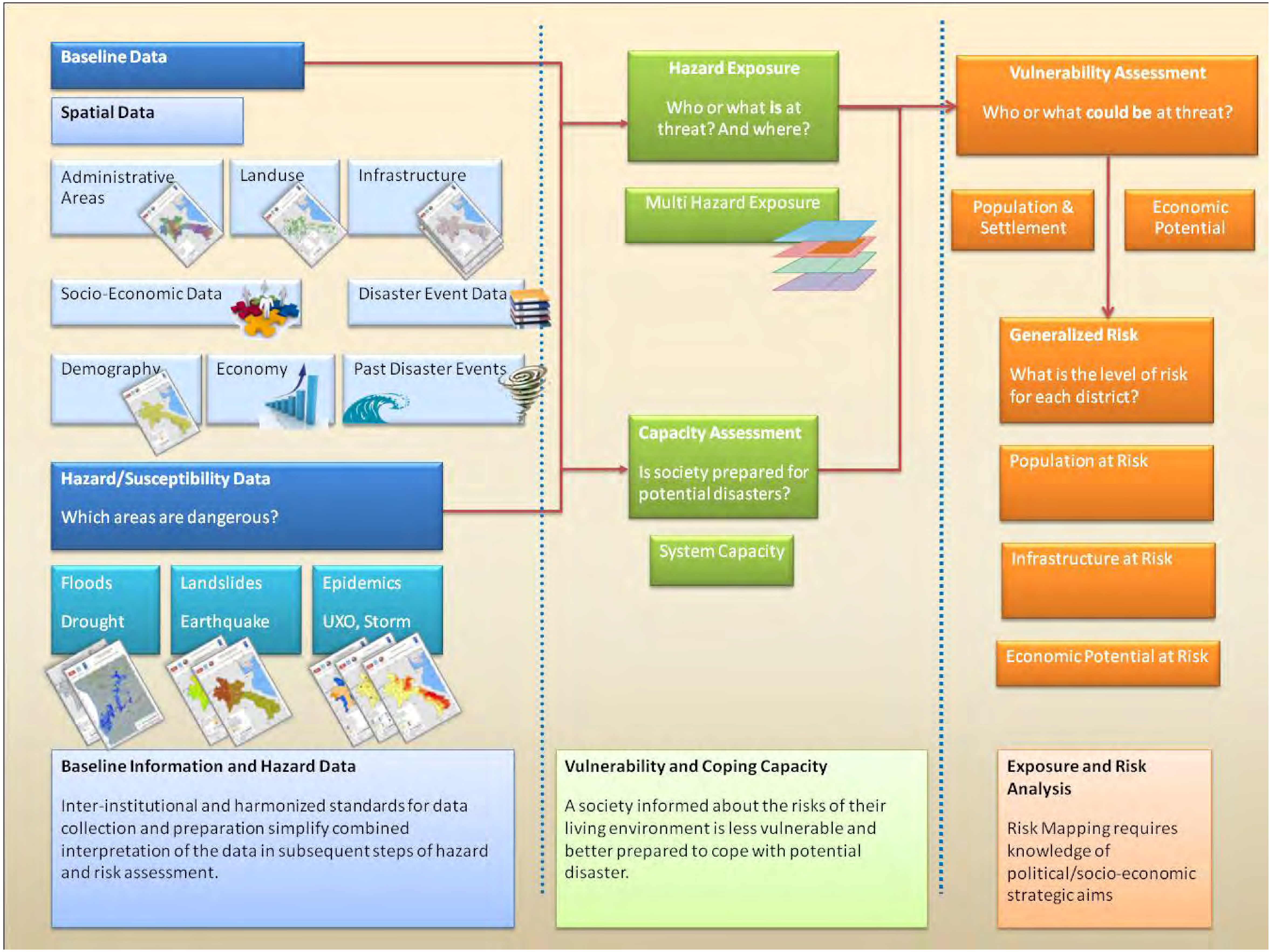
The project report is divided into two parts. The first part covers the project profile and background, as well as the sectoral database and hazards assessment and mapping. The second part of the report contains the exposure, vulnerability and risk assessments for earthquakes, floods, storms and droughts, as well as recommendations for the development of a national DRR strategy.

Part One: The report is divided into three chapters.

- Chapter 1 presents the background of the project. It describes the relationship between the disaster management cycle and risk assessment process. The risk assessment process is mostly carried out during the pre-disaster phases, which provides diagnosis of disasters for a specific geographic location. This helps significantly in developing the basis for DRM. The chapter further discusses the purpose of hazard and risk assessment mapping at national level and the necessary assumption framework. The chapter also describes project implementation agencies and mode of partnership for project implementation, project objectives, scope, adopted methodology and expected outcomes. The chapter shows the flowchart of the project methodology.
- Chapter 2 presents brief profile of natural hazards, and their respective trend in the country, characteristics of secondary data from various sources and various map information including administrative boundaries, population, land-use characteristics, housing, education, health, fisheries, irrigation, agriculture, transportation, power and tourism, mining and trade sectors.
- Chapter 3 provides detailed understanding of hazard assessment, mapping and analysis of seven major hazards in Lao PDR. It includes earthquakes, floods, landslides, epidemics, storms, UXOs and droughts. The chapter presents the overview of the hazard assessment approach, earthquake hazard analysis, respective mapping for 250-year return period and the spatial distribution of hazards in Lao PDR. The landslide hazard mapping has been presented based on heavy precipitation. The next section discusses about flood hazard assessments for major rivers. The flood hazard assessment has been discussed with regards to 10-year, 25-year and 100-year return periods. The drought hazard mapping is carried out using SPI. The chapter discusses the severity of drought in various parts of the country. The hazard assessment further discusses implications of epidemics in the country, their distribution and respective causative factors. The UXO mapping is done based on UXO density. The storm hazard mapping is developed for 10-year, 20-year, 30-year and 50-year return periods. The chapter concludes by developing multi-hazard scenarios for Lao PDR.

Part Two: The report is divided into six chapters.

- Chapter 1 discusses the concepts, applications, processes and challenges of exposure, vulnerability and risk assessments. The methodology adopted in the project is discussed in detail.
- Chapter 2 discusses earthquake exposure, vulnerability and risk assessments. The chapter presents the methodology for the exposure assessment and the analysis of exposure considering population, housing, education, health, roads and power sectors. It further elaborates the methodology for vulnerability assessment along with risk assessment of various assets due to 100-year and 500-year return periods.
- Chapter 3 presents flood exposure, vulnerability and risk assessments and the methodology adopted for these assessments. The implication of flood hazards due to 10-year and 100-year return periods are discussed with respect to various important physical assets including agriculture.
- Chapter 4 presents storm exposure, vulnerability and risk assessment and the methodology adopted to carry out these assessments. The implication of a 50-year return period of storm hazards on various important physical assets including housing, health and education sectors are discussed.
- Chapter 5 elaborates on drought risk assessment, which is presented in terms of potential losses to various important crops in the country. The chapter discusses the methodology for drought risk assessment along with detailed analysis of paddy crop losses and recommendations for enhancing the risk modeling and mitigation measures.
- Chapter 6 concludes the project outcomes and provides some realistic recommendations for national DRR planning.



Flowchart1 Methodology for Developing National Risk Profile of Lao PDR

1 EXPOSURE, VULNERABILITY AND RISK ASSESSMENT (EVRA)

1.1 INTRODUCTION

The National Risk Profile of Lao PDR Report consists of a Hazard profile and Exposure, Vulnerability and Risk Assessment (EVRA) profile. The hazard profile is discussed in Part 1 of the report. The first step of a risk assessment is to evaluate the elements at risk exposed to different hazards. The exposure[1] can be defined as the total value of elements at risk. Elements at risk defined in this study are population, housing, transportation, health and education infrastructure, hydropower and agriculture which are exposed to hazards in a given area. It is expressed as the number of human lives and value of the properties or assets that can potentially be affected by hazards. Exposure is a function of the geographic location of the elements at risk. Exposure Assessment (EA) is an intermediate stage of risk assessment, which links hazard assessment with assets under consideration for risk assessment.

The objective of the EA is to create an extensive national level database of various assets related to major economic sectors, quantification of number of assets located in hazard prone areas and development of an asset profile and analysis of their exposure to various natural hazards. The EA will provide inputs to the vulnerability and risk assessment. The scope of the EA includes the following:

- The EA collects all data related to various economic sectors' assets from nodal and focal departments. The major sectors include agriculture, transportation, population, housing, education, and health. The analysis is carried out for the sectors which are significantly affected and for which detailed data is available. Updated data and information from various relevant sources were collected: primarily the Lao Department of Statistics, National Geographical Department, Ministry of Communication, Transport and Construction and other focal departments.
- The analysis provides a national, sectoral asset profile as located in different hazard zones. The analysis has been carried out based on available national data.

The Vulnerability and Risk Assessment approach adopted in this study is based on definitions from UN-ISDR. The basic function of risk can be divided into the three components: hazard, vulnerability, and elements at risk. Risk can be presented conceptually with the following basic equation:

Risk = Hazard x Vulnerability x Element at risk

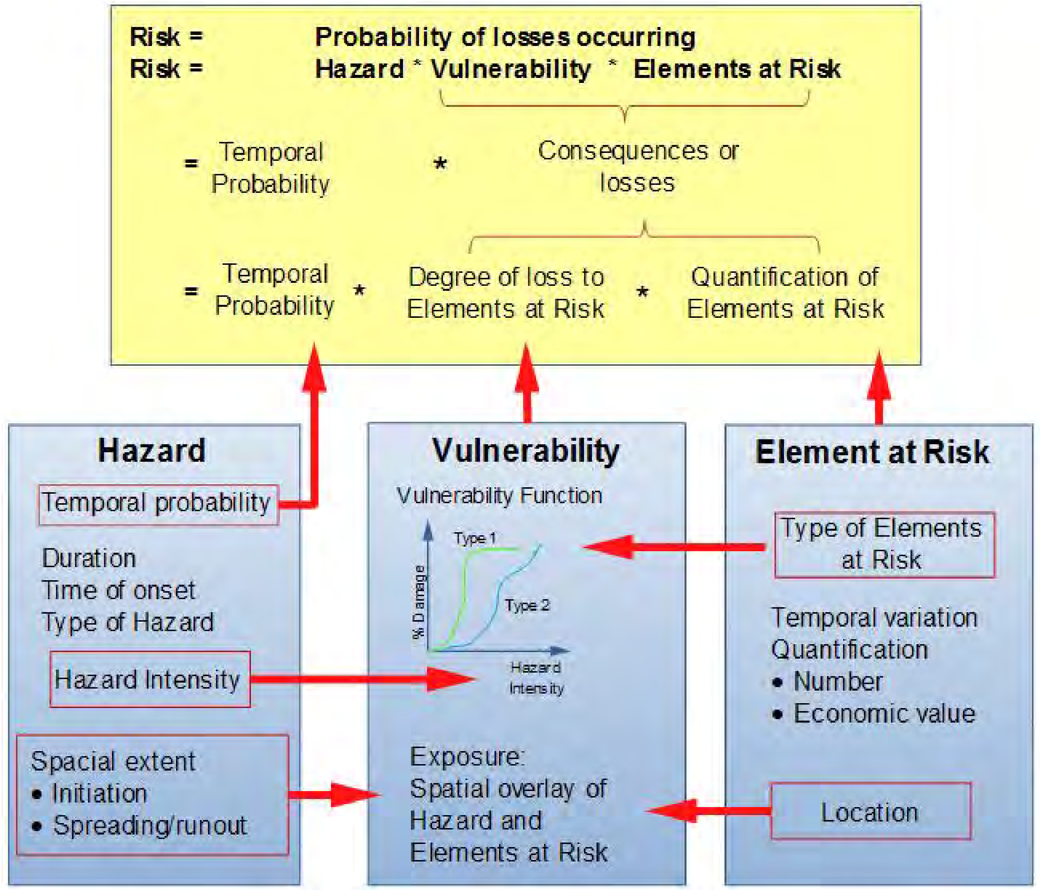


Figure 1.1 Vulnerability and Risk Assessment Approach

Table 1.1 The Definition of Elements at Risk, Exposure, Vulnerability and Risk (UN-ISDR, 2004)

Elements at Risk	Population, properties, economic activities, including public services, or any other defined values exposed to hazards in a given area. Also referred to as "assets".
Exposure	The degree to which the elements at risk are exposed to a particular hazard.
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. Can be subdivided into physical, social, economic and environmental vulnerability.
Risk	The probability of harmful consequences, or expected losses (deaths, injuries, property loss, livelihoods loss, economic activity disruption or environmental damaged) resulting from interactions between (natural and/ or human-induced) hazards and vulnerable conditions in a given area and time period.

[1] *UNDP (2004): Reducing Disaster Risk: a challenge for development. A global report (M. Pelling, A. Maskrey, P. Ruiz, L. Hall, eds.). John S. Swift Co., USA, 146 pp,*

1.2 VULNERABILITY ASSESSMENT

This chapter discusses one of the most complicated components of multi-hazard risk assessment: *vulnerability assessment.* It is complicated because the concept of vulnerability has a wide range of interpretations, including:

- Physical vulnerability: the potential for physical impact on the built environment and population. The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of natural phenomenon of a given magnitude and usually expressed on a scale 0 (no damage) to 1 (total damage);
- Economic vulnerability: the potential impacts of hazards on economic assets and processes;
- Social vulnerability: the potential impact of hazards on groups of people such as the poor, single-parent households, pregnant or lactating women, children and the elderly; and
- Environmental vulnerability: the potential impacts of hazards on the environment.

In this study, the concept of vulnerability is only discussed for physical vulnerability. This vulnerability is related to buildings and structures at risk and how these building and structures are damaged by a particular hazard, due to physical forces exerted by ground motion (earthquake), water (floods), wind (storms) and droughts.

1.3 APPLICATION OF EVRA

- EVRA provides a basic framework of understanding about linkages between hazards, exposure, vulnerability and risk of various physical, social and infrastructural assets existing in various part of the country.

- The vulnerability assessment identifies the characteristics of physical and social elements with respect to a specific hazard's severity, which reflects the asset's strengths and weaknesses. Vulnerability assessments are able to provide basic understanding about a sector's vulnerability and therefore provide an evidence-based approach for DRR. The chapter highlights vulnerability assessments of various essential sectors which will further help decision makers, policy makers and planners when it comes to safer sectoral development.

- The risk assessment will provide details of sectoral elements at risk for various geological and hydro-meteorological hazards. This will further enable policy makers and decision makers to understand potential damage and losses to specific sectors. The risk assessment is an essential tool for planning bodies such as the Planning Department and those in charge of allocating funds and resources for DRR.

- The economic risk assessment shows the economic losses to various sectors including housing, education, health, human lives, power, transportation and population. This information is important when considering how disaster events impact on the economic growth of an area or country.

- EVRA will bring out the existing gaps in sectoral development which could then be addressed in future sustainable development plans or projects.

- EVRA will help develop recommendations for national DRR planning.

1.4 KEY ISSUES OF EVRA

- Essential elements of EVRA: elements at risk of a particular hazard, exposure, vulnerability and risk assessment. EVRA will further analyze risk caused by earthquake, floods, droughts and storm events. The details of risk are shown in subsequent sections.

- EVRA is developed based on national hazard assessments. The details of hazard assessments may be referred to in part 1 of the report. The vulnerability and risk assessment has been carried out for various severities of earthquakes, floods, drought conditions and storms. Though the hazard assessment produced scenarios for various return periods, EVRA scopes has only been done for the most frequent hazards, which are illustrated in the table below:

Table 1.2 Scope of EVRA for Various Hazards with Their Severity

Type of Hazard	Criteria to be considered for EVRA
1. Earthquake	For 250-year return periods which divides the country into three zones (MMI scale)
2. Flood	100-year return periods where the area is categorized as inundated area with water level > 2 m
3. Drought	Dry season - Moderate to extreme drought susceptibility where its area falls under 20 percent or above probability of having drought
4. Storm	50-year return periods where the area is categorized as class 2 and class 3

- EVRA results largely depend upon availability of data. The project scope is to develop an EVRA profile based on available authentic secondary information. The data is mostly collected from authentic governmental and reputed international sources. The risk assessment has been carried out mainly based on data collected from Lao PDR Department of Statistics, Government of Lao PDR 2005. The precision of EVRA largely depends upon quality of data. The respective departments and ministries may further carry out detailed assessments based on the suggested methodology.

- The characterizing vulnerability of various assets needs extensive technical and scientific inputs. Though significant work has been carried out in the past to characterize vulnerability of housing, human beings and other physical infrastructure internationally, limited work has been carried out in Lao PDR. This results in challenges with developing vulnerability functions for Lao PDR under the scope of the project. There is not much literature available for vulnerability functions for earthquakes, floods, droughts and storms in Lao PDR. Literature available for similar geographical and cultural locations is applied for defining the vulnerability functions. The vulnerability functions are also drawn from expert opinions and field-based judgment.

- Triggered hazards show different impacts on specific sector. In case of earthquake, large impact is observed on lives and physical development. In case of floods, severe impacts are witnessed on agriculture, lives and housing. In case of drought, larger impacts are observed on agriculture sector. In case of epidemics, human lives are most affected. These factors are considered while carrying out EVRA.

- EVRA evolves the specific recommendations for major development sectors. The process brings out specific recommendations for housing, agriculture, education, health, social sectors, industries, and other important sectors. The details are provided in subsequent chapters.

- The results are represented in more simplistic terms so as to be understood by various classes of stakeholders. This report will be largely used by policy-makers, decision makers, planners, the community and non-government agencies involved in DRR planning.

- The scale of EVRA is limited to the national level (provincial-wide).

Table 1.3 Impact on Sectors Affected - Identified in the Exposure Assessment

Type of Hazard	Sectors to be Analyzed for EVRA
1. Earthquake	Human life (population), housing, education, health, hydropower*, transportation (roads)*,
2. Flood	Human life (population), housing, education, health, hydropower*
3. Drought	Agriculture (paddy fields)
4. Storm	Human life (population), housing, education, health, hydropower*
* Hydropower and transportation sectors are only considered for exposure assessment. At given severity of earthquakes, floods and storms, the impacts of disaster on these sectors are not significant	

2 EARTHQUAKE EXPOSURE, VULNERABILTY AND RISK ASSESSMENT

2.1 EXPOSURE ASSESSMENT

2.1.1 INTRODUCTION

In the past, Lao PDR has witnessed several small and moderate-scale earthquakes in the northern and western parts of the country. Only one big event of an earthquake with a magnitude of more than seven was reported in 1988. There is, however, no official evidence / report of the impacts on human life and physical infrastructure. It is necessary to study the distribution of earthquake hazards, vulnerability and risk factors, as well as the exposure of social and physical infrastructure to earthquakes. Chapter 2 discusses the approach adopted in this project to assess earthquake exposure, vulnerability and risk in Lao PDR. The approach is supported by quantitative evidence, identifying the exposure and risk of a number of vital sectors. The sectors studied are human life, housing, education, health, power and transportation. The chapter further analyzes the degree of earthquake risk present in particularly risk-prone provinces. The analysis is carried out based on an earthquake hazard zone of a 250-year return period scenario which has been developed by UNOCHA. This scenario is analyzed in terms of human life, housing, education, health, power and transportation sectors. Since hydropower and transportation systems are of better construction quality, there is not a significant chance of these sectors getting affected by earthquakes with an intensity of VII. The earthquake risk assessment analysis has been presented in a series of user-friendly charts and graphs. The analysis should be easily understood by policy makers and sectoral development officials.

2.1.2 METHODOLOGY FOR EARTHQUAKE EXPOSURE ASSESSMENT

As defined by UN-ISDR, 2004, exposure indicates the degree to which the elements at risk are exposed to a particular hazard. For the last several years, several attempts have been carried out to define and establish the methodology for EA. There are many methodologies used in relating exposure of particular hazards to human kinds and impact on environment. Much of the research on environmental hazards EA is focused on characterizing the nature of geophysical processes that pose risks, including the magnitude, frequency, spatial dispersion, duration, speed of onset, timing and temporal spacing of physical conditions.

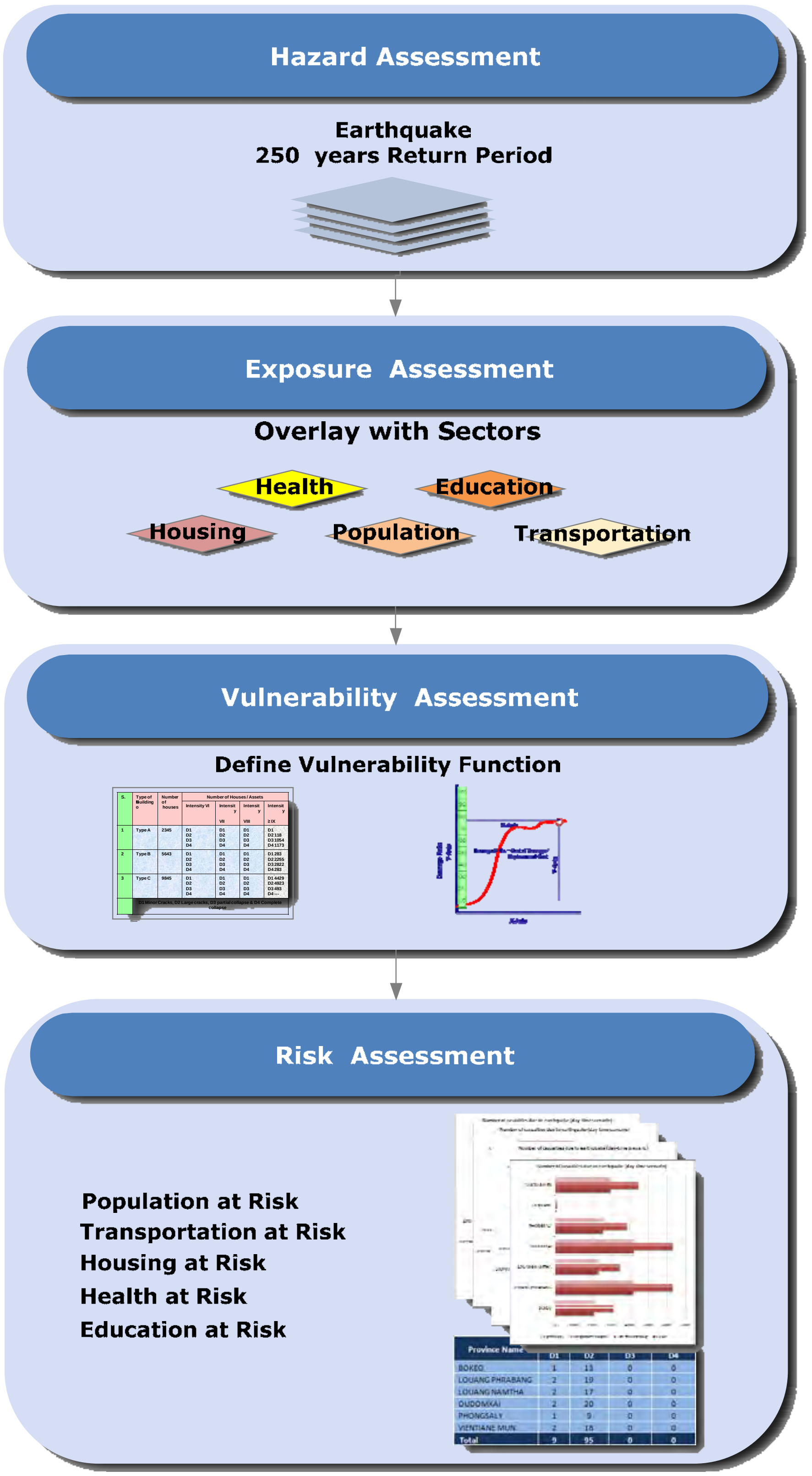


Figure 2.1 Methodology of Earthquake Exposure, Vulnerability and Risk Assessment

The identification of sectors for the EA and primary affected sectors is based on past impacts.

Data Collection: Data relating to the primary sector is collected from a number of reliable sources. The details of the data may be found in Chapter 2, Part 1 of this project report. The data is analyzed in Geographic Information Systems (GIS) format and is created at the provincial level.

Application of GIS tools for EA: Chapter 3, Part 1 discusses the hazard maps whilst considering the different severity of the hazard. GIS tools facilitate overlaying susceptibility / hazard maps within the identified sectors. The overlapping areas of the hazard maps and sectoral data allow for the identification of different elements at risk. This report quantified the number of houses, their classes, and the number of population, schools, hospitals / health centers and infrastructure falling in earthquake hazard-prone areas.

Analysis of EA: The analysis of the EA provides information about the stock of assets in hazard-prone areas. The application of EA has been discussed, briefly, in paragraph 1.2.

2.1.3 ELEMENTS AT RISK AND EXPOSURE ASSESSMENT

Different methods can be used to classify elements at risk, depending on the objectives of the risk assessment, the scale and the available resources. For the national risk profile of Lao PDR, there are several physical elements which have been considered and discussed in the following sections. These can be linked later to physical and social vulnerability.

2.1.3.1 POPULATION

The exposure of total population in the earthquake hazard-prone area is presented in Figure 2.2. The population data is obtained from the National Census 2005 of Lao PDR. Analysis for the population exposure is based on total number of population and age distribution in each province with regards to economic activity (dependent age and working age).

The analysis reveals that 24.11 percent of the population in the productive age group (age 15-63 years) are falling in the Intensity VI and VII zones. While 19.90 percent of dependent people (children under 15 and elderly 64 years and above) are falling in Intensity VI and VII zone. Figure 2.2 to Figure 2.4 show the distribution of the population exposure to various earthquake hazard zones. Oudamxai followed by Luang Prabang has the highest percentage of people who are exposed to the earthquake hazard zone (VII MMI). There are also a high proportion of dependent people (children under 5 and elderly 64 years and above) and people at working age (age 15 – 63 years) falling in Intensity VII zone. Several provinces are not included in this analysis because they are not exposed to a VII intensity zone and are therefore classified as living in an earthquake-safe zone.

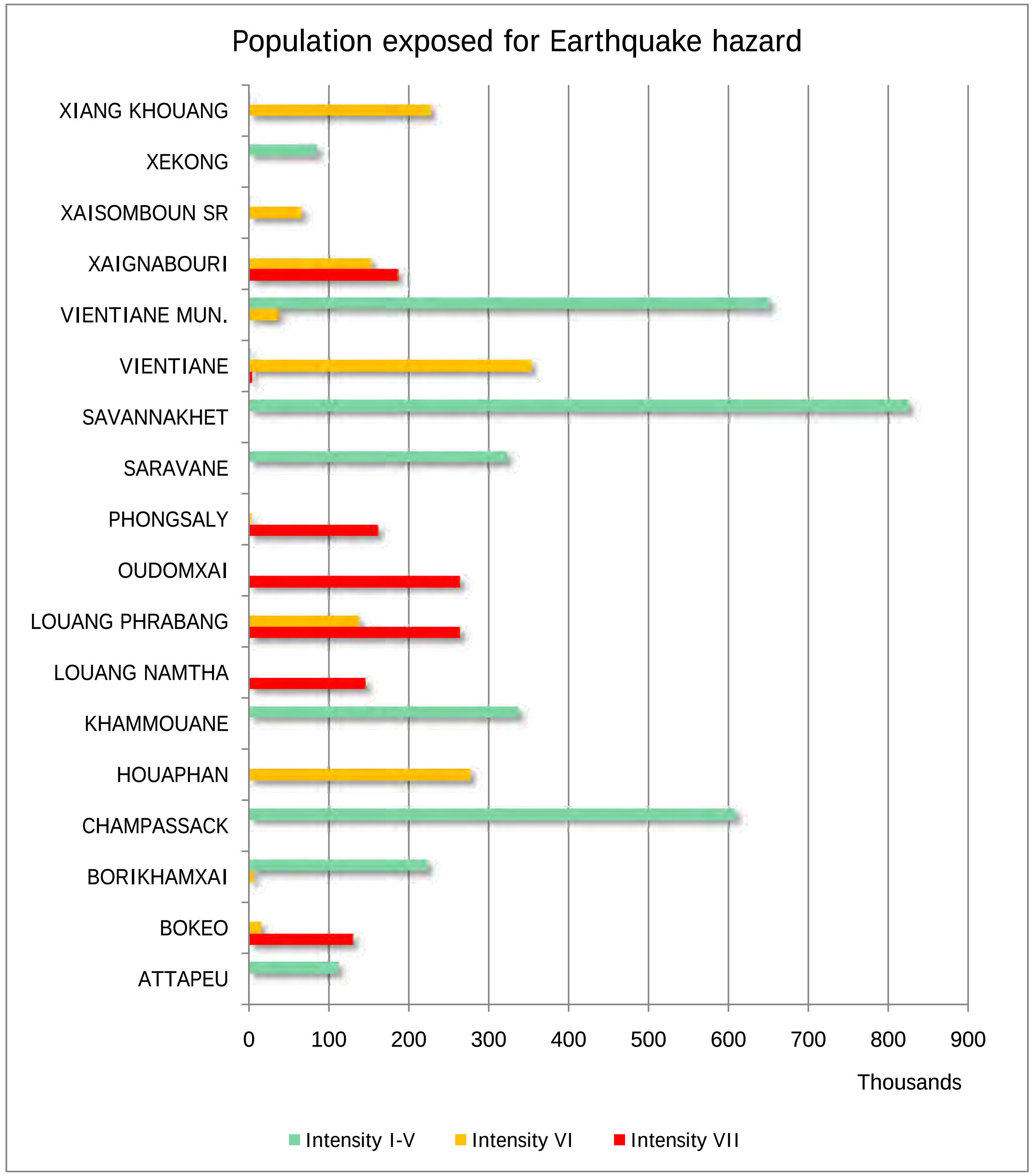


Figure 2.2 Population Exposed to Earthquake Hazards with Respect to Provinces

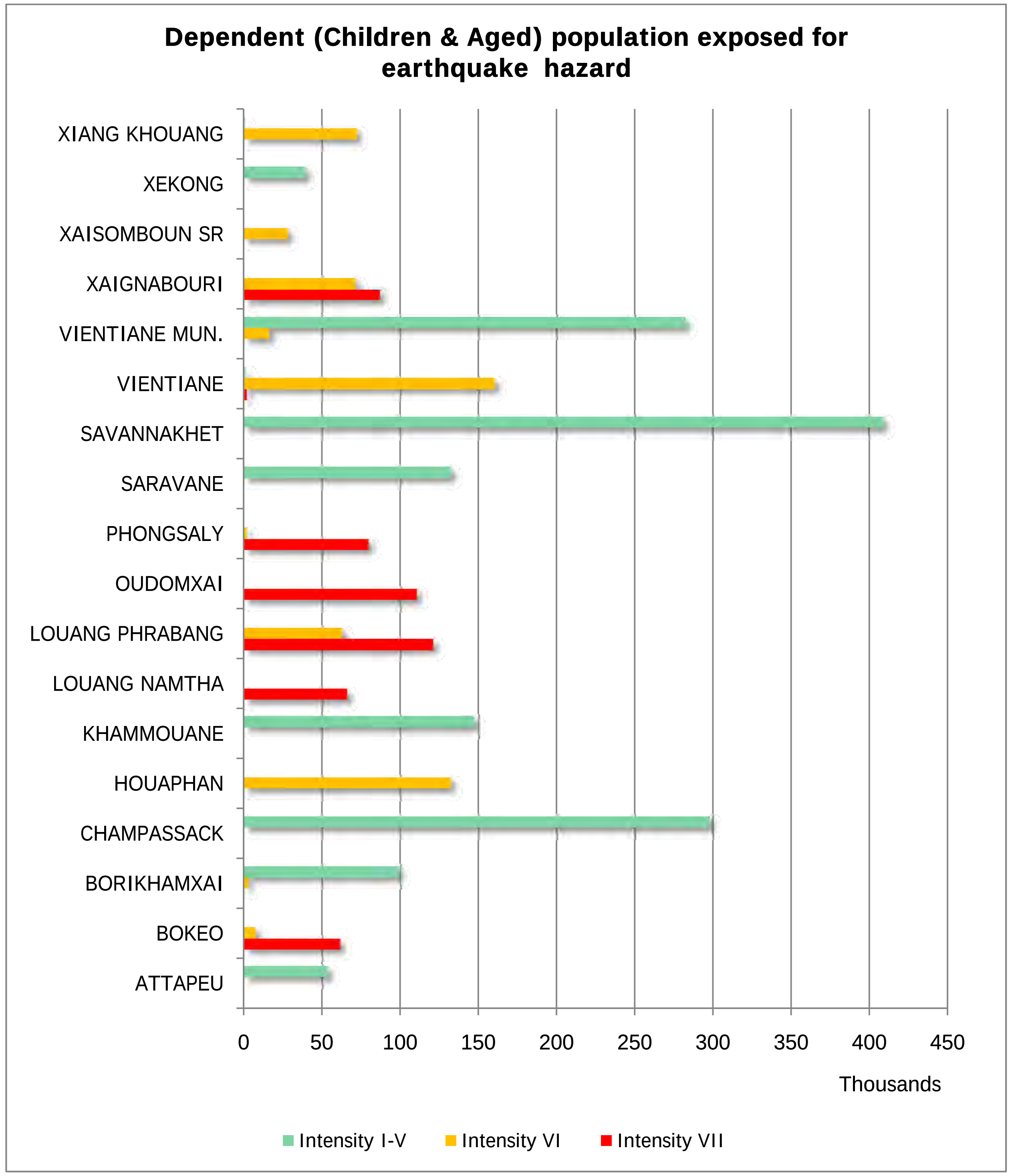


Figure 2.3 Dependent Population Living in Earthquake Hazard-Prone Areas

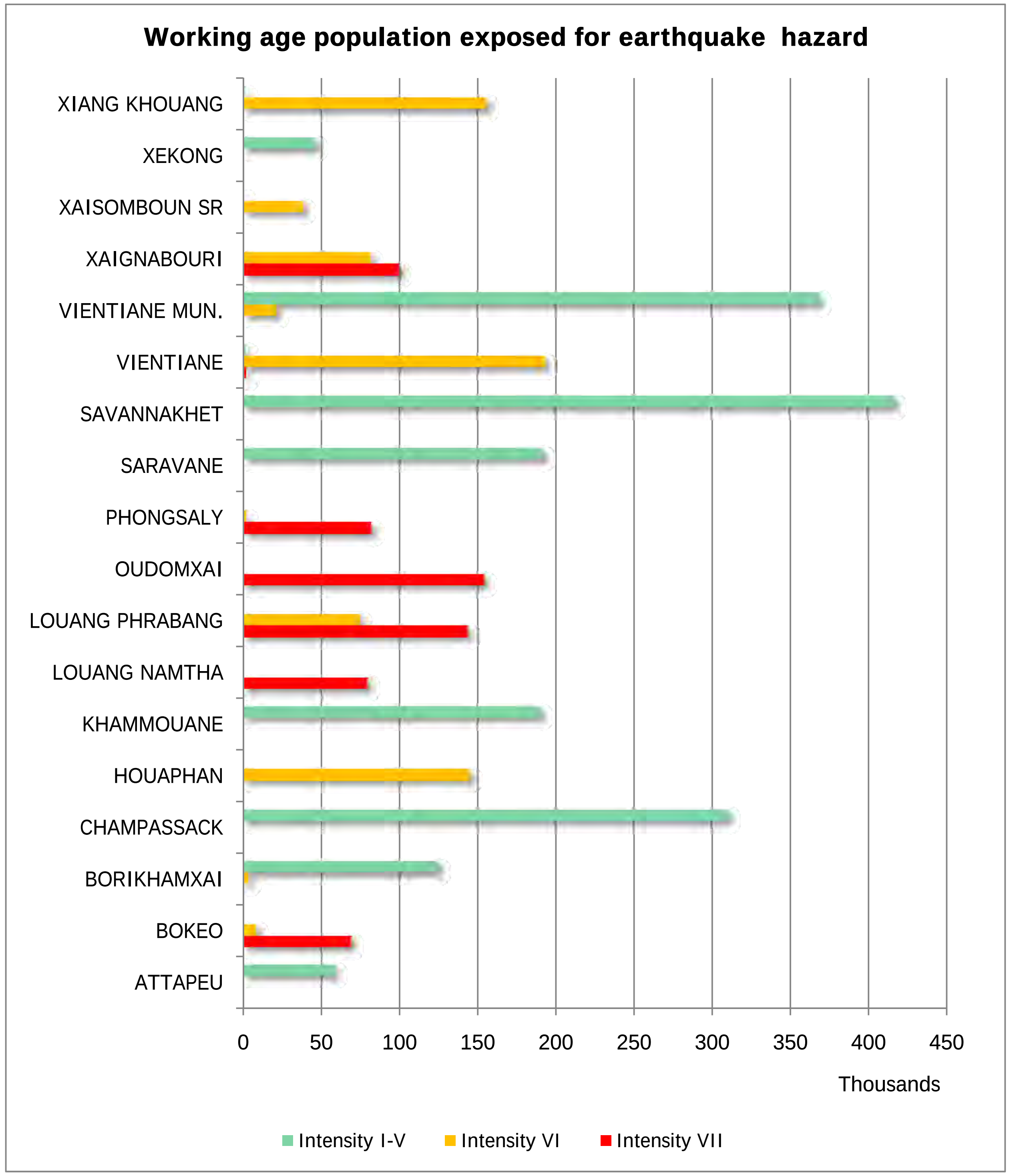


Figure 2.4 Working Age Population Living in Earthquake Hazard-Prone Areas

2.1.3.2 HEALTH SECTOR

Hospitals / health centers located in earthquake hazard-prone zones are presented in Appendix I (Table1).

Hospitals/ health center infrastructure exposed to earthquake hazard is presented in Figure 2.5. There are seven provinces, namely, Oudamxai, LuangPrabang, Luang Namtha, Xayabury, Bokeo and Phongsaly which have hospitals/ health centers exposed to Intensity VII earthquake hazard zone. This is illustrated in Figure 2.5. The analysis reveals that 23.30 percent hospitals/ health centers are falling in the Intensity VII earthquake hazard zone, while about 17.13 percent of the provinces are falling in the Intensity VI zone.

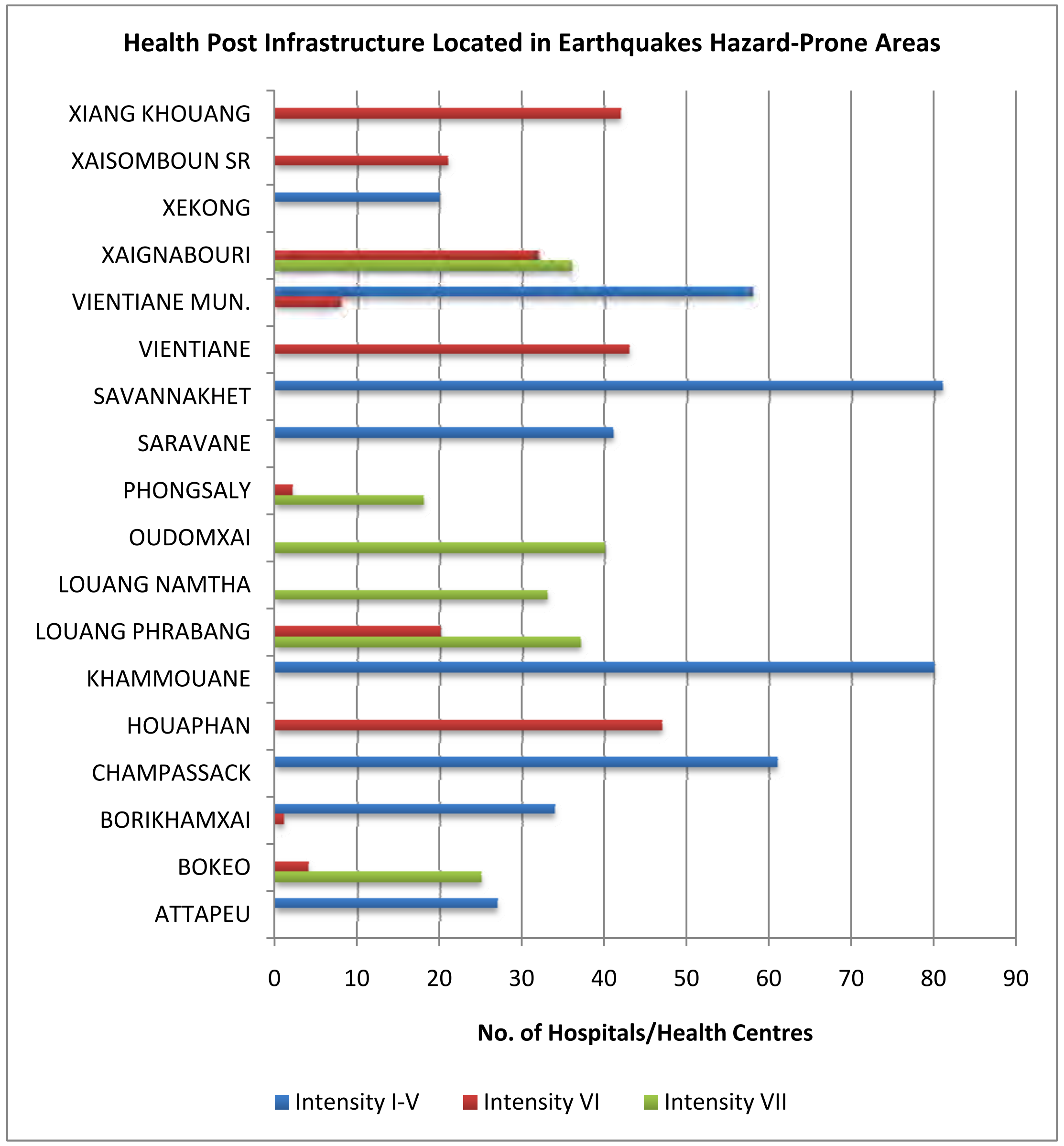


Figure 2.5 Health Post Infrastructure Located in Earthquakes Hazard-Prone Areas

2.1.3.3 TRANSPORTATION SECTOR

The EA has been carried out for the transport sector. At national level, there are about 7008.62 km of roads distributed across Lao PDR. Data and source information may be found in Chapter 2, Part 1 of this project report. Based on the data obtained from the Department of Geography, the total length of the road exposed to earthquake hazards of VII intensity is 1761.06 km. Figure 2.6 shows that provincial roads in Xayaburi, Phongsaly, Oudomxai, Luang Namtha, Luang Phrabang and Bokeo are located in an earthquake hazard-prone zone. The exposed road network in each province may be referred to Appendix I, Table 2.

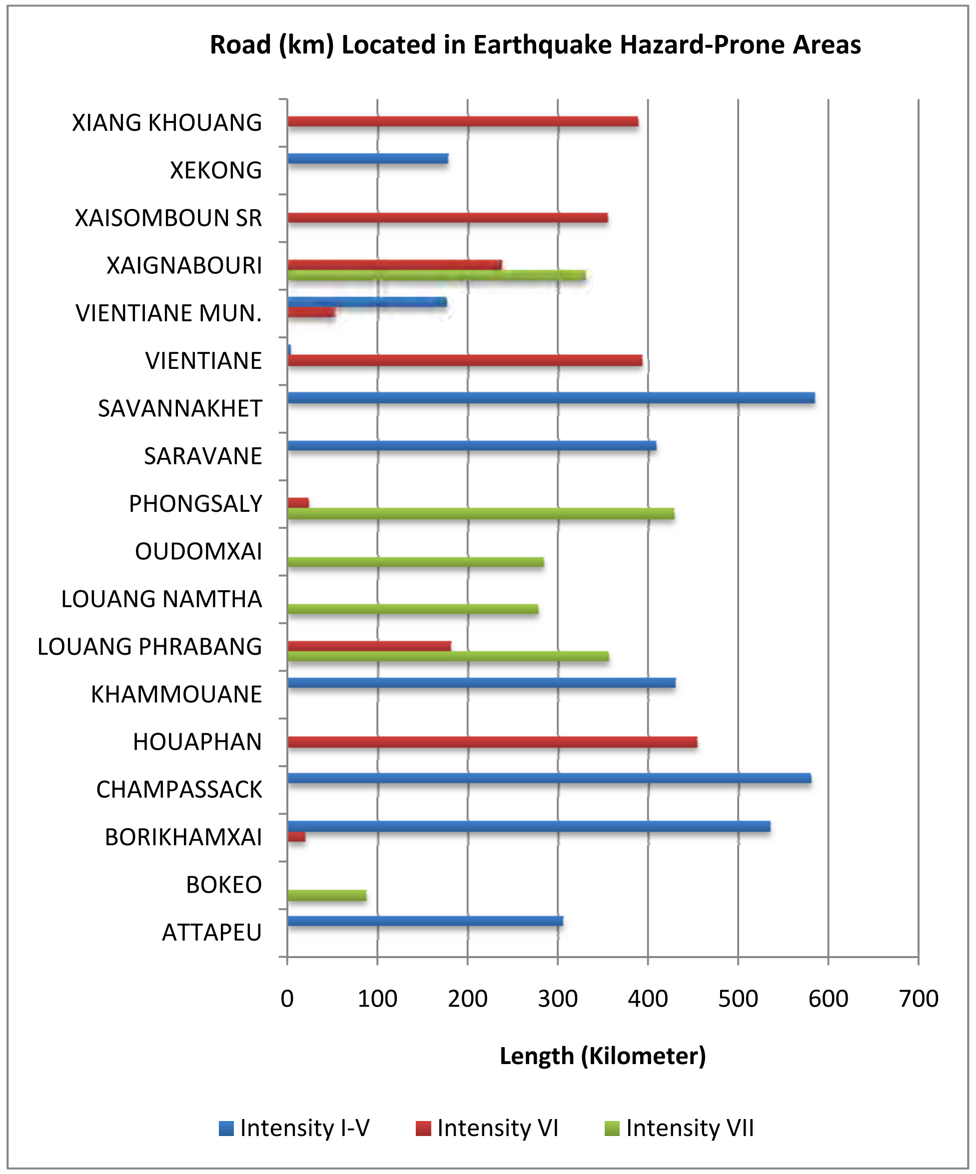


Figure 2.6 Road (km) Located in Earthquake Hazard-Prone Areas

2.1.3.4 HOUSING SECTOR

Part 1 of Chapter 2 describes the classification of buildings in Lao PDR by materials: brick/ reinforced cement concrete (RCC), wooden, bamboo and others. For the EA, the type of walls is used to determine the number of houses exposed in each earthquake hazard prone area. Figure 2.7 and Figure 2.8 shows the graphical presentation of the number of houses exposed in VI and VII intensity earthquake hazard zone, with four different colors that represent each type of wall constructed with wood, brick, bamboo and others.

Six provinces in Lao PDR will experience earthquakes of VI intensity. As presented in Figure 2.7, there are three provinces in the central region of Lao PDR where their provincial administrative boundaries are partly falling in the earthquake hazard zone (VI intensity). These provinces are Vientiane, Vientiane Municipality and Xaisombourn SR. Most of the houses these three provinces are built from bamboo, followed by wood. Apart from the three provinces in the central region, there are three other provinces in the northern region which are likely to be affected by earthquakes: Xiangkhuang, Huaphan and a small part of Bokeo province. More than 70 percent of houses in Huanphan and Xiangkhuang are built from wood, followed by bamboo.

Figure 2.8 shows provinces exposed to earthquake hazard of VII intensity. These provinces are Bokeo, Luang Namtha, Luang Prabang, Oudomxai, Phongsaly, Xayaburi and a small part of Vientiane. More than 73 percent of houses in Bokeo and Oudomxai are built from bamboo. About 65.87 percent of houses in Luang Namtha are built from bamboo, followed by 33.73 percent built from wood. More detailed distribution of housing by building material may be referred to in Appendix I, Table 3.

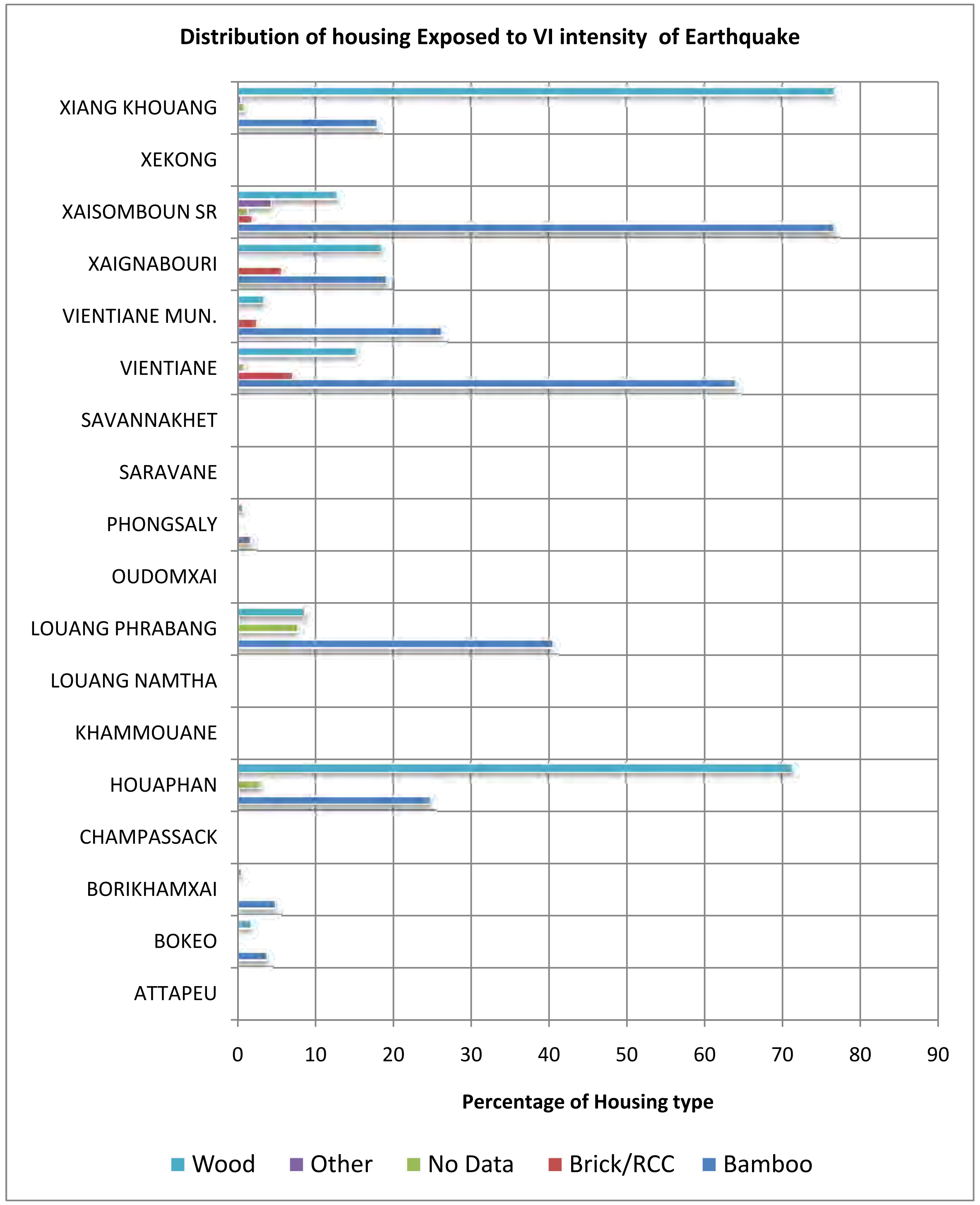


Figure 2.7 Distribution of Housing Exposed to VI Intensity Earthquakes

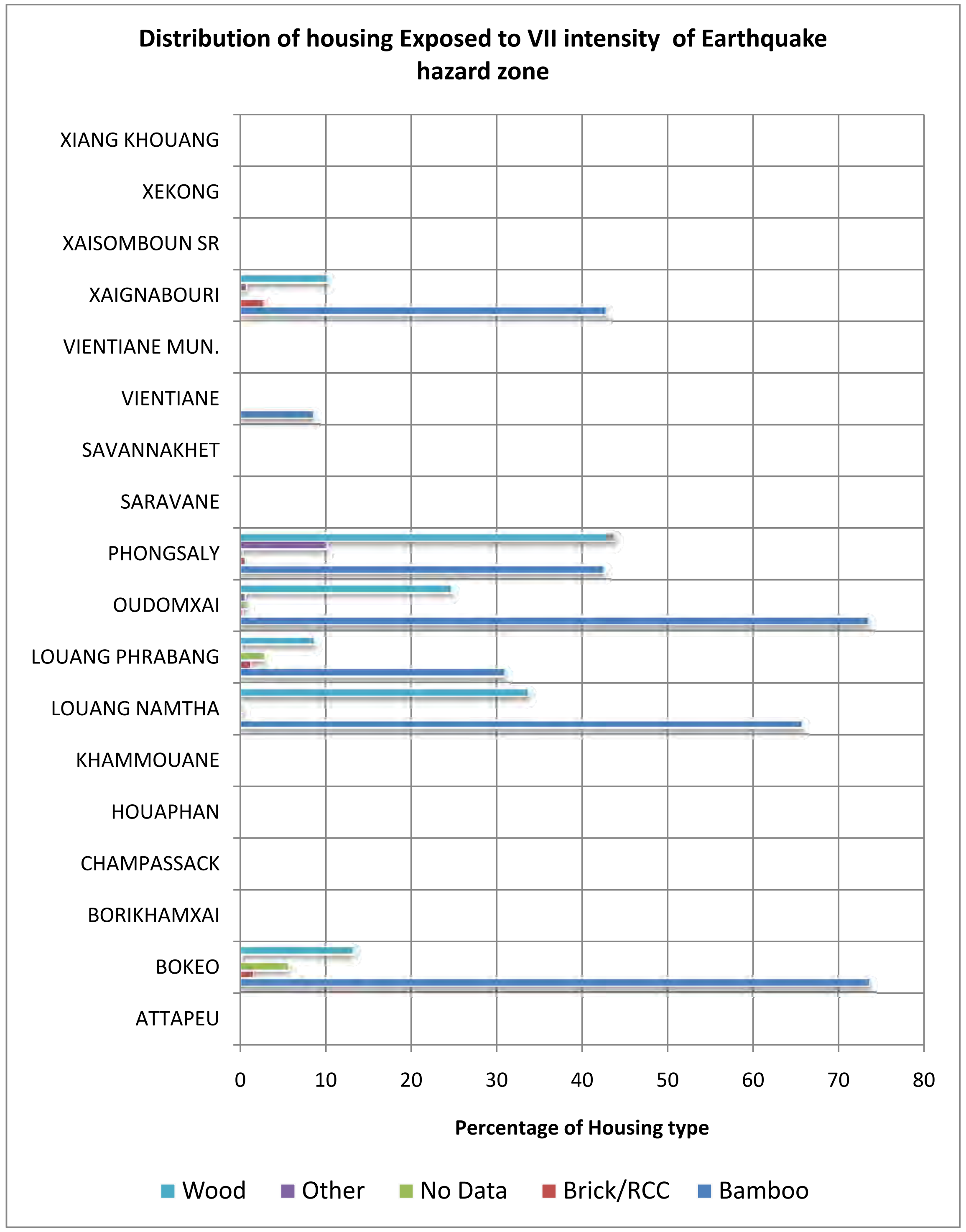


Figure 2.8 Distribution of Housing Exposed to VII Intensity Earthquakes

2.1.3.5 EDUCATION SECTOR

The exposure of the education sector may be referred to in Appendix I Table 4.

Figure 2.9 shows the province-wide distribution and exposure of schools in earthquake hazard zones. Analysis reveals that 23.48 percent of schools in Lao PDR are located in and exposed to VII Intensity earthquake hazard-prone zones. These schools are located in Phongsaly (5.69%), Oudamxai (4.45%), Luang Namtha (3.64%), Luang Prabang (4.43%), Xayabury (2.80%) and Bokeo (2.38%). Similary, 23.83 percent of schools in Lao PDR are exposed to V1 intensity earthquakes. These schools are located in Bokeo (0.26%), Huaphan (6.92%), Luang Phrabang (3.04%), Vientianne (4.68%), Vientianne Municipality (0.55%), Xayabury (2.16%), Xaisomboun SR (1.33%) and Xiang Khuang (4.68%). The exposure profile of schools in all earthquake hazard zone areas is presented in Figure 2.9.

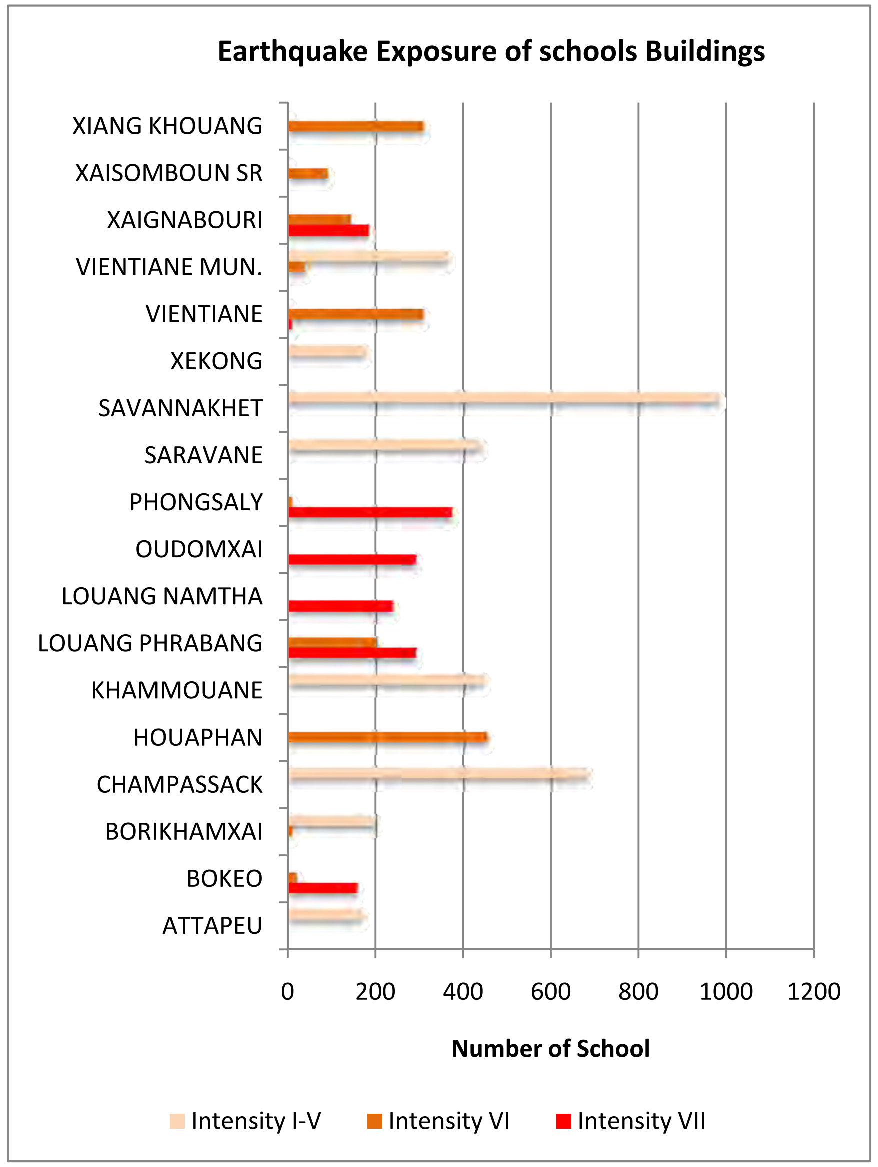


Figure 2.9 Earthquake Exposure of Schools Buildings (Provinces-wide)

2.1.3.6 HYDROPOWER SECTOR

Hydropower plays an important role in the country of Lao PDR. The main resource for hydro power data has been obtained from the Department of Electricity of Lao PDR. Out of 13 hydropower plants, four of them are located in and exposed to a VII intensity earthquake hazard-prone zone. These four are located in Phongsaly, Oudomxai and Luang Namtha. Figure 2.10 presents the distribution of hydropower plants in Lao PDR.

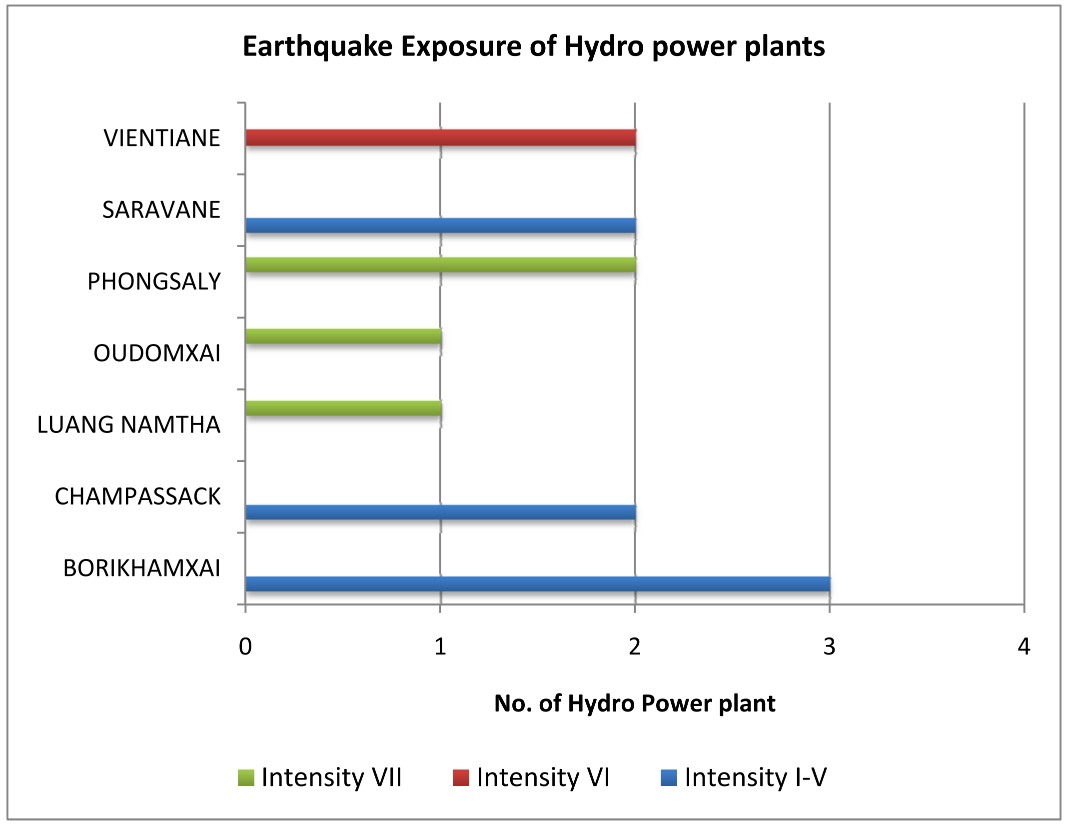


Figure 2.10 Earthquake Exposure of Hydropower Plants

2.2 VULNERABILITY AND RISK ASSESSMENT (VRA)

There are several ways to approach vulnerability and risk assessments (VRAs) for earthquakes. The scope of this project focuses on physical and direct assessment of sectoral vulnerability. The precision of a VRA depends upon the classification of building functions, the construction materials, the age and usages of the building, its physical characteristics and the seismic intensity of the earthquake.

The physical VRA of this project considers buildings used for population, housing, education and health.

The VRA of physical sectors at the national level depends upon the classification of structures according to their materials and structure. In Lao PDR, housing has been categorized by their walls, roofs and floor material types. This classification was used in the national census as well. The performances of buildings are different as per their material of construction. In Lao PDR building typology, brick and RCC buildings are kept in the same category. This affects the VA because both types of buildings perform differently at the same earthquake intensity.

Several fragility curves are available for determining the fragility of buildings according to varying earthquake severity. The most commonly used fragility functions are the Applied Technology Council (ATC), ATC-13, the Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters (RADIUS), the Global Earthquake Safety Initiative (GESI) and Arya et al. (1994). These fragility functions are based on data from California and cover many different types of masonry and frame structures. Further fragility curves have been developed for various essential lifelines. RADIUS fragility functions have been developed for Latin American countries. Housing categories differ, however, from California and Latin America to Lao PDR. GESI has developed fragility curves based on building design, the quality of materials used and building code regulations. It is difficult, however, to apply the attributes used in this fragility curve to a large-scale geographical area as they are too specific to the area for which they were developed.

The building stock and building practices in Lao PDR are similar to those in South and South-East Asia. Much research has been conducted on correlating housing stock classifications with the damage sustained at varying hazard intensities. An effort has been made to integrate the housing classifications used in this study with already-established classes and methodologies. Table 2.1 presents the classifications used to categorize buildings in Lao PDR, define their respective characteristics and determine their similarity with ATC-13, RADIUS and Arya et al. (1997).

Table 2.1 Comparison of the Characteristics of Buildings in Lao PDR

No	Type of House as per Walls	Characteristics of Housing	ATC-13 Class	RADIUS Class	Arya et al.'s Class
1	Brick / RCC	Wall are made up of brick and RCC roofing	FC No 78	Res-4	Type C
2	Wood	Either walls or roof are made with wood	FC No 1	Res -4	Type C
3	Bamboo	Both wall and roof are made with bamboo)	N/A	Res -1	N/A
4	Plywood	Light-weight material for walls and roof	FC 1	Res 1	N/A
5	Grass	Light-weight material for walls and roof	N/A	RES -1	N/ A

The Damage Probability Matrix (DPM) shows the ratio of damage to each different category of house. Arya et al. (1997) characterized building responses for the South Asian region. In addition, they developed potential building damage for the 1905 Kangra earthquake for the Indian region of South Asia. This assessment is based on Arya et al. (1997). The building response table is displayed in Table 2.2 and the DPM.

In Table 2.3 the damage levels in the DPM are (D1) slightly damaged, (D2) moderately damage, (D3) severely damage, and (D4) completely collapsed.

For education and health infrastructure, all buildings are considered as permanent structures and falls under brick / RCC type of construction.

Table 2.2 Building Response to Earthquake Intensity Scale

Building Type	Intensity VI	Intensity VII
Brick / RCC type of buildings	Negligible fine cracks	Few have fine cracks in walls Many have wide cracks in walls
Well-built wooden buildings	No damage	Many have fine plaster cracks Few have wide cracks
Bamboo/ grass / ply wood / other type of light houses	Few/ Small cracks in the wall	Most of the walls will collapse

Since maximum expected intensity of earthquake will be VII, there will not be much structural damage to hydropower plants, roads and bridges. Hence risk assessment for hydropower plants, bridges and roads will not be considered for further analysis.

Table 2.3 Damage Probability Matrix for Housing, Education and Health Sector

Type of Asset		Intensity VI				Intensity VII			
		D1	D2	D3	D4	D1	D2	D3	D4
House	Brick / RCC type of buildings	-	-	-	-	5 %	50 %	-	-
	Well-built wooden buildings	-	-	-	-	50 %	5%	-	-
	Bamboo/ grass / ply wood / other type of light houses	5 %	-	-	-	-	-	75%	
Education Building	Brick / RCC type of buildings	-	-	-	-	5 %	50 %	-	-
Hospitals/ Health Centres	Brick / RCC type of buildings	-	-	-	-	5 %	50 %	-	-

2.2.1 POPULATION

The vulnerability of population can be subdivided into direct physical vulnerability of the population (injury, casualties and homeless) and indirect social vulnerability and capacity. For this study, the direct physical vulnerability of the population is considered.

One of the very important next steps is to analyze the degree of injury caused by building collapse or severe damage. For the evaluation of population losses, a first step is to define population injury severity classes. There are four classes defined for this study:

- Dead : instantaneously killed or mortally injured;
- Life threatening: pose an immediate life threatening risk if not treated adequately and immediately . The majority of these injures are the result of structural collapse and subsequent entrapment or impairment of occupants;
- Hospitalized: requiring a greater degree of medical care and hospitalization, but not expected to progress to a life threatening status; and
- Lightly injured: requiring basic medical aid without requiring hospitalization.

The methodology for estimating loss of life and injury is based on the Lethality ratio developed by Coburn, Spence and Pomonis (1992). The number of people killed (*K*) can be expressed as:

M = Noh (M1*M2*M3*(M4+M5))

The model is developed on the basis of five major factors: population per building (M1), occupancy at time of earthquake (M2)), occupants trapped by collapse (M3), injury distribution at collapse (M4), post-collapse mortality (M5) and number of houses (Noh). The parameters for calculating death and injury are worked out based on the rationale given below. The coefficients of the Lethality ratio has been developed for Lao PDR based on expert opinion and existing factors in the region.

Population per building (M1) is calculated based on a field survey. The M1 factor for the study area is based on the population per building in each province. This value is calculated from the total population divided by the total number of houses in the province. Occupancy at the time of earthquake (M2) is shown in

Table 2.4. The values are derived based on the lifestyle of common people.

Occupants trapped by collapse (M3) is based on studies conducted by Okada and Pomonis (1990). The research is based on data from developing countries on the number of people trapped in collapsed buildings due to earthquakes.

Table 2.4 Parameters for Calculation of Casualty Model

Factor	Value Description	
Population per building (M1)	Based on each province	
Population per building (M2)	**Time**	**Occupancy**
	Day time	40%
	Night time	95%
Occupants trapped by collapse (M3)	**Intensity**	**Value**
	VI	Nil
	VII	5%
	VII	30%
Injury severity scale (M4)	**Category**	**Value**
	Dead	20%
	Life threatening	30%
	Hospitalized injury	30%
	Light injury	20%
Post-collapse mortality (M5)	95%	

The causes of death and injury of those trapped inside damaged structures varies considerably. In masonry buildings a primary cause of death is suffocation from the weight and dust of collapsed walls or roofing. Noji (1989) proposes a number of injury severity scales. One of the simplest and most useful is the four point standard triage categorization of injuries (M4). The last factor considered in the equation is post-collapse mortality (M5) which has value of around 95 percent.

The population injury severity grades are assigned to the population of earthquake risk zones for day-time and night-time scenarios. The casualty profile of the population due to earthquakes (intensity VII) is presented in Appendix I, Table 5. Figure 2.11 and Figure 2.12 illustrate the distribution of casualties in different severity stages (light injury, hospitalized, life threatening and dead) based on day-time and night–time scenarios. The Coburn (1992) fragility model has been adopted to calculate the population at risk. The analysis reveals that the night-time scenario results show more casualties than the daytime scenario. The casualties (dead and life threatening) are comparatively higher for Luang Phrabang and Oudomxai with more than 25,000 in the night-time scenario and less than 11,000 in the day-time scenario. The analysis further reveals that Vientiane province is comparatively safer than other provinces. The casualties are less than 250 for both the night-time and day-time scenarios.

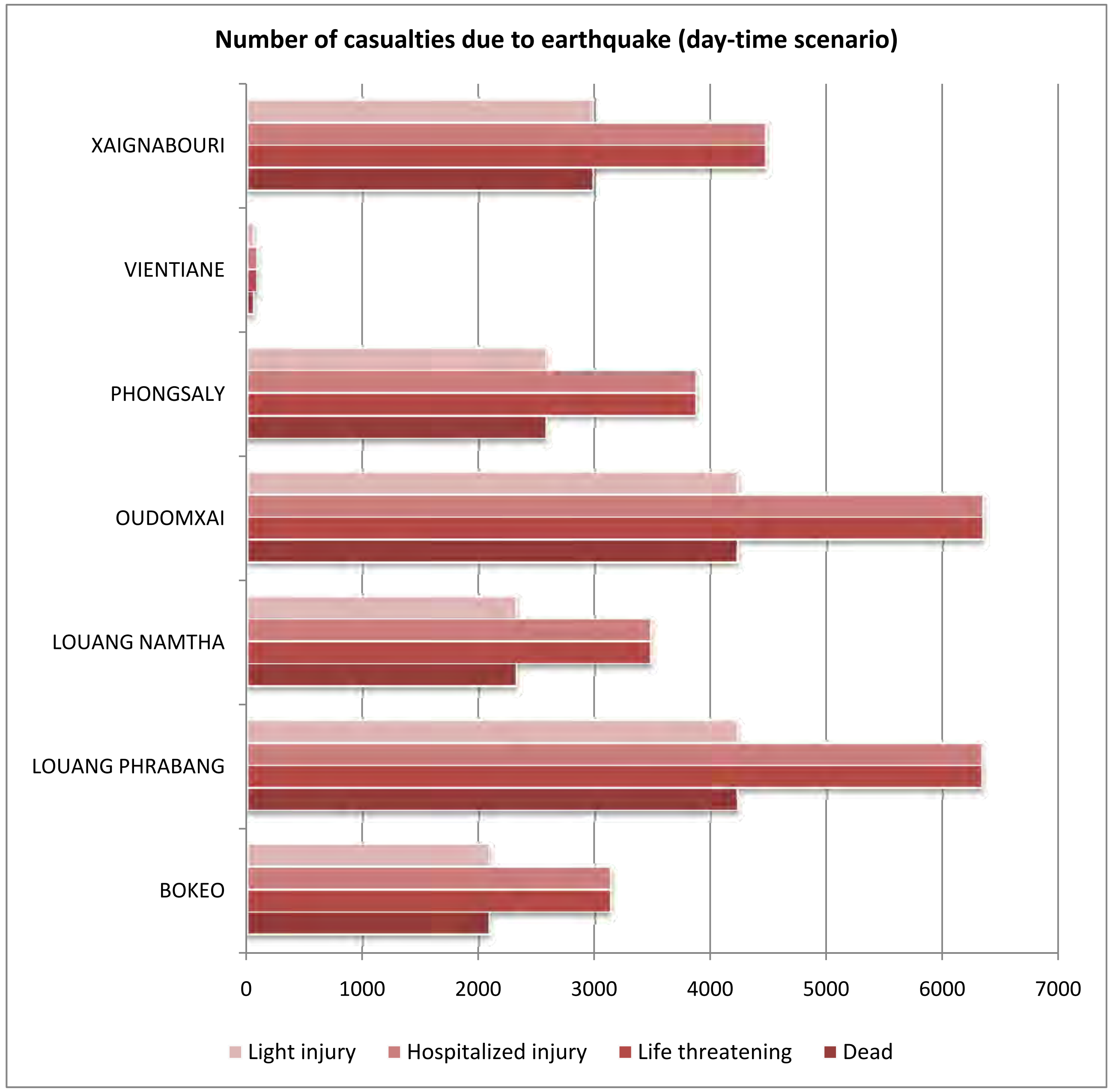


Figure 2.11 Number of Casualties Due to Earthquakes (Day-time Scenario)

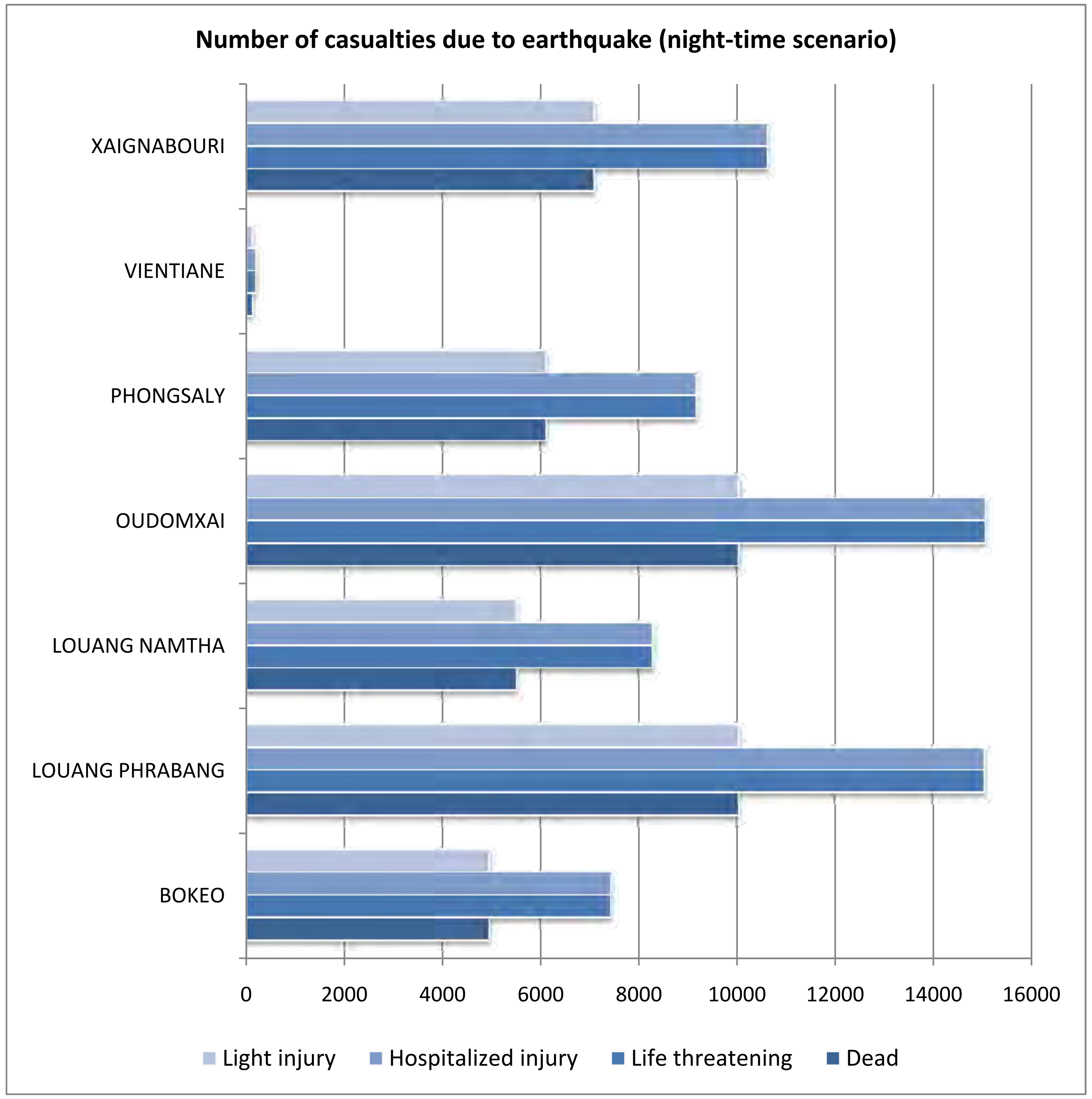


Figure 2.12 Number of Casualties Due to Earthquakes (Night-time Scenario)

2.2.2 HEALTH SECTOR

Earthquake disaster will severely impact the health sector of the affected areas. The risk analysis has been carried out for health sector infrastructure, namely health posts and hospitals. The condition of health posts and hospitals are a primary concern when carrying out earthquake mitigation and response. The proper spatial distribution of health infrastructure is crucial for relief and recovery as some districts will sustain higher damage than others. The spatial distribution of health post damage risk is illustrated in Table 2.5 and Figure 2.13. The result reveals that there are six provinces that have hospitals/ health posts at risk for a D1 and D2 level of damage. In this scenario of earthquake intensity VII, 95 school building will suffer a D2 level of damage as seen in Table 2.5. Another nine school buildings will sustain a D1 level of damage (slightly damaged).

Table 2.5 Distribution of hospitals/health centers

Province Name	Intensity VII			
	D1	D2	D3	D4
BOKEO	1	13	0	0
LOUANG PHRABANG	2	19	0	0
LOUANG NAMTHA	2	17	0	0
OUDOMXAI	2	20	0	0
PHONGSALY	1	9	0	0
VIENTIANE MUN.	2	18	0	0
Total	9	95	0	0

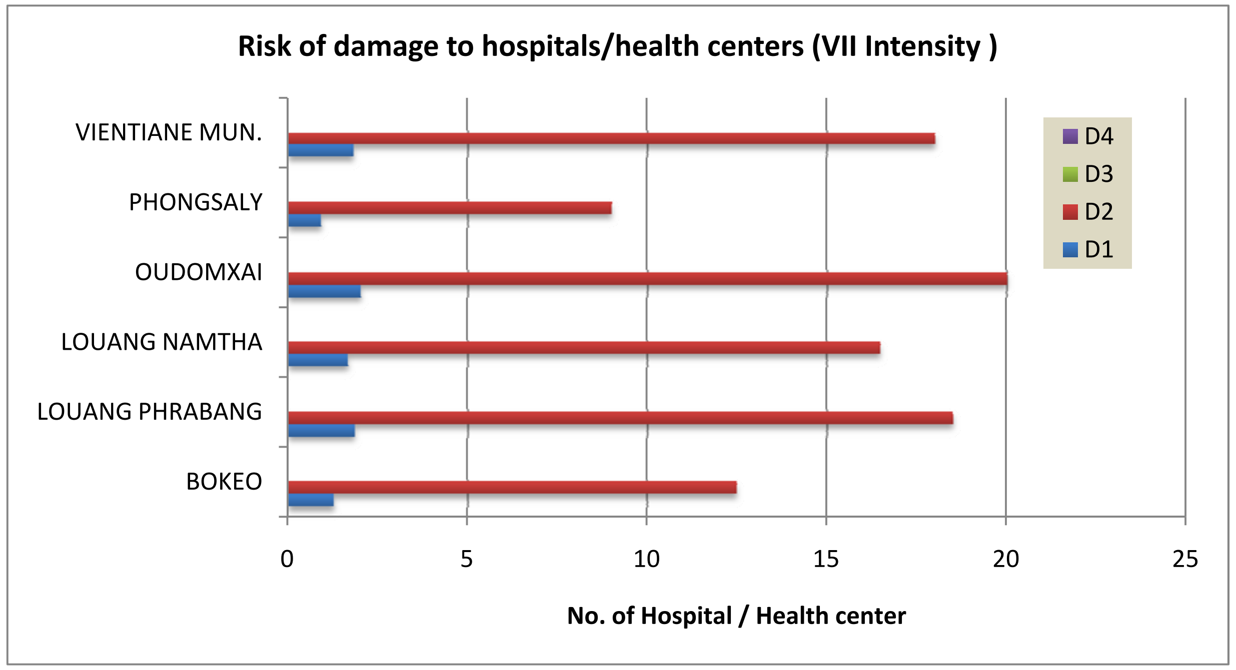


Figure 2.13 Risk of Hospitals/ Health Center Damage Due to Earthquakes (Intensity VII)

2.2.3 HOUSING SECTOR

The VRA for the housing sector is carried out based on earthquake intensity VI and VII. Table 2.6 shows the distribution of damage in various zones for all types of buildings. To simplify, all four damage levels have been considered together. The four levels are used to determine the risk of damage for each particular province. Figure 2.14 and Figure 2.15 shows housing damage risk for earthquake intensity of VI and VII.

Damage distribution of earthquake intensity VI

Figure 2.14 shows the distribution of house damage in case of earthquake intensity VI. Based on the damage probability matrix for houses, there are 13 provinces in Lao PDR that have a probability of loss caused by earthquakes of VI and VII intensity. These provinces are Bokeo, Borikhamxai, Houaphan, Luang Namtha, Luang Prabang, OudomXai, Phongsaly, Vientianne, Vientianne Municipality, Xayabury, Xaisomboun XR and Xiang Khouang.

Analysis reveals that there are 7,533 houses which have damage probability that falls in the D1 category (slight damage). It can be concluded from Figure 2.14 that the highest percentage (27.84 %) of 7,533 houses having a probability of slight damage (D1) is located in Vientianne Capital. This is followed by Luang Prabang (22.14%), Vientianne Municipality (21.81%), Xayabury (7.96%), Houaphan (7.88%), Xaisomboun SR (5.60%), XiangKhouang (4.55%), Borikhamxai (1.26%), Bokeo (0.64%) and Phongsaly (0.32%).

Damage distribution of earthquake intensity VII

In case of Intensity VII, 133,721 houses will experience damage ranging from D1 (slight damage), D2 (moderate damage) and D3 (severe damage). About 79 percent of houses are falling in the category of D3 (severe damage) followed by 17.91 percent of D1 (slightly damage) and 3.05 percent of D2 (moderate damage). Figure 2.15 depicts the distribution of damage probability of houses for each category.

- Analysis shows that for category D3 (severe damage), the biggest portion of houses having damage probability is located in Oudomxai province (22.66 %), followed by Xayaburi (19.34%), Luang Prabang (16.65%), Bokeo (14.51 %), Luang Namtha (12.24%), Phongsaly (10.63 %) and Vientianne Capital (3.97%).
- Table 2.6 shows there are 4,073 houses which will experience moderate damage (D2). The biggest percentage of these 4,073 houses is located in Xayaburi province (29.63%) followed by Luang Prabang (18.05 %), Phongsaly (17.38%), Oudomxai (14.61 %), Luang Namtha (11.05%) and Bokeo province (9.17%).
- Table 2.6 shows that there are 23,948 houses out of 133,721 houses having damage in category of D1 (slight damage). About 25.88% of these are located in Phongsaly province, followed by Oudomxai (22.05%), Luang Namtha (18.37%), Xayabury (13.79%), Luang Prabang (12.70%) and Bokeo province (7.21%).

Table 2.6 Risk of Earthquake Damage for Earthquake Intensity V1 and VII

Province Name	Intensity VI				Intensity VII			
	D1	D2	D3	D4	D1	D2	D3	D4
BOKEO	48	0	0	0	1727	374	15333	0
BORIKHAMXAI	95	0	0	0	0	0	0	0
HOUAPHAN	594	0	0	0	0	0	0	0
LOUANG NAMTHA	0	0	0	0	4399	454	12937	0
LOUANG PHRABANG	1668	0	0	0	3041	735	17594	0
OUDOMXAI	0	0	0	0	5281	595	23956	0
PHONGSALY	24	0	0	0	6197	708	11241	0
VIENTIANE	2097	0	0	0	0	0	4193	0
VIENTIANE MUN.	1643	0	0	0	0	0	0	0
XAIGNABOURI	600	0	0	0	3302	1207	20447	0
XAISOMBOUN SR	422	0	0	0	0	0	0	0
XIANG KHOUANG	343	0	0	0	0	0	0	0
Total	7533	0	0	0	23948	4073	105701	0

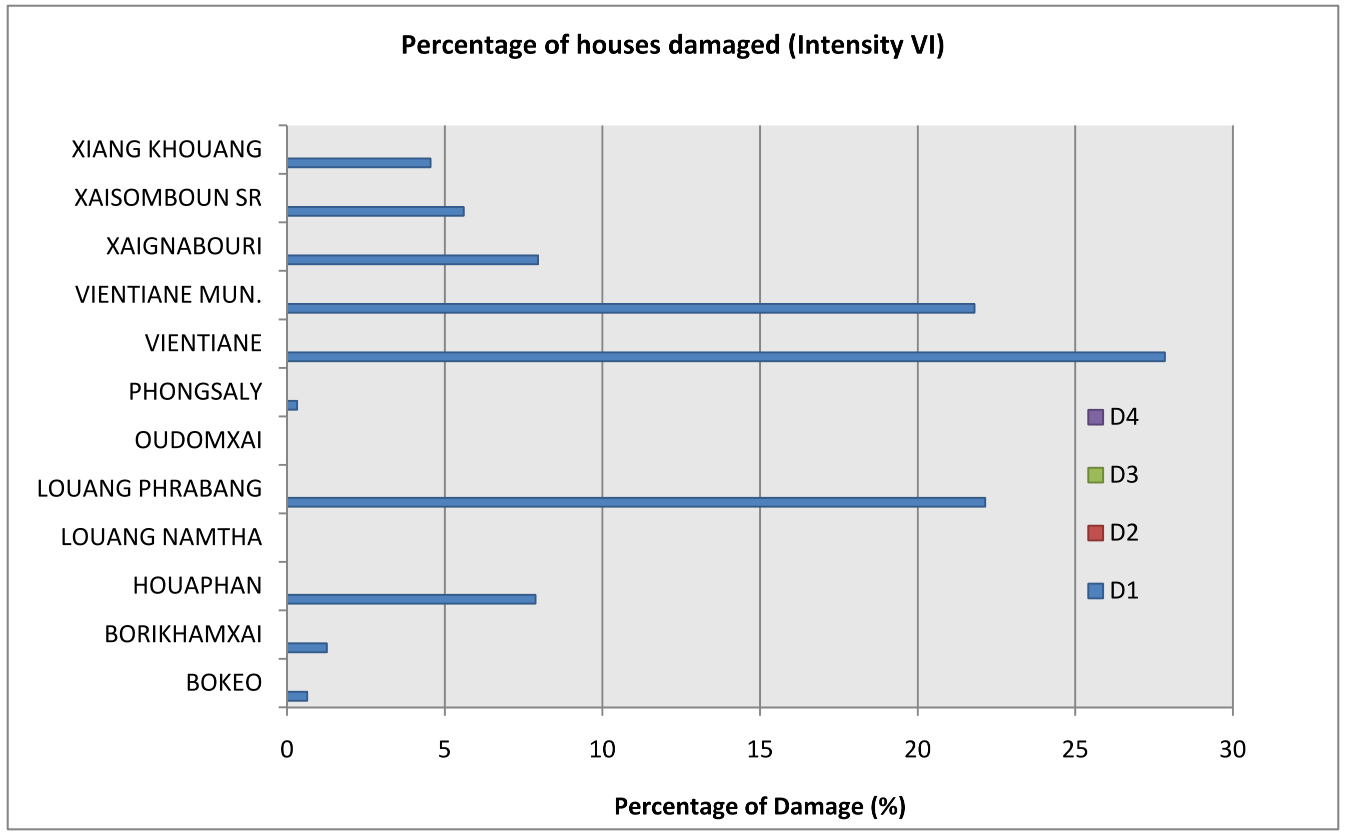


Figure 2.14 Percentage of Houses Damaged (Intensity VI)

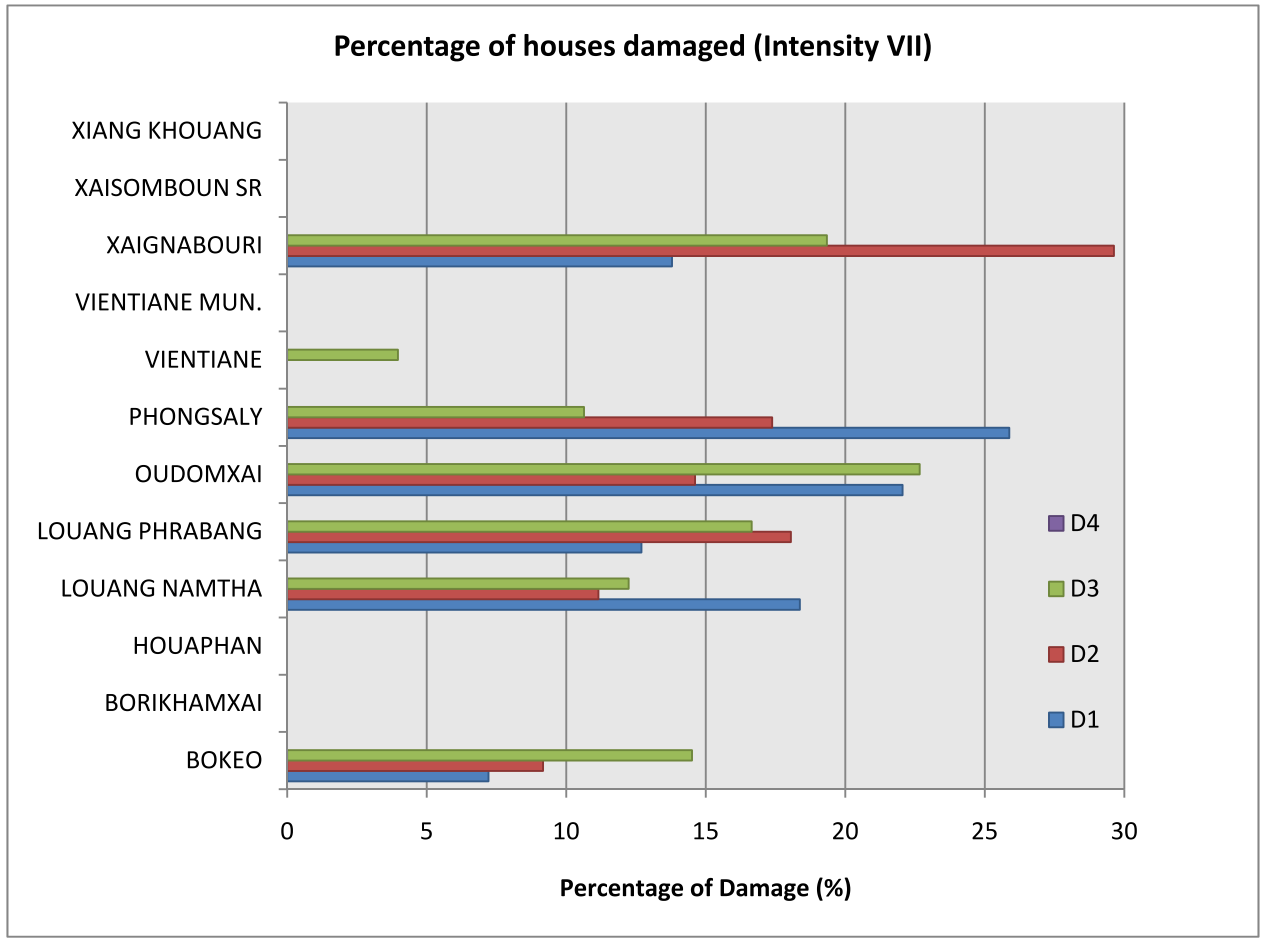


Figure 2.15 Percentage of Houses Damage (Intensity VII)

2.2.4 EDUCATION SECTOR

In the education sector, only school data is available in detail. Thus, the analysis focuses on the risk of school buildings exposed to earthquakes. Building typology for school buildings is not available. Based on information gathered from both field and consultation with national experts it was determined that all school buildings are classified as permanent or semi-permanent buildings.

Table 2.7 and Figure 2.16 show the distribution of damage levels to school buildings. Under a scenario of earthquake intensity VII, the analysis shows that 845 schools buildings will sustain a D1 (9.09%, slight damage) and D2 (90.91%, moderate damage). This damage probability is distributed across seven provinces of Lao PDR: Bokeo, Luang Prabang, Luang Namtha, Oudamxai, Phongsaly, Vientinne Capital and Xayaburi province.

Table 2.7 Risk of Damage to School Buildings (Intensity VII)

Province Name	Intensity VII			
	D1	D2	D3	D4
BOKEO	8	78	0	0
LOUANG PHRABANG	15	145	0	0
LOUANG NAMTHA	12	119	0	0
OUDOMXAI	15	146	0	0
PHONGSALY	19	186	0	0
VIENTIANE	0	3	0	0
XAIGNABOURI	9	92	0	0
total	77	768	0	0

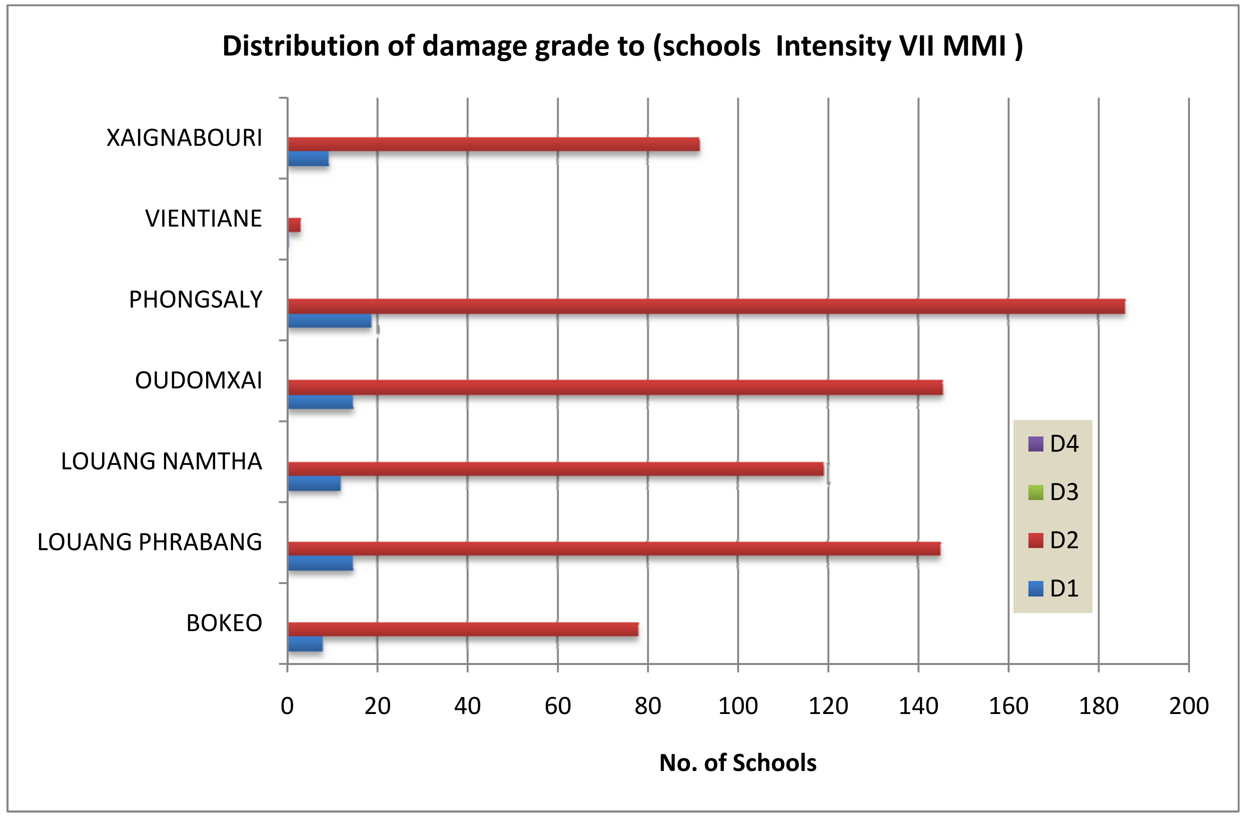


Figure 2.16 Distribution of Damage Levels to Schools (Intensity VII)

2.3 CONCLUDING REMARKS

EVRA is carried out for vital sectors in Lao PDR, namely human life (population), health, housing and education. Due to a lack of available data and a restricted time frame, the scope of the project was limited. Thus, there are several improvements that may be carried out beyond the project deliverables. Future detailed EVRA activities will further support policy makers, decision makers and development agencies in achieving safe and sustainable development.

- The private housing in Lao PDR has been classified into two basic categories, namely permanent and temporary houses including semi-permanent (Census, 2005). The main basis of this classification is the type of building materials used for the roof, walls and floor. The definition of each class of housing, however, is not entirely clear and fails to reflect the building materials used and their respective earthquake force resilience. It is difficult to develop fragility curves for such types of houses. In the future, it will be necessary to create a system for the categorization of buildings based on their engineering characteristics.

- No database exists that identifies which class of buildings schools and hospitals are in. Although a database of the spatial distribution of state schools, health posts and hospitals already exists, there is no such database for private schools or health infrastructure. Building a comprehensive database to incorporate these buildings would allow for a comprehensive analysis of the building exposure, vulnerability and risk.

- In the transport sector the classification of roads is not clear, thus it is difficult to reflect their respective earthquake force resilience. Due to the unavailability of information in the necessary spatial format, the present analysis has not incorporated updated information on road infrastructure. It is necessary to obtain updated information on road infrastructure from the Department of Roads and integrate it into the spatial format needed to develop a realistic and updated EVRA.

- Data on the power and electricity infrastructure in Lao PDR has not been updated along with new developments. It is necessary to update the database for power and electricity infrastructure. The Department of Electricity Development should develop the updated spatial database to enable an extensive EVRA for the power and electricity sector to be carried out.

- A comprehensive fragility curve must be developed for electricity and power infrastructure. At present the fragility curve and vulnerability characteristics have not yet been developed for the existing power and electricity infrastructure in Lao PDR. Thus, a realistic fragility curve for such infrastructure must be developed.

- EVRA has only been carried out for limited sectors. There remains a need to develop an EVRA for economic sectors such as tourism, trade and real estate.

- EVRA has been developed on a national scale. The appropriate national level government departments and agencies should take the initiative to develop EVRAs at the district and Village Development Committee (VDC) levels.

- There is a need for capacity building within focal development departments for EVRA as will be discussed in the recommendation section of the report. NDMO can take initiatives and arrange capacity building programs for identified departments and agencies.

3 FLOOD EXPOSURE, VULNERABILITY AND RISK ASSESSMENT

3.1 EXPOSURE ASSESSMENT

3.1.1 INTRODUCTION

Chapter 3, Part 1 discusses the seven hazard zones in Lao PDR, including flood hazard. Eight basins are analyzed in this flood hazard assessment and mapping: Nam Ou, Nam Ngum, Nam Ngiap, Nam Xan, Se Bangfai, Xe Banghiang, Xe Don and Xekong. The elements exposed to flood hazard zone includes human lives (population), housing, hydropower, education and health infrastructure at the national scale. The detailed description of elements at risk to flood hazards are presented in the following sections. For general understanding, EVRA is carried out for 100-year return period flooding.

3.1.2 METHODOLOGY FOR FLOOD EXPOSURE ASSESSMENT

Data Collection: Data relating to the primary sector is collected from a number of reliable sources. The data is presented in GIS format, at the provincial level.

GIS has been applied to identify and analyze elements exposed to flood hazard. Chapter 3, Part 1 iscusses the hazard maps whilst considering the different severity of the hazard. GIS tools facilitate overlaying susceptibility / hazard maps within identified sectors. The overlapping areas of the hazard maps and sectoral data allow for the identification of different elements at risk. This report quantified the number of houses, their classes, and the number of population, schools, health posts and infrastructure falling in earthquake hazard-prone areas. Methodology for flood exposure assessment may be referred to in Figure 3.1.

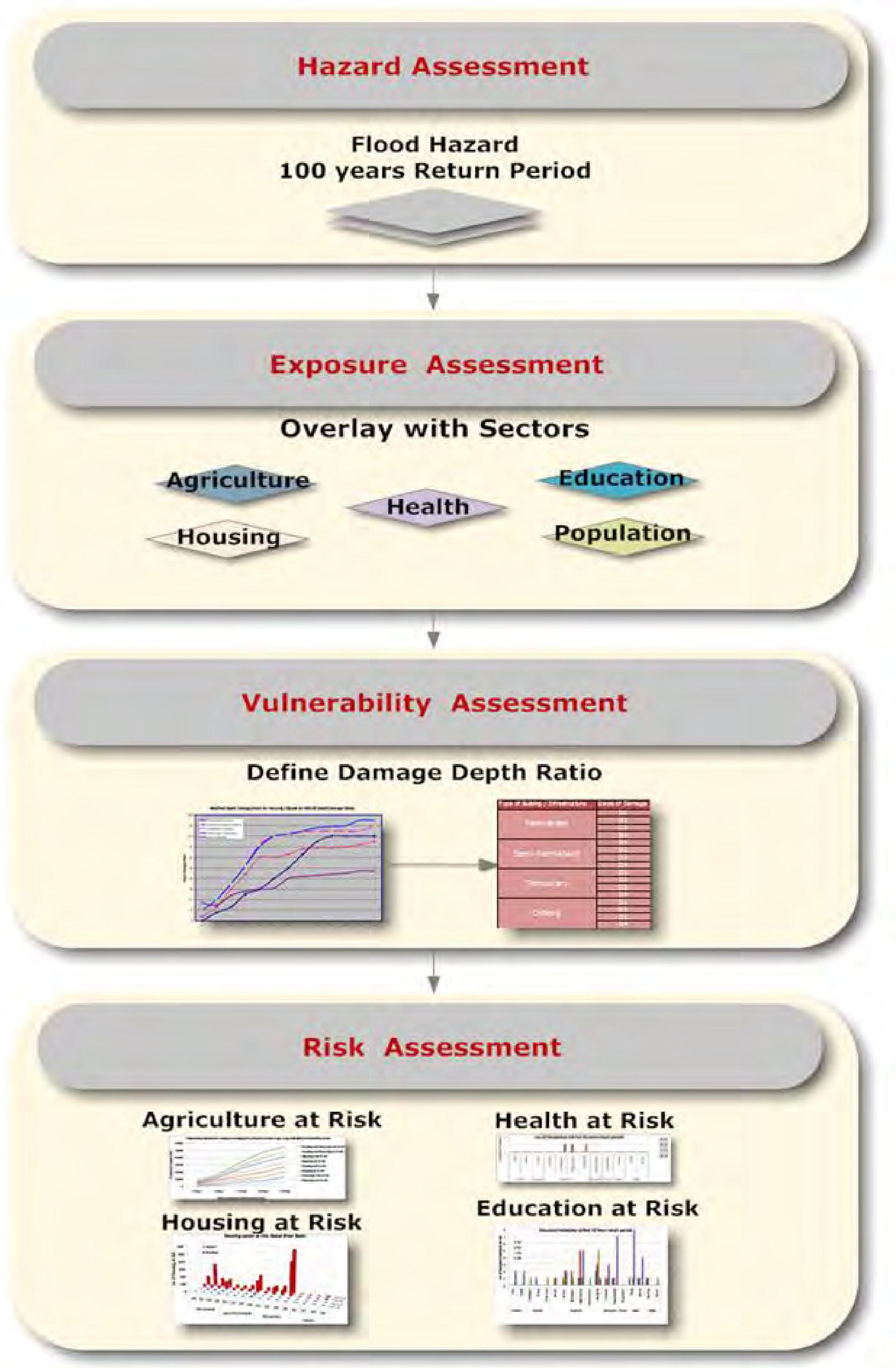


Figure 3.1 Methodology of Flood Exposure, Vulnerability and Risk Assessment

3.1.3 ELEMENTS AT RISK AND EXPOSURE ASSESSMENT

3.1.3.1 POPULATION

- An EA is carried out to assess people living in the flood hazard zones with varying water depth and area. Figure 3.2 shows the distribution of people exposed to flood hazard in different depth of water. Figure 3.3 and Figure 3.4 shows the distribution of working age population (above 15 and below 64 years) and dependent population (below 15 and above 64 years) in flood hazard zones of eight river basins. Appendix I, Table 6 shows the population exposure in each province.

- In all eight identified basin, about 76.47% of the exposed population are located in the flood hazard-prone area of water depth ≥ 2 meters.

- In all eight identified basins, 131,866 working age population is exposed to the flood hazard zone. About 76 percent of working population is exposed to flood hazard zone with water depth ≥ 2 meters. This exposed population is located in Savannakhet (33.90%), Attapeu (14.10%), Khammuane (13.15%) and Luang Phrabang province (12.12 %).

- Similarly, analysis reveals that 115,322 dependent population (age under 15 and above 64 year) are exposed to the flood hazard. About 77 percent of this population is exposed to the flood hazard with water depth ≥ 2 meters.

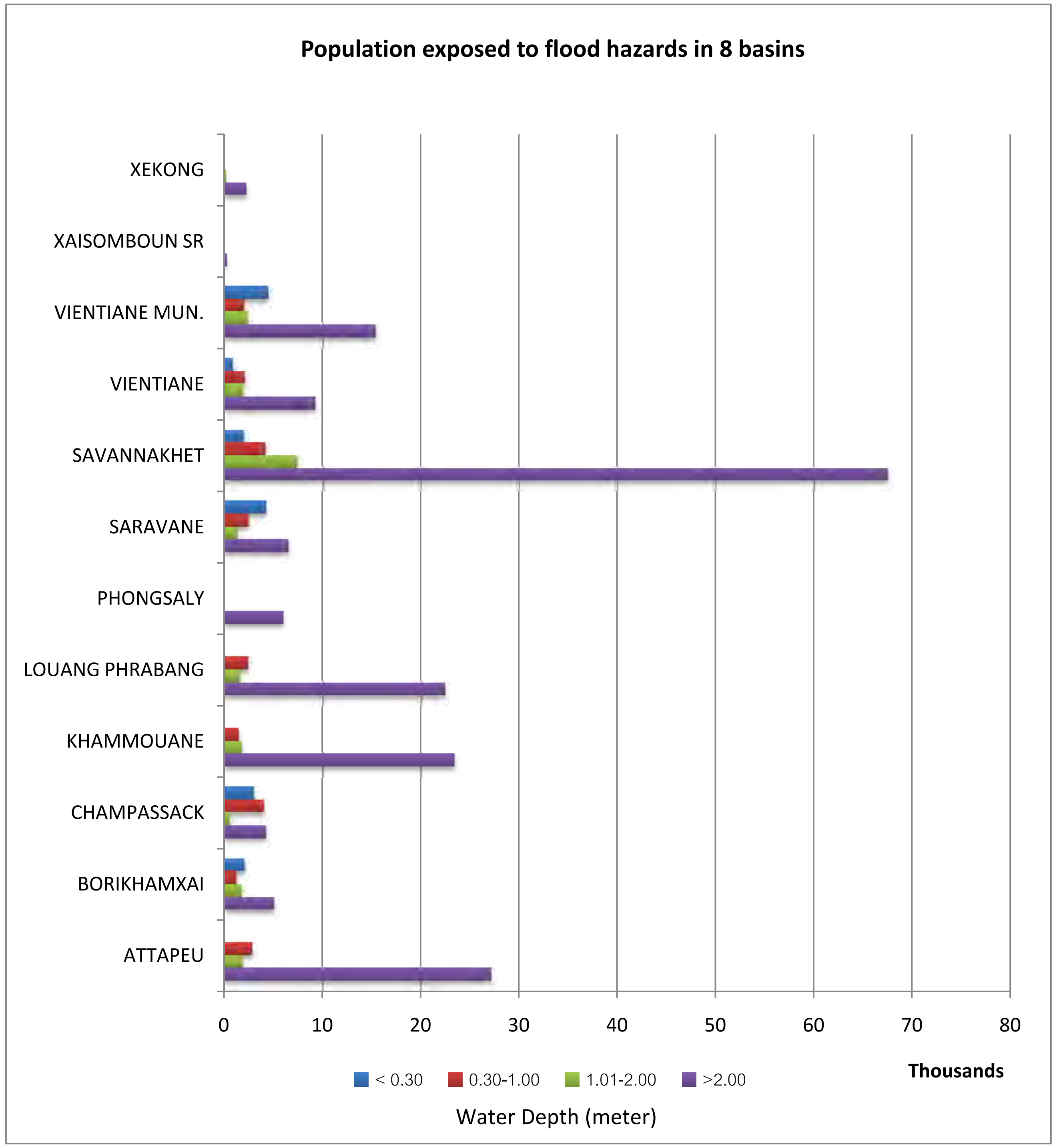


Figure 3.2 Population Exposed to Flood Hazard

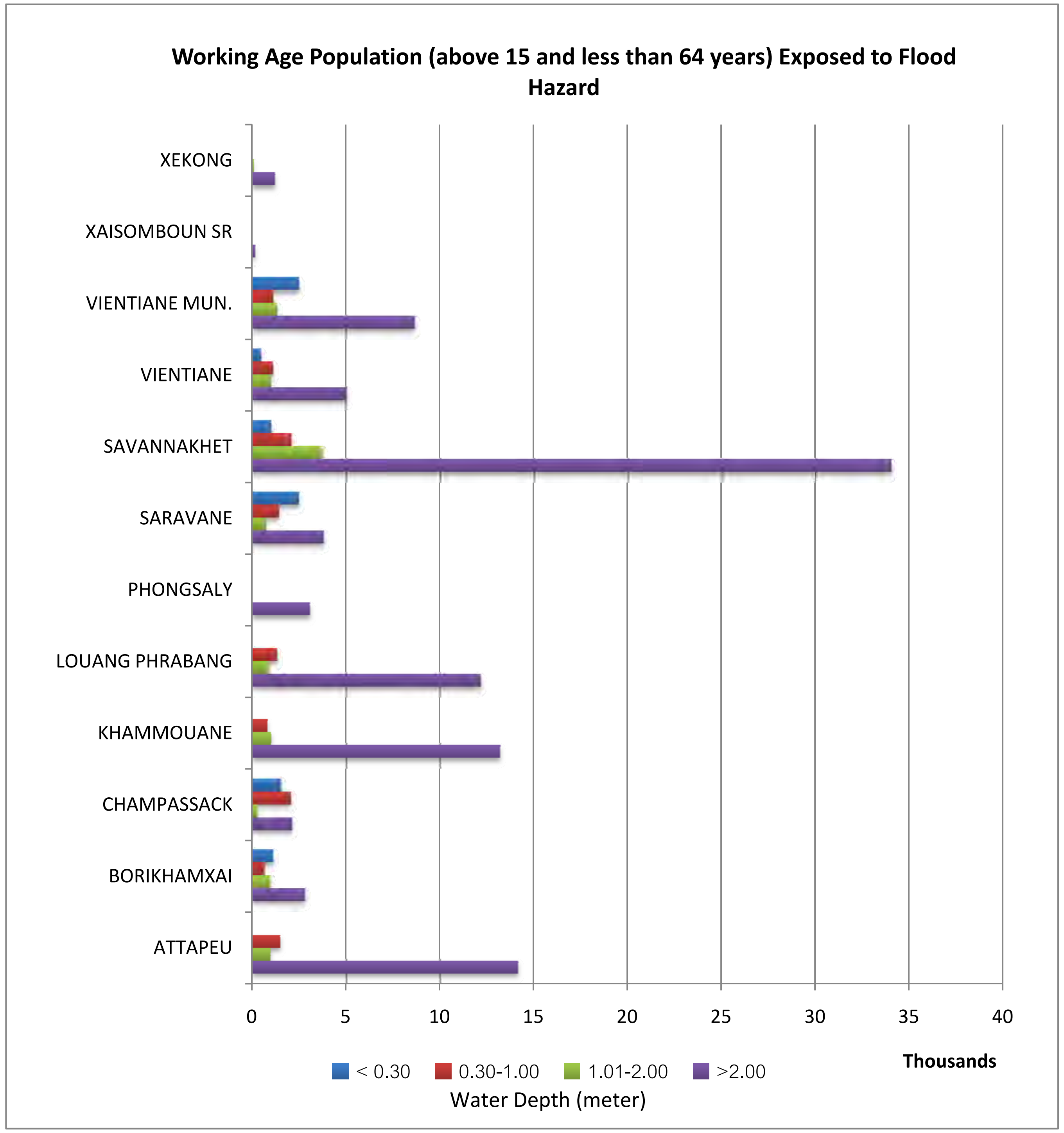


Figure 3.3 Working Age Population (above 15 and less than 64 years) Exposed to Flood Hazard

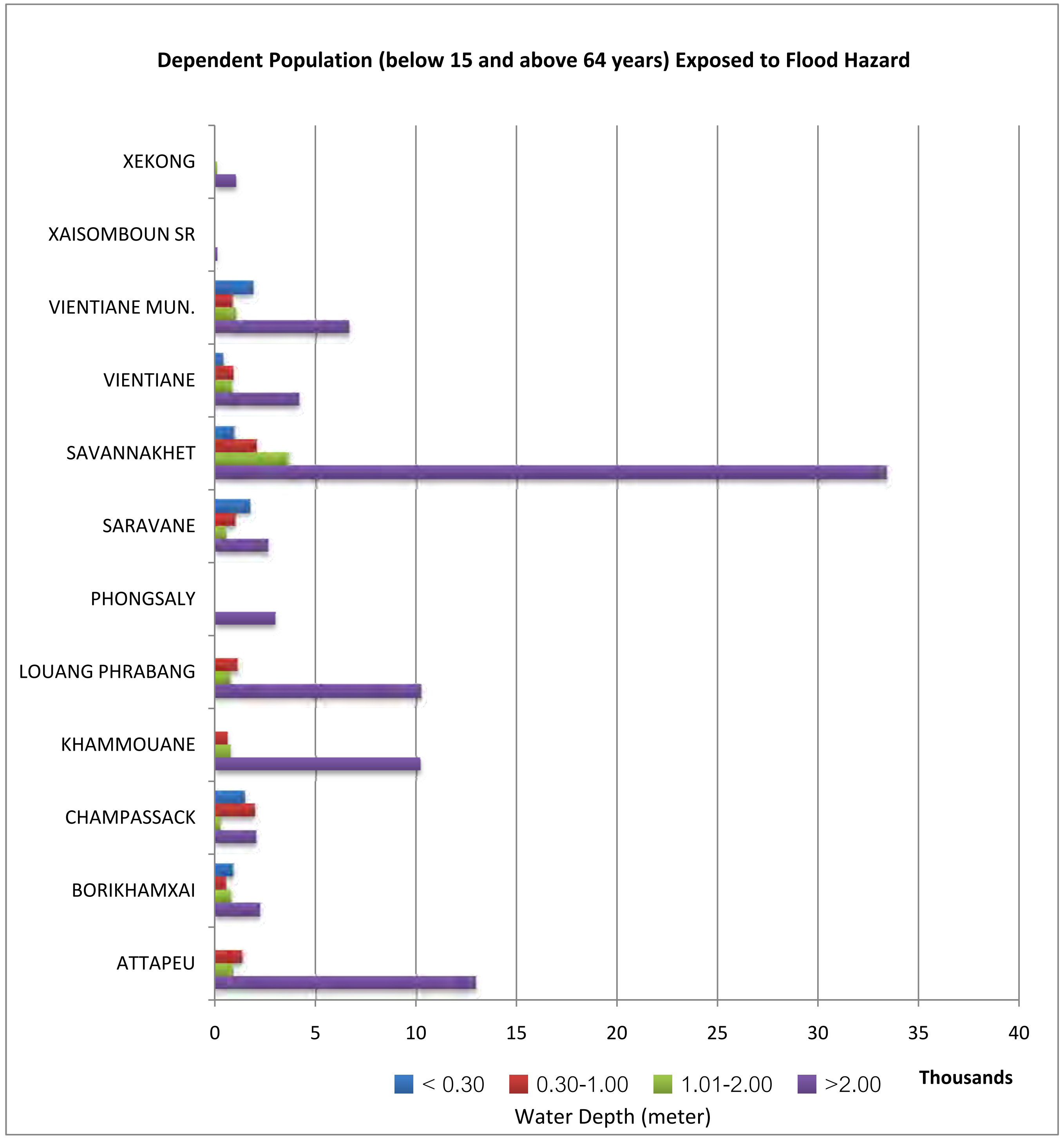


Figure 3.4 Dependent Population (below 15 and above 64 years) Exposed to Flood Hazard

3.1.3.2 HEALTH SECTOR

EA is carried out for health infrastructure using provincial level data. Primarily, hospitals and health centers are considered under health infrastructure. There are 32 hospitals/ health centers exposed to flood hazards, 20 of them falling in the zone of above 2 meters water depth. These are located in Savannakhet, Luang Prabang, Attapeu, Borikhamxai, Khammuane, Phongsaly, Saravane, Xe kong, Vientianne and Vientianne Municipality. Another two hospitals/ health centers which are exposed to the flood hazard with water depth below 1 meter are located in Khamuanne and Saravane. The distribution of the hospitals/ health centers exposed may be refer to in Figure 3.5.

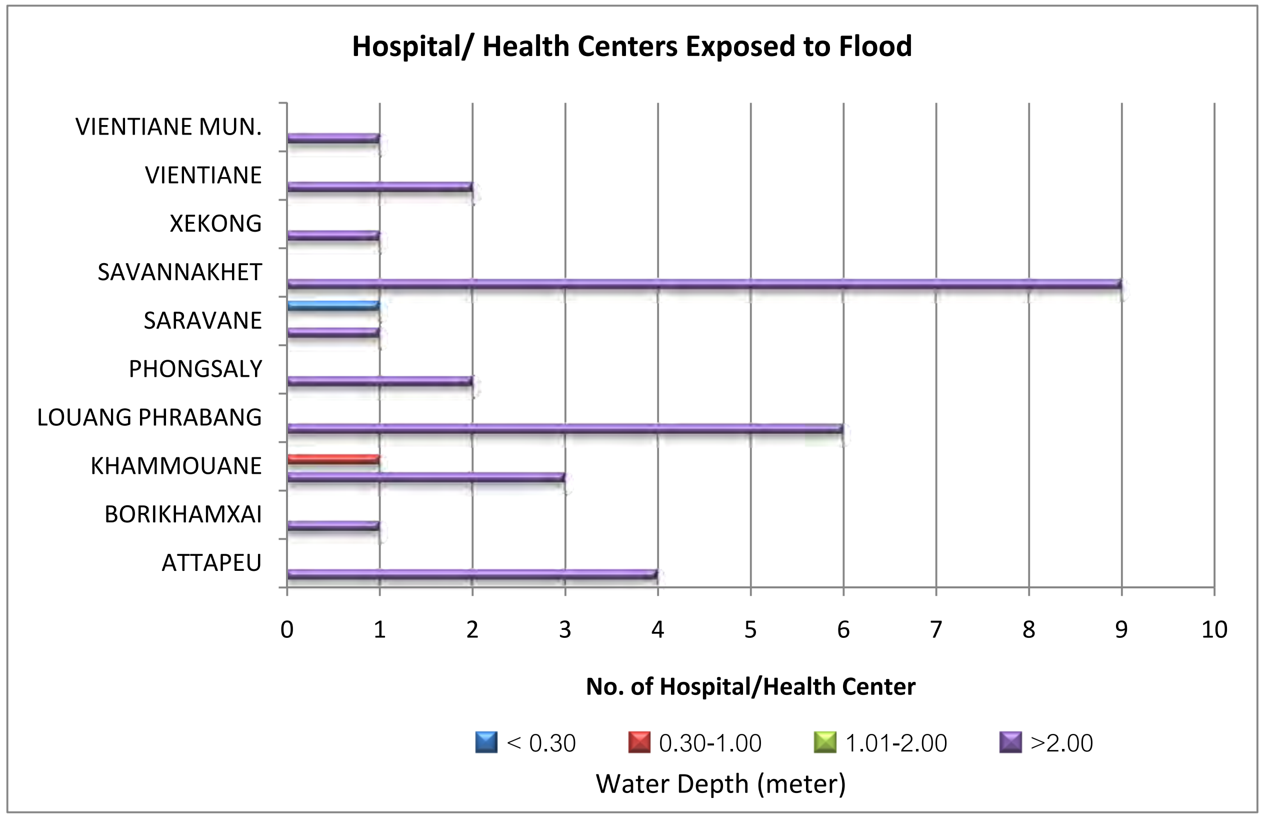


Figure 3.5 Hospital/ Health Centers Exposed to Flood

3.1.3.3 HOUSING SECTOR

Housing is the second worst affected sector after agriculture. Flooding leads to damage and loss of household items, and impacts on the functionality of the household. There are several complex losses associated with the impact of flooding on housing. Figure 3.6 to Figure 3.9 illustrate the profile of flood exposure to all four types of housing that were previously discussed.

- An EA for the housing sector was carried out for the eight river basins. Figure 3.6 to Figure 3.9 show the distribution of housing exposed to flood hazard with different inundation depths (100-year return periods). Housing in this case is classified according to the four types of materials house walls are made from: bamboo, brick/ RCC, wood and others).

- Figure 3.6 depicts the distribution of bamboo housing exposed to flood hazards. It is observed that 493 houses (wall type - wood) are exposed to flood hazards with 77.17% of them falling in flood zones with the water depth > 2 meters. A large percentage of these houses are located in Savannakhet (36.61 %), Vientianne Municipality (18.97 %), Attapeau (8.09%) and Khammuane (8.54%).

- Figure 3.7 shows the distribution of brick/ RCC housing. The figure shows that 130 houses (wall type - brick/RCC) are exposed to flood hazards with 78 of them located in the flood hazard zone with water depth ≥ 2 meters. About 53 of these houses are located in Vientianne Municipality.

- Figure 3.8 depicts the distribution of wooden houses. Analysis reveals that out of the 840 houses, with 659 of them are located in the flood hazard zone with water depth ≥ 2 meters. A large portion of these houses exposed to flood hazards are located in Savannakhet (402) followed by Vientianne Municipality (110), Attapeu (59) and Khamuanne (56).

- Figure 3.9 shows the distribution of other houses exposed to flood hazard. Out of the 71 houses, 58 of them are located in the flood hazard zone with water depth ≥ 2 meters.

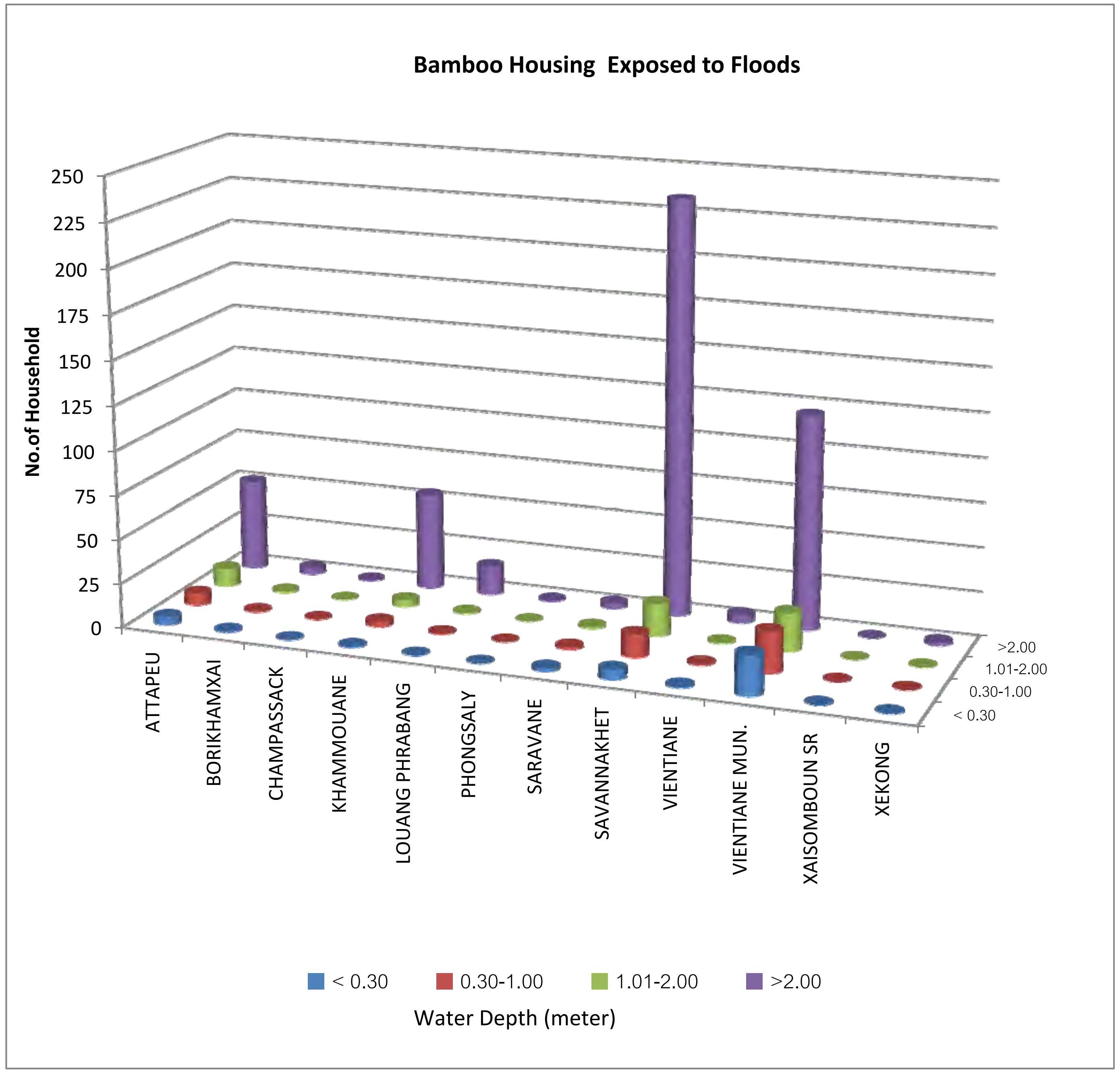


Figure 3.6 Bamboo Housing Exposed to Floods

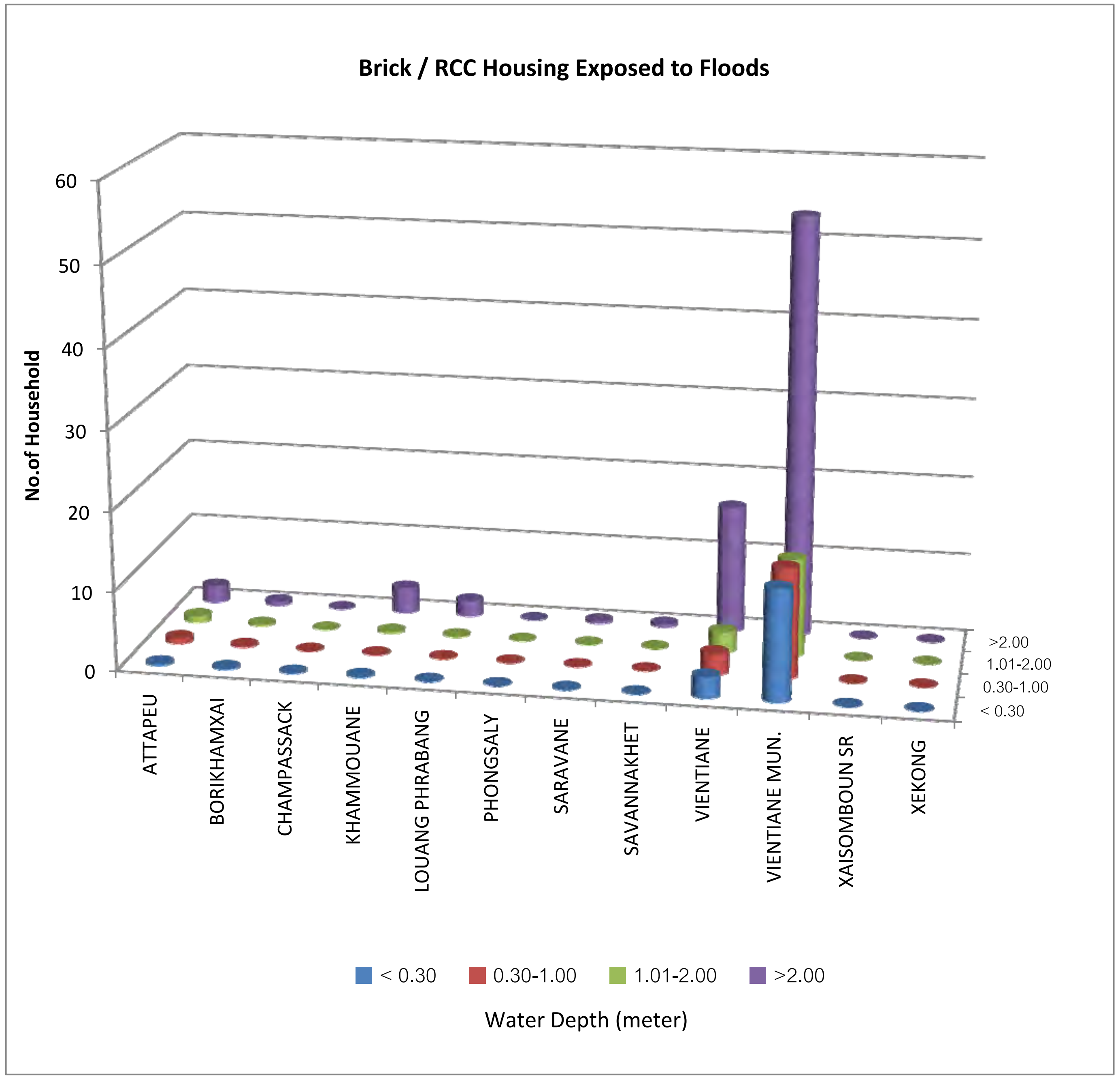


Figure 3.7 Brick/ RCC Housing Exposed to Floods

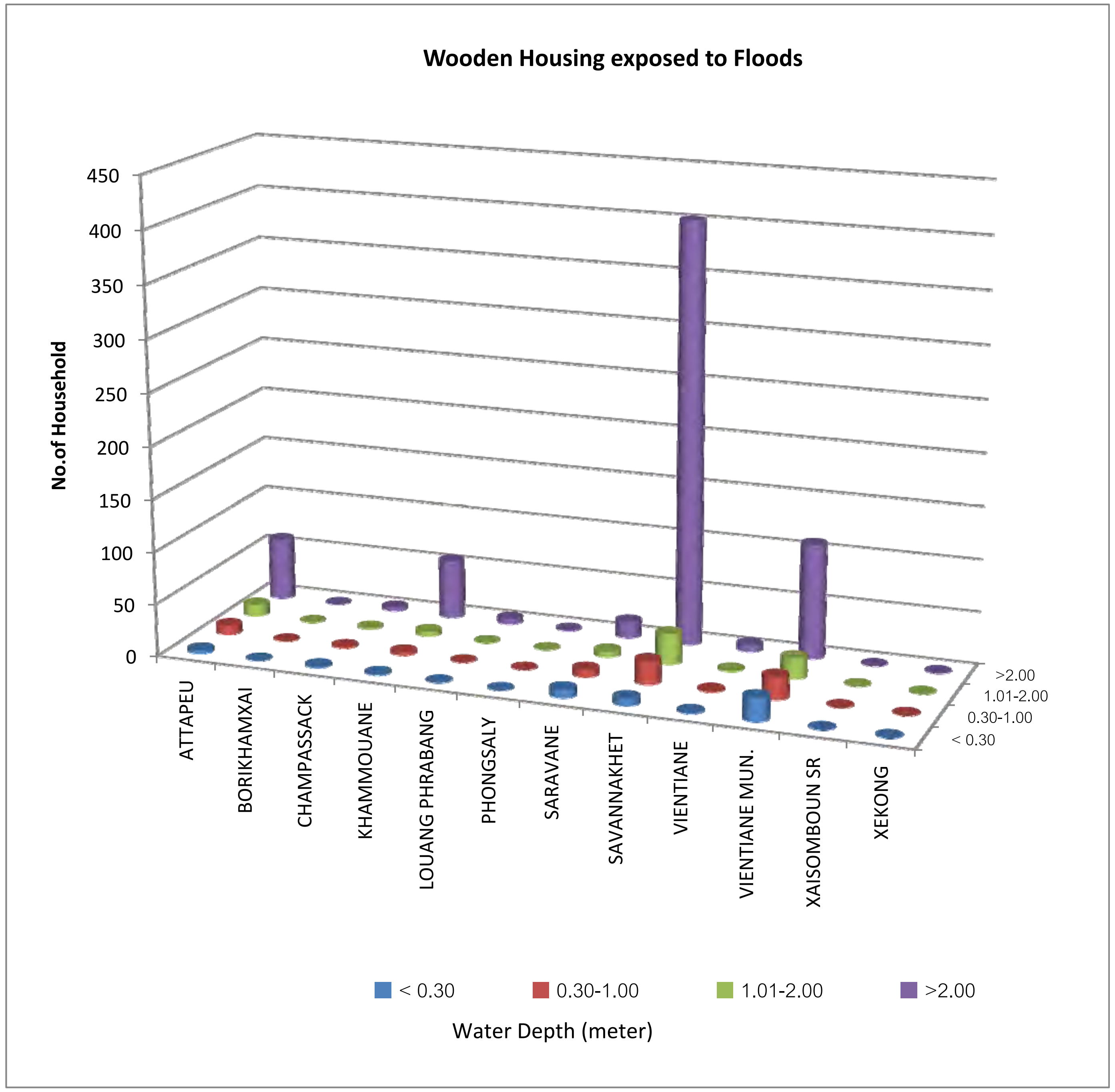


Figure 3.8 Wooden Housing Exposed to Floods

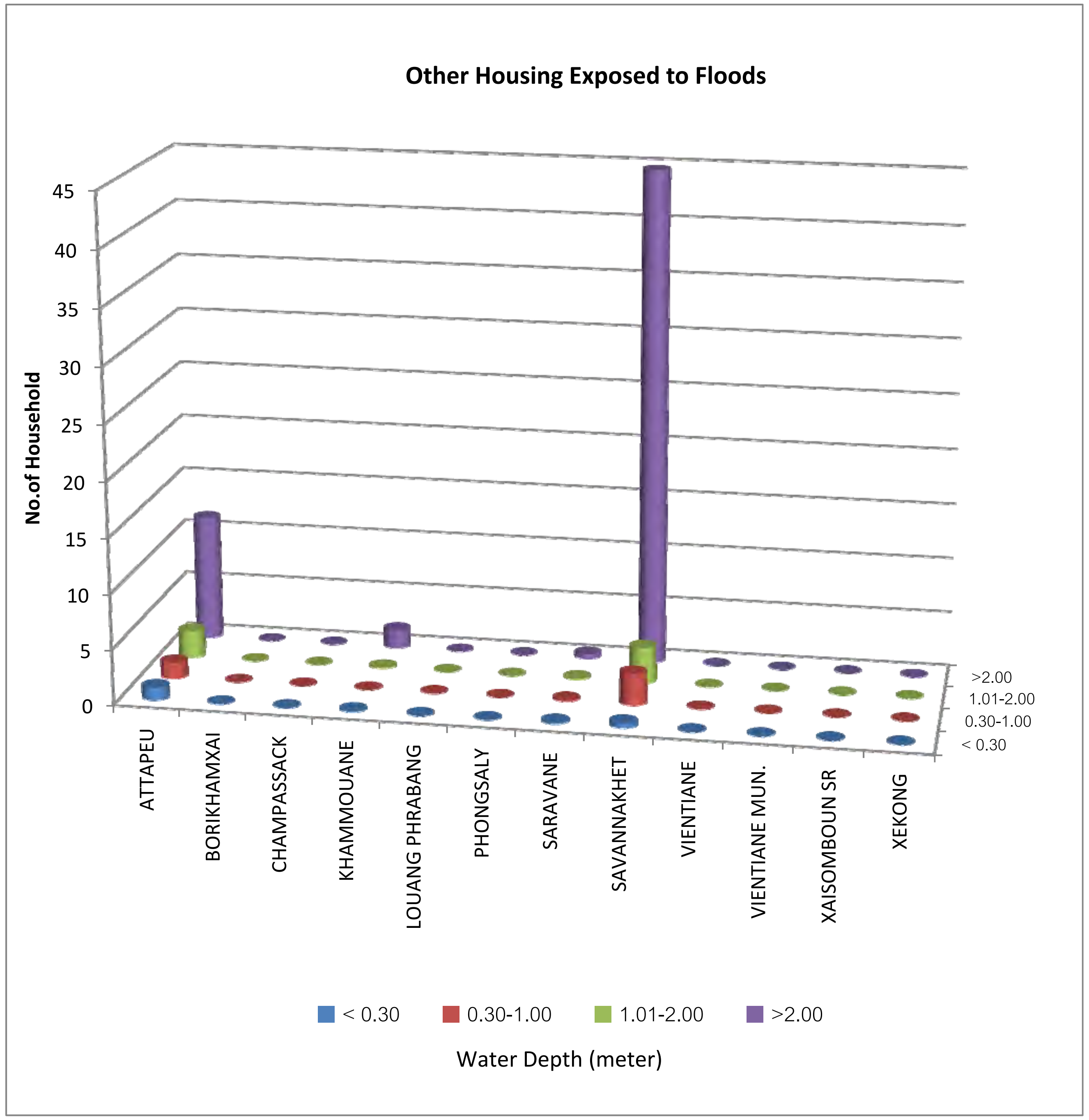


Figure 3.9 Other Housing Exposed to Floods

3.1.3.4 EDUCATION SECTOR

Figure 3.10 illustrates the education institutions exposed to flooding in 12 provinces. Appendix I, Table 8 provides further details about the exposure of the school buildings.

- Figure 3.10 shows the number of schools exposed to flood hazard (100-year return period). There are 300 schools exposed to different flood hazards with varying water depths ranging from < 0.30 meter up to > 2 meters. Analysis shows that 81.67% (245 schools) are exposed to flood hazards with water depth above 2 meters. The largest portion of these schools exposed to the flood hazard are located in Savannakhet (30.33%) followed by Luang Prabang (11.33%), Attapeau (10%), Khammuanne (9.33%), Phongsaly (4.67%), Vientianne Municipality (4.33%), Xekong (3%), Champassack (1.67%), Borikhamxai (1.67%) and Xaisomboun SR (0.33%).

- Another 55 schools exposed to flood hazards are located in zones with water depth < 2 meters.

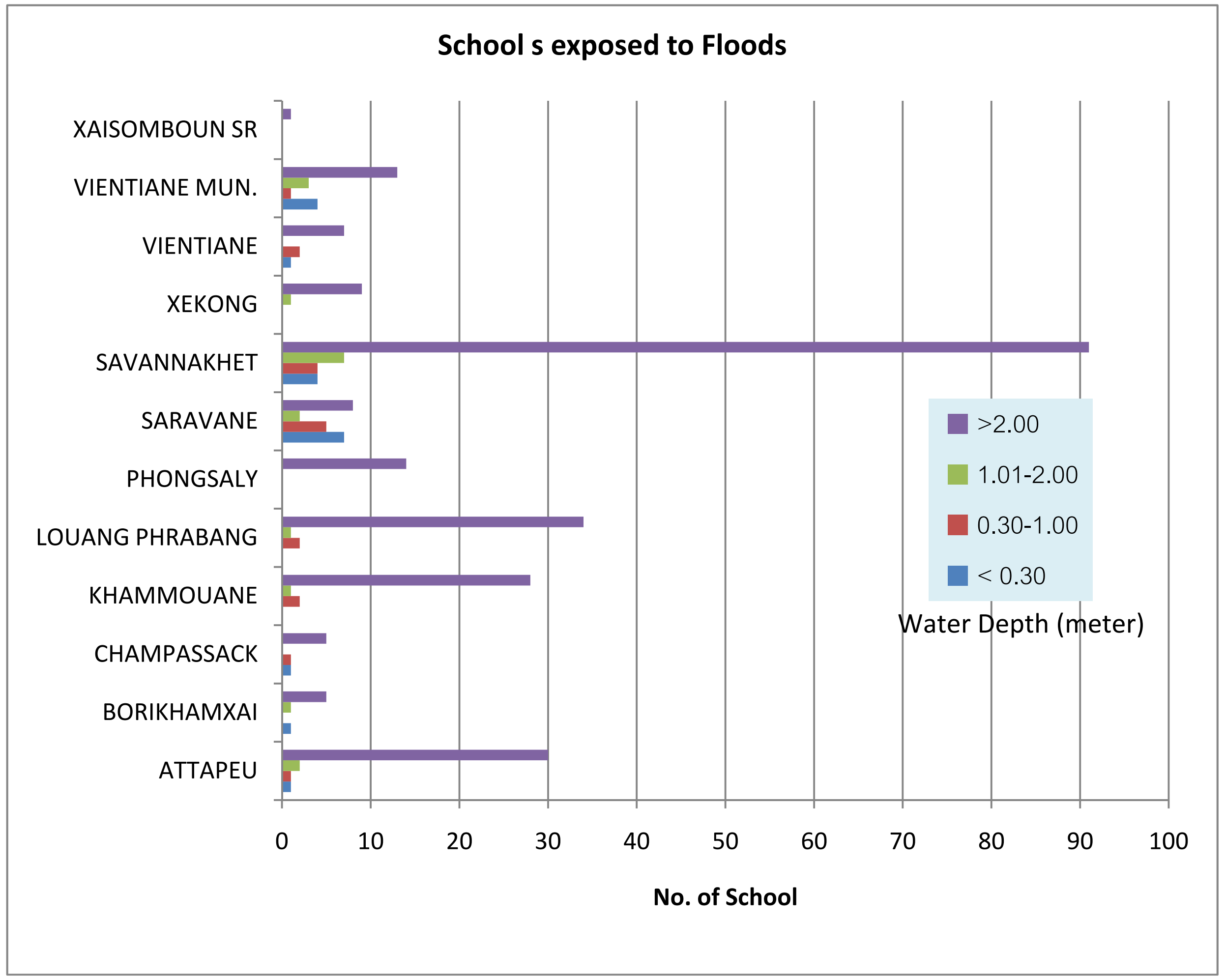


Figure 3.10 Schools Exposed to Floods

3.2 VULNERABILITY AND RISK ASSESSMENT

The flood VRA primarily defines the characteristics of potentially vulnerable elements, their susceptibility to damage during flood inundation and their relationship to resilience. There are several ways to carry out a VRA. The assessment is applicable to the social, physical and environmental elements in society. The project scope includes an assessment of physical vulnerability and a direct assessment of sectoral vulnerability. The precision of VRA depends upon the classification of building functions, the materials used in construction, the age and condition of the building, its physical characteristics uses and water depth. Conducting VRAs in developing and underdeveloped countries can be difficult for the following reasons:

- Flood VRA of economic sectors at the national level depends on the types of crops being cultivated, the classification of physical assets and their interaction with flood water. The damage largely depends upon the velocity of flowing flood water, the depth of water and the water detention period. Each asset is impacted differently under these varying circumstances.

- Though the census has compiled data on education and health institutions it is still a challenge to collect detailed characteristics of education and health buildings.

- The extent of expected flood damage must be studied based on historical records of the performance of agriculture and various classes of buildings at varying flood depths, areas and detention periods. The literature review reveals that there is a distinct lack of damage data as such. For instance there exists little data that can correlate the damaged state of crops to the detention period and velocity of specific floods. Thus it is very difficult to precisely gauge expected damage to the agricultural sector and other sector assets. This lack of historical records and damage data is seen throughout most other sectors as well.

- The depth-damage (DD) ratio is used to carry out the VRA in Lao PDR because there are no fragility functions available for the country.

- Frequent floods have a high damage impact on physical infrastructure and agriculture in Lao PDR. The scope of this project addresses flood VRA and includes important sectors like agriculture, housing, education and health. Due to the limitation of available data for a precise VRA, the following issues must be considered when developing the methodology for a VRA.

- The flood VRA has been carried out for various categories of buildings. Only the direct damage to buildings has been considered, for example, structural damage. Intangible impacts such as the loss of household items, functional losses, and loss of livelihood, rental income and the cost of relocation are not considered in a VRA.

- In the education and health sectors, only buildings are considered for physical VRA. Based on field information and expert judgment, only the permanent buildings are considered for schools and hospital buildings.

- In order to define the vulnerability factors for the aforementioned sectors, there is a need to develop the DD curve based on conditions in the field. There is no literature review available, however, on the DD curve for Lao PDR to determine the performance of various building structures. Previous DD curve models must be modified to suit conditions in Lao PDR. For this study, the DD curve has been appropriately modified. The approach for modification will be discussed in the next paragraph.

The methodology for VRA is as follows:

- **Collection of Data:** The flood VRA requires flood hazard mapping for various return periods, a database on housing, characteristics of housing types, past data on housing damage due to floods, an EA for housing due to specific flood return periods, a cropping calendar and characteristics of crops at varying stages of growth. This data must be then be correlated with the flood water depth.

- **Flood exposure of Buildings and Agriculture:** The flood EA of buildings and agriculture is carried out using GIS tools. The housing, education and health sectors EA determine the number of buildings located in different depths of flood water within the study area.

- **Establishing the DD Ratio:** There are methodologies established by flood experts and hydrologists based on DD ratios. Dushmantha et.al. (2003), Smith et.al. (1993), Kang et.al. (2005), and Edward et.al. (1988) have developed a damage depth ratio/ curve for floods suitable to diverse urban environments. These methods, however, are developed for site specific conditions and cannot be applied on a large regional or country-wide scale. Within the scope of this project, HAZards United States (HAZUS) GIS software by the Federal Emergency Management Agency (FEMA) has guidelines for flood damage estimation which could be more appropriately applied. The HAZUS guidelines utilize the DD curve developed by the United States Army Corps of Engineers (USACE) and the USACE Institute for Water Resources. In a VRA HAZUS considers ten classes of buildings. The most commonly seen type of building for this project is a single story building with no basement. The graph used for the DD ratio for such a building has been used as the base VRA curve. Since the graph is largely based on US based data, the DD curve must be corrected to suit Lao PDR's conditions. The graph has been corrected and modified based on expert opinion and HAZUS-based DD curves. The modification of the DD is based on the past performance of buildings during floods. The characteristics and performance of each type of building in floods has been considered when finalizing the DD ratio curve.

- **Calibration of Flood Vulnerability Grade:** The VRA results in the identification of a number of houses prone to various grades of damage. The grades are classified as low, moderate, high and very high. There are several ways by which the damage ratio can be correlated with the damage grade. HAZUS has defined the depth damage ratio as:

  Slight 1-10 percent DD ratio

  Moderate 11-50 percent DD ratio

  Significant >= 50 percent DD ratio

  The vulnerability grades are modified as per the country's situation. In Lao PDR, the proposed grades are as below:

  D1 Slight 1-15 percent

  D2 Moderate 15–35 percent

  D3 High 36-60 percent

  D4 Very High >=61 percent

Vulnerability Assessment (VA) Matrix

The VA matrix presents the distribution of building classes with respect to varying damage grades. The assessment provides a matrix of the vulnerability profile of housing stock and other sectors. The format of the VA is as below:

Table 3.1 Vulnerability Assessment

No	Type of Building / Infrastructure	Number of Houses	Level of Damage	Remarks
1	Permanent		D1 D2 D3 D4	
2	Semi-Permanent		D1 D2 D3 D4	
3	Temporary		D1 D2 D3 D4	
4	Others		D1 D2 D3 D4	

- For the eight river basins, the VA has been carried out for agriculture, housing, education and health sectors which are expected to be affected by flood in one of eight river basins (Nam Ou, Nam Ngum, Nam Ngiap, Nam Xan, Sebangfai, Sebanghiang, Xe Don and Xe Kong). In the case of housing, education and health sectors, the VRA quantifies the number of buildings falling in all defined four damage levels. These damage levels are Minor (D1), Moderate (D2), Partial Collapse (D3) and Complete Collapse (D4). The VRA is carried out for all building stock at the provincial level. The profile and distribution of damage levels are tabulated for 100-year return periods.

3.2.1 HEALTH SECTOR

The VA has been carried out for health sector buildings including health centers and hospitals. Figure 3.39 show the distribution of the health sector at flood risk of 100-return period. For this study, all the schools buildings have been determined as brick/ RCC type, hence the vulnerability assessment has been done based on the damage level of Brick/ RCC building type.

- For the eight river basins, about 26 hospitals/ health centers are estimated to be exposed to flooding. 12 of the exposed hospitals/ health centers are estimated to fall into the D3 damage level. These hospitals/ health centers are located in Attapeu, Khamouanne, Luang Prabang, Phongsaly, Savannakhet and Vientianne province. The detailed distribution of damage level for these types of hospital/ health centers in each province is presented in Appendix I, Table 9.

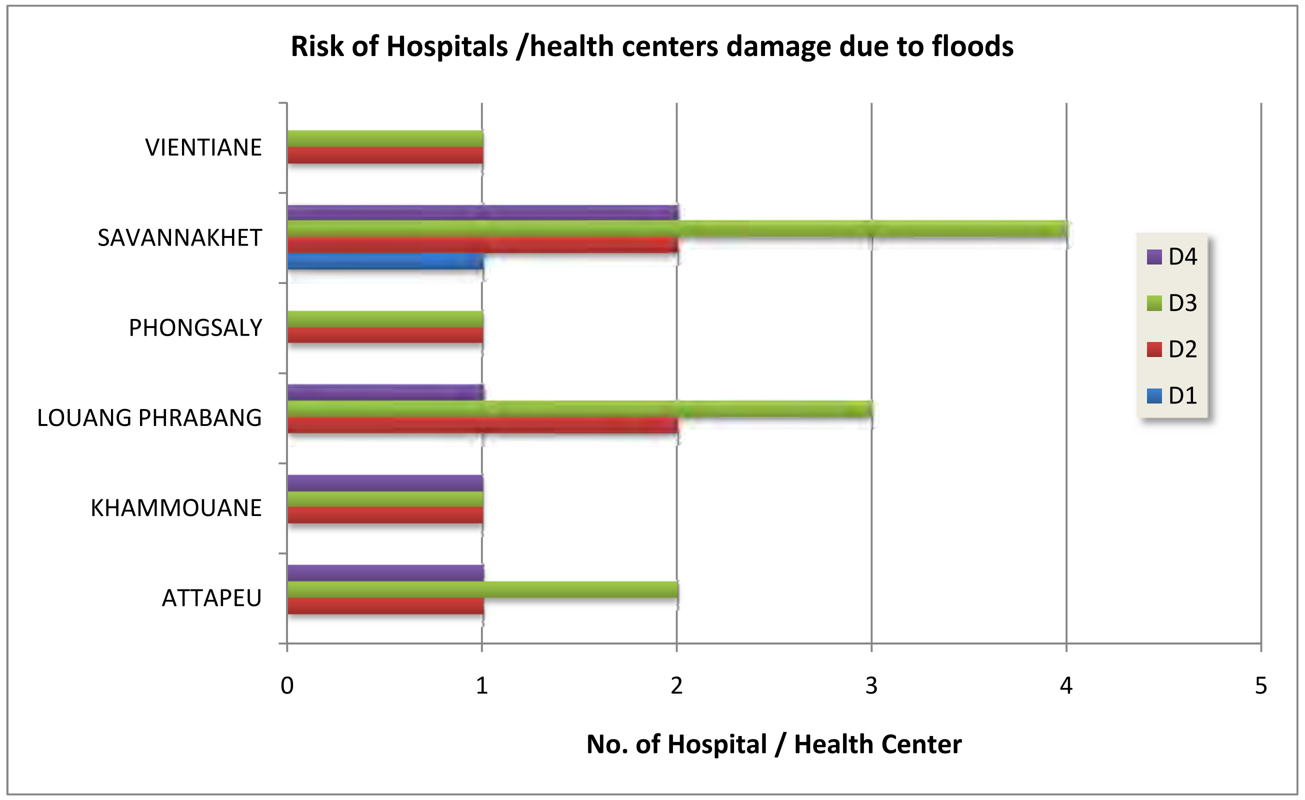


Figure 3.11 Risk of Hospitals/ Health Centers Damaged Due to Floods

3.2.2 HOUSING SECTOR

- Figure 3.12 shows the distribution of number of houses (bamboo and others) with regard to different damage levels for each province. Most of these types of building are estimated to fall into the D4 level (67.98%).The biggest number of these houses is located in Savannakhet province. The detailed distribution of damage level for these types of houses in each province is presented in Appendix I, Table 10.

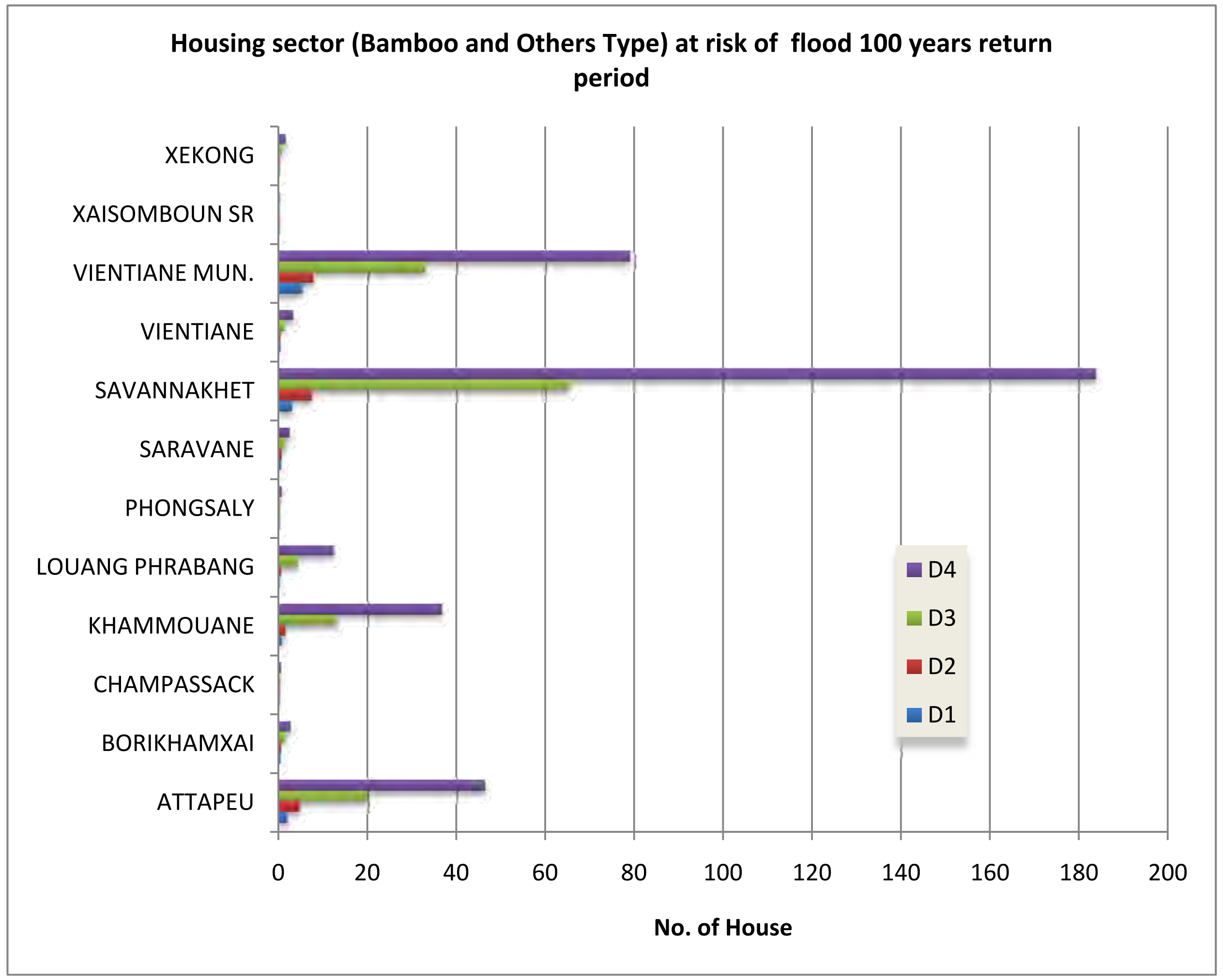


Figure 3.12 Housing Sector (Bamboo and Others) at Risk of Flood for 100-year Return Period

- Figure 3.13 shows the distribution of number of houses (brick/ RCC and wooden) with regard to different damage levels for each province which are expected to be affected by a 100-year return period of flooding. The biggest percentage of these type of building damage estimated falls into the D3 level (43.90%), with most of these houses located in Savannakhet province. The detailed distribution of damage level for these types of houses in each province is presented in Appendix I, Table 11.

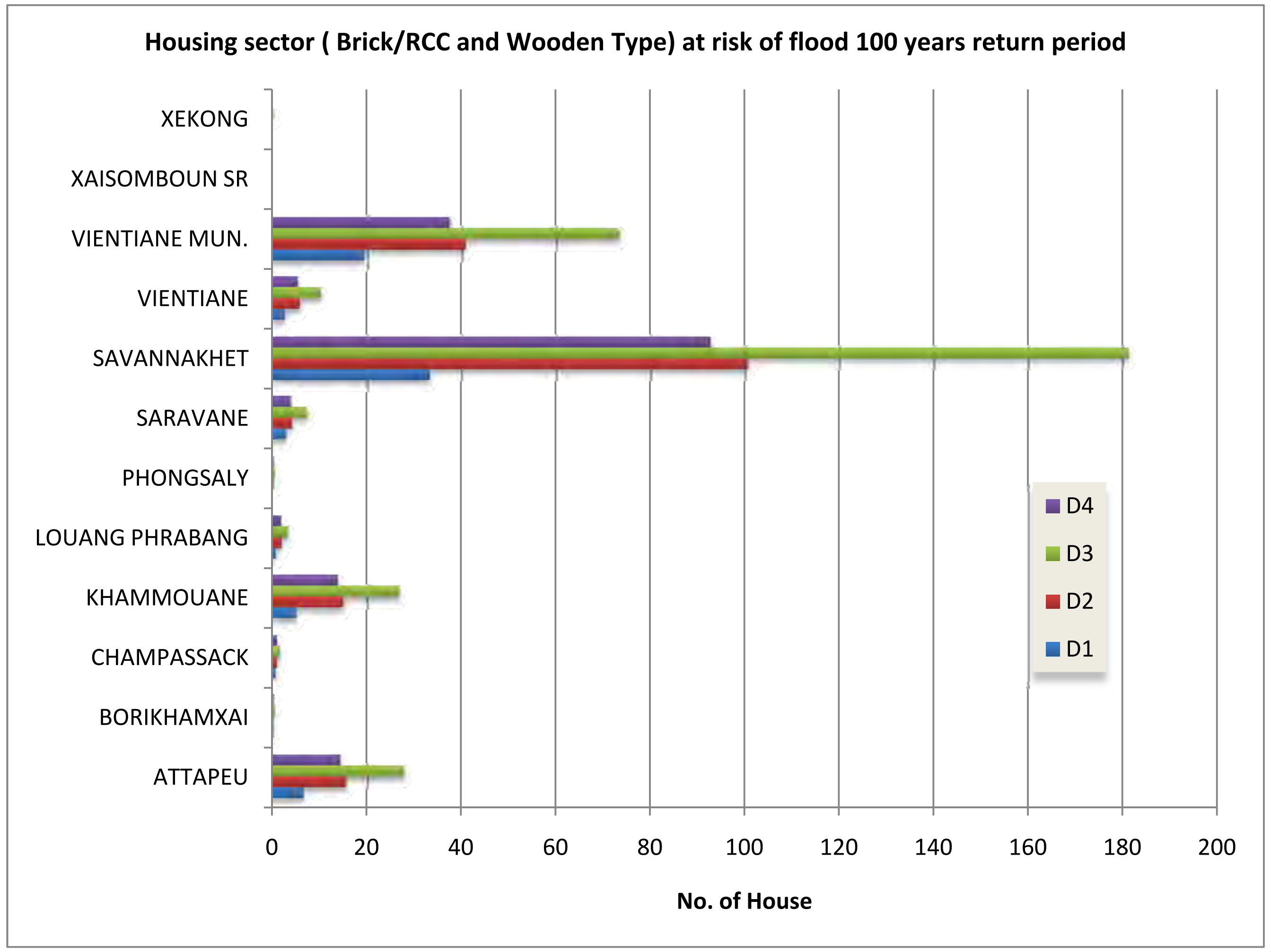


Figure 3.13 Housing Sector (Brick/ RCC and Wooden) at Risk of Flood of 100-year Return Period

3.2.3 EDUCATION SECTOR

Figure 3.14 shows the distribution of school buildings at flood risk on the provincial scale. For this study, all the school buildings have been determined as brick/ RCC, hence the VA has been done based on the damage grade of Brick/ RCC building type.

- On the national scale, the number of school buildings exposed to a 100-year return period of flooding is 250. Most of these types of school building damage falls under the D3 level (44.00%) with the biggest number of school buidlings located in Savannakhet province (44 schools). About 24.80% of these type of school building are estimated to fall under the D2 damage level, followed by D4 (22.40%) and D1 (8.40 %). The detailed distribution of damage level for school buildings in each province is presented in Appendix I, Table 12.

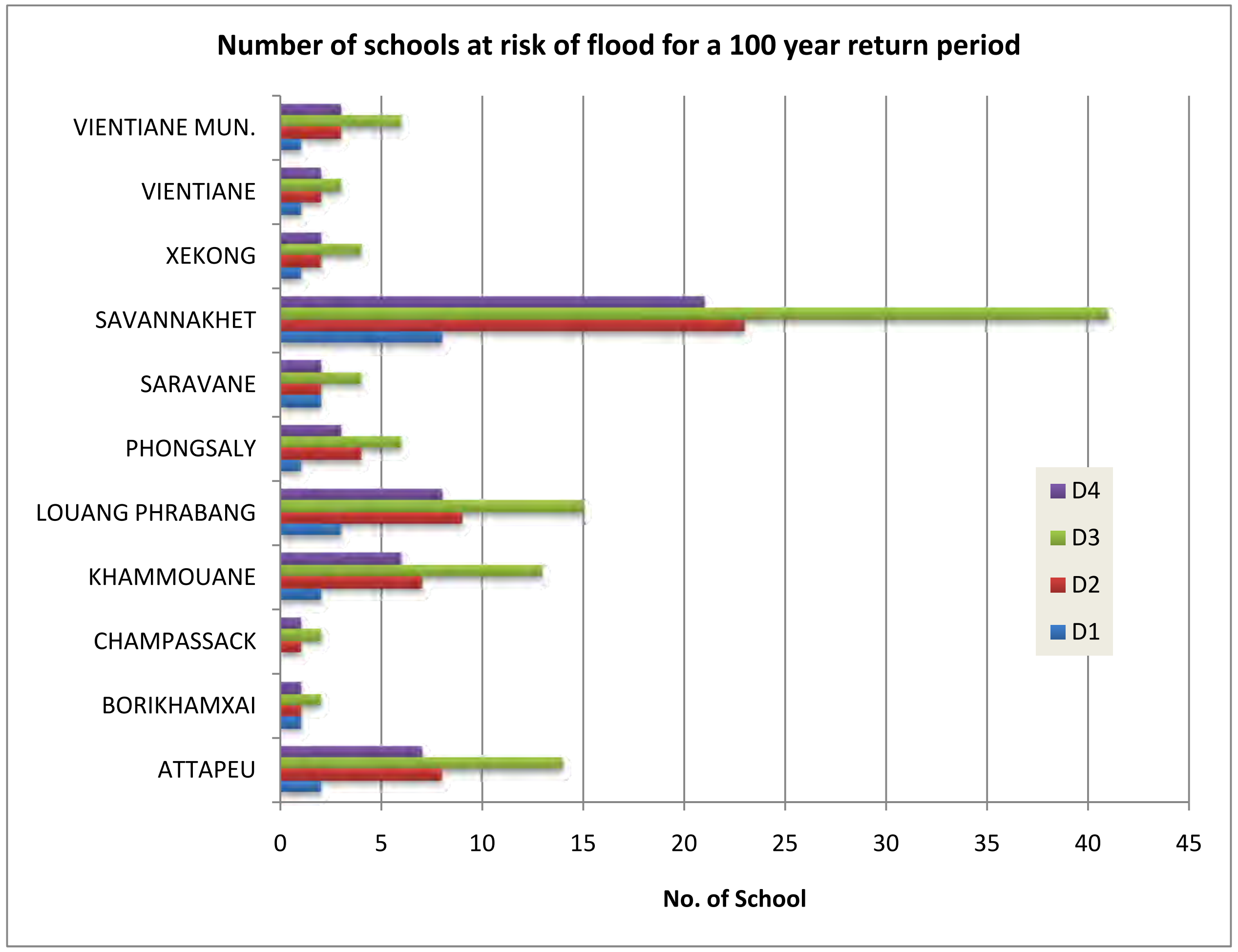


Figure 3.14 Number of Schools at Risk of Floods with a 100-year Return Period

3.2.4 AGRICULTURE SECTOR

Both extreme and regular floods typically occur during the monsoon season. Paddy is the most prominent crop cultivated during this season and this study has therefore carried out VRAs for paddy crops under the agriculture sector.

Exposure of Inundated Paddy Areas

The number of affected inundated areas in Lao PDR provinces affected by flooding in various return periods is estimated based on secondary data. The paddy areas in particular provinces were obtained from the land use maps provided by Department of Geography, Lao PDR. The inundated paddy crop area was estimated based on the size of the paddy area in each provinces and those areas that become inundated during floods (Table 3.2).

Table 3.2 Inundated Areas in Affected Provinces

Province Name	Paddy cultivation under Flooded area (sq km)				
	< 0.30	0.30-1.00	1.01-2.00	>2.00	Total
ATTAPEU	3.78	8.71	11.77	61.30	85.57
BORIKHAMXAI	1.14	1.43	2.22	6.22	11.00
CHAMPASSACK	10.13	9.31	7.15	16.43	43.03
KHAMMOUANE	2.36	8.60	12.24	174.89	198.09
LOUANG PHRABANG	0.16	0.40	0.55	7.49	8.59
SARAVANE	27.00	23.85	18.34	47.13	116.32
SAVANNAKHET	4.54	18.99	25.20	396.93	445.66
VIENTIANE	10.82	11.08	10.74	61.06	93.69
VIENTIANE MUN.	21.93	22.95	21.89	114.15	180.92
XAISOMBOUN SR	0.06	0.05	0.04	0.19	0.34
XEKONG	0.00	0.00	0.00	0.00	0.00

- **Vulnerability of Paddy Crops Due to Floods**

The effect of floods on paddy crops was determined through a literature review and expert consultations. The analysis of these effects was conducted by considering inundation of the paddy crop through a two-prong approach. The first aspect of this approach was to consider the number of days of submergence. The second aspect was to consider the stage of growth of the crop at the time of submergence. The survival rates of crop varied with the number of days of submergence and the stage of crop as presented in Figure 3.15.

Table 3.3 Percentage of Paddy Crops that Survive after Being Submerged

Percentage Survival of Paddy Crops When the Crops are Submerged					
Stage of growth	Number of days of inundation (submergence)				
	4	8	12	16	20
Plantation stage	88	79	55	45	0
Booting stage	83	60	40	12	0
Heading and flowering stage	86	71	35	0	0
Ripening stage	90	70	25	0	0

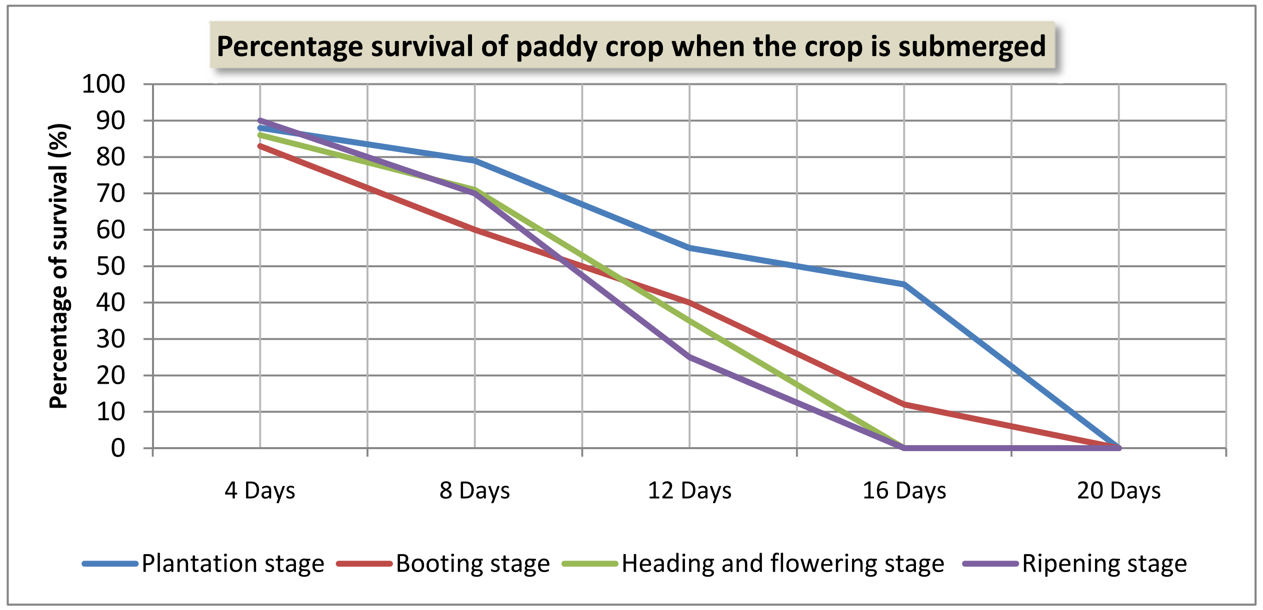


Figure 3.15 Percentage of Paddy Crops that Survive after Being Submerged

- **Estimated Production Loss Due to Flooding**

Based on the percentage of the paddy area affected by flooding, coefficients for the percentage lost due in paddy crop areas at various stages of growth and potential loss are estimated as presented in Table 3.4 and Figure 3.16. The detailed production loss for each province at different stages of growth may be referred to in Appendix I, Table 13.

Table 3.4 Estimated Production Loss (%) Due to Floods of 100-years Return Period

Stage of growth	Number of days of inundation (submergence)				
	4	8	12	16	20
plantation	12	21	45	55	100
booting	17	40	60	88	100
head and flowering	14	29	65	100	100
ripening	10	30	75	100	100

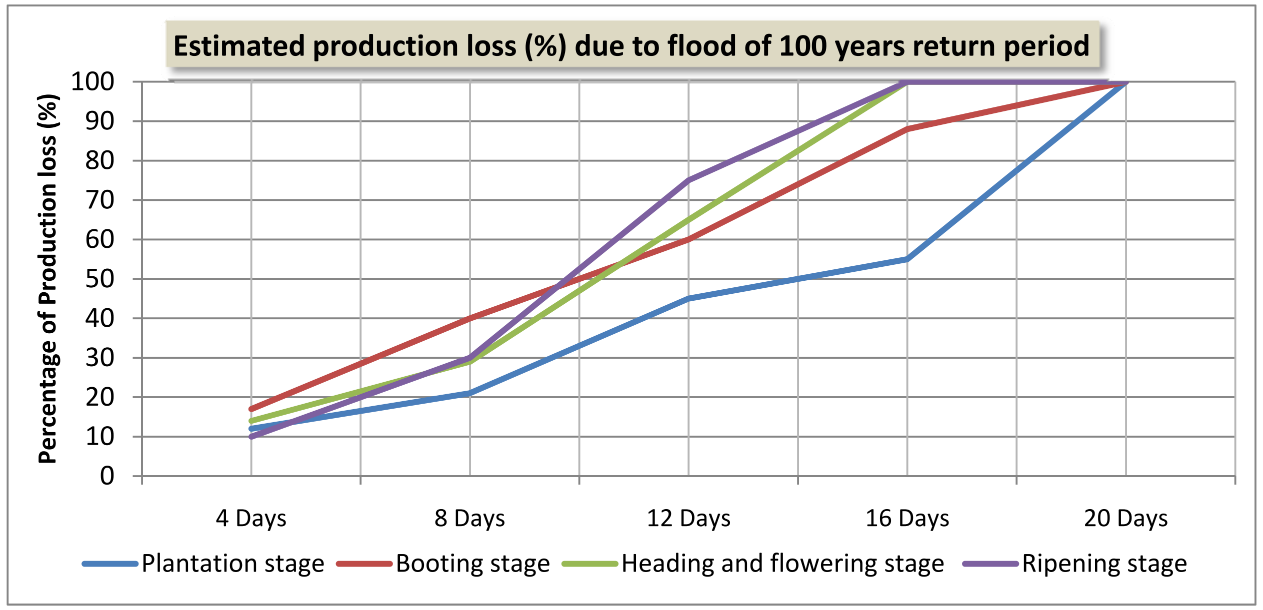


Figure 3.16 Estimated Production Loss (%) Due to Floods of 100-year Return Periods

3.3 CONCLUDING REMARKS

- EVRA has been carried out for the eight river basins suggested by the national advisory committee. These river basins are the most prone to floods annually. There is, however, a need to carry out flood EVRAs for the other river basins as well. It is suggested that focal flood mitigation departments such as the WREA, the Irrigation Department and the Department of Meteorology and Hydrology be trained to conduct flood risk management for the remaining major river basins. In light of the restricted time and field data available, Hydraulic Engineering Centers River Analysis System (HECRAS) software has been used for flood hazard assessments. It is very important to carry out detailed flood EVRAs using more detailed and scientific models.
- At present very little research and technical data is available for VRA. The literature review reveals that there is a lack of data and well-established coefficients available for flood VRA for various sectors. Research and technical groups should develop DD curves and vulnerability functions for various sectors, including infrastructure and agriculture.
- The outcome of flood VRA should increase awareness of all responsible stakeholders involved in the flood VRA. A short-term orientation course should be organized by focal disaster management departments for all associated stakeholders to increase their understanding in VRA outcomes and flood risk reduction planning.

4 STORM EXPOSURE, VULNERABILITY AND RISK ASSESSMENT

4.1 EXPOSURE ASSESSMENT

4.1.1 INTRODUCTION

Many storms (typhoons) are reported in Lao PDR in the past. Significant typhoons were Xangsane (2006), Lekima (2007) and the most recent one Ketsana (2009) which hit the southern part of Lao PDR on 29 September 2009. The storm brought heavy rains and strong winds, causing heavy flooding in the provinces of Xekong, Attepeu, Savannakhet, Champassak and Saravan. Houses, crops, roads and other infrastructure were severely damaged by the rains. Despite this, not much data or many reports are available for storm events. The analysis reveals that storms developing in the South China Sea die out in the western part of Vietnam. The eastern hilly terrain of Lao is a natural barrier to wind hazards, thus protecting the easternmost provinces from typhoons. Low depressions do result in heavy rain which can cause flooding in some of the affected provinces.

Chapter 3.7, Part 1, discusses storm hazard assessments. Storm track maps and their return periods are developed on World Meteorological Organization (WMO) scale which is adopted from the Saffir-Simpson Hurricane Scale. The storm track and return period maps have been prepared for 10-year, 20-year, 30-year and 50-year return periods. Identification and analysis of elements exposed to storm hazards, including human lives (population), housing, hydropower, education and health infrastructure has only been done for the most damaging storms (50-year return periods) at the national level. EVRA of infrastructure and population is presented in the following sections.

4.1.2 METHODOLOGY FOR STORM EXPOSURE ASSESSMENT

Data Collection: Data relating to the primary sector is collected from a number of reliable sources. The data is structured in GIS format and is created for the provincial level.

GIS has been applied to identify and analyze elements exposed to storm hazards. Chapter 1 discusses the hazard maps whilst considering the different severity of the hazard. GIS tools facilitate overlaying susceptibility/ hazard maps within the identified sectors. The overlapping areas of the hazard maps and sectoral data allow for the identification of different elements at risk. This report quantified the number of houses, their classes, and the number of population, schools, health posts, and infrastructure falling in the storm hazard-prone areas. The methodology for storm exposure assessment may be referred to Figure 4.1

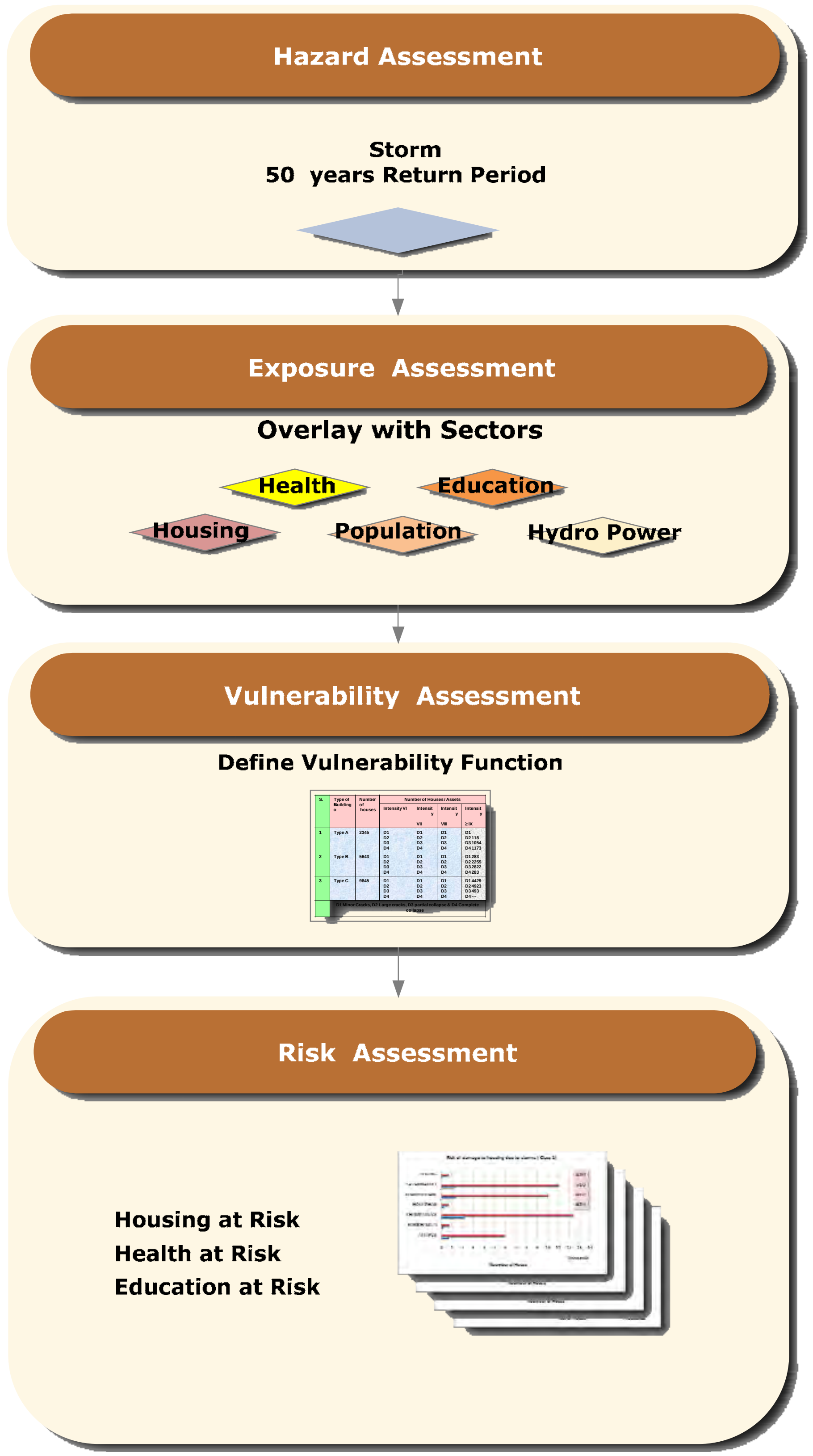


Figure 4.1 Methodology of Storm EVRA

4.1.3 ELEMENTS AT RISK AND EXPOSURE ASSESSMENT

4.1.3.1 POPULATION

- Figure 4.2 shows the distribution of population exposed to storm hazards (50-year return period). Analysis reveals 67.960% of the total population exposed to tropical storms (63-117 km/h), followed by 28.45% of tropical depressions (0-62 km/h), 3.53 % of class I (119-153km/h) and 0.06% of class II (154-177 km/h) which are located in Khammuanne.
- Figure 4.3 presents the distribution of working age population (age under 15 and below 64 years) exposed to storm hazards. About 67.61 % of working age population are exposed to tropical storms, followed by tropical depressions (28.83%), class I (3.50%) and class II (0.06%).
- Similarly at national level, analysis reveals that 68.38% of dependent age population (age under 15 and above 64 years) are exposed to tropical storms. About 1503 people in this age group, located in Khammuane are exposed to class II storms (Figure 4.4).

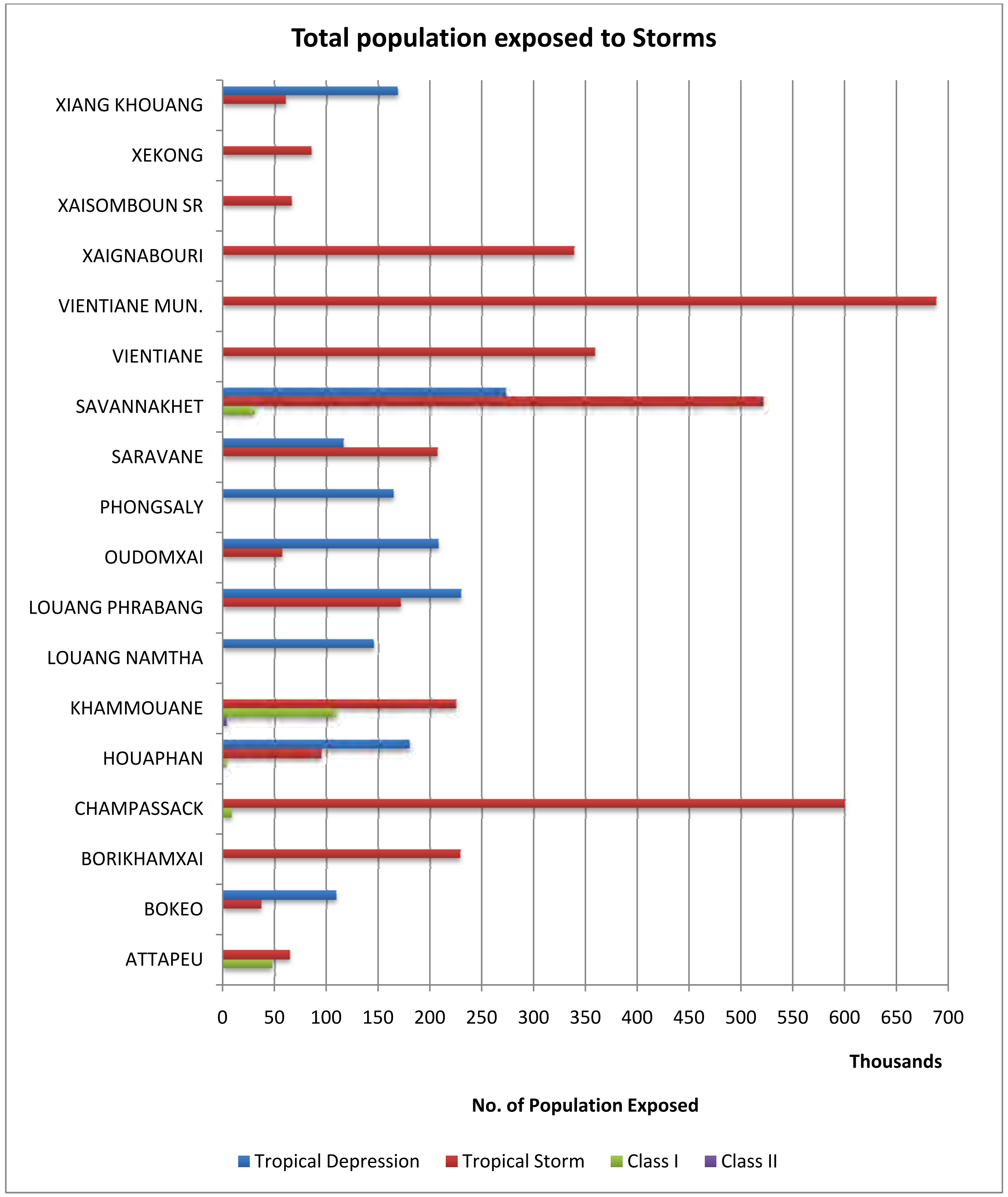


Figure 4.2 Total Population Exposed to Storms

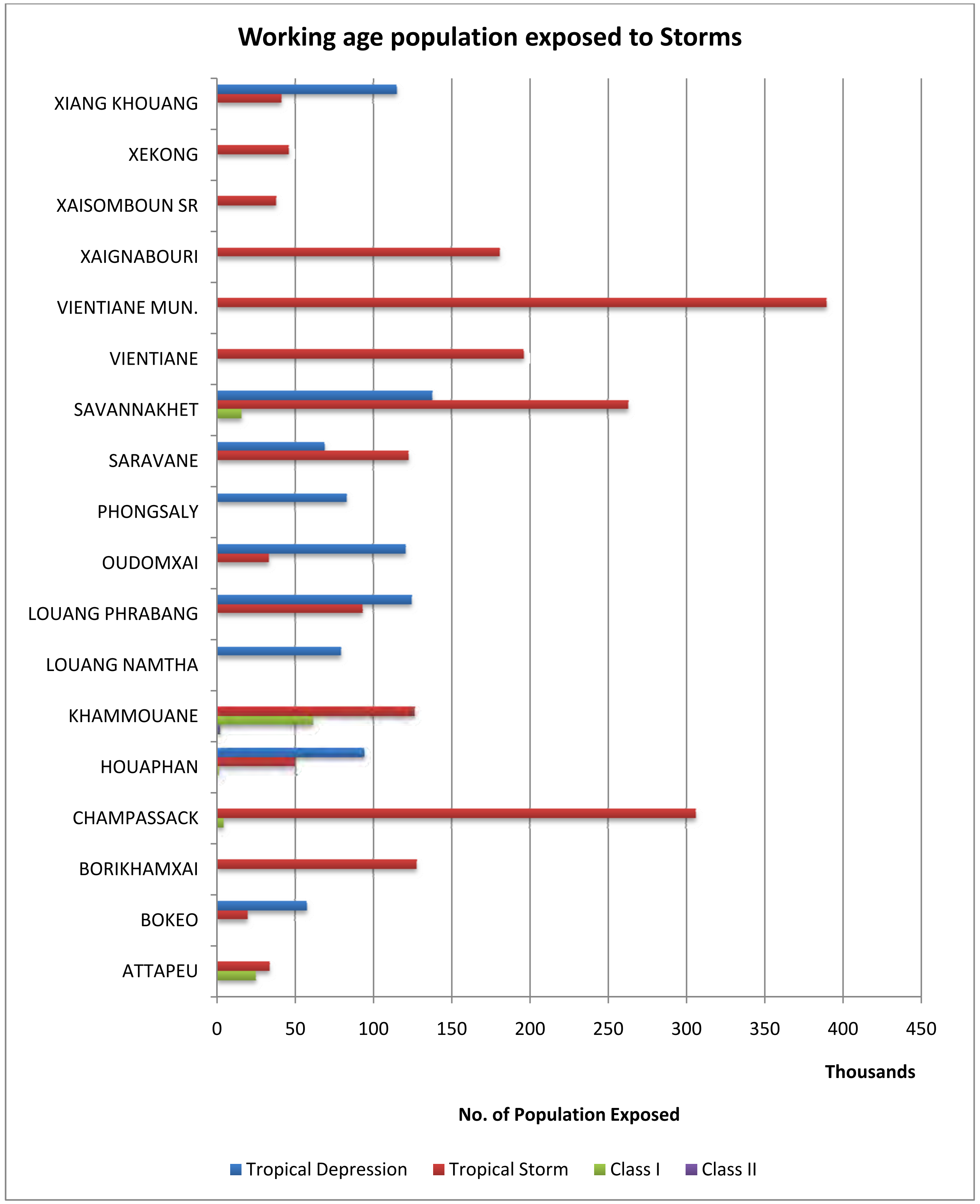


Figure 4.3 Working Age Population Exposed to Storms

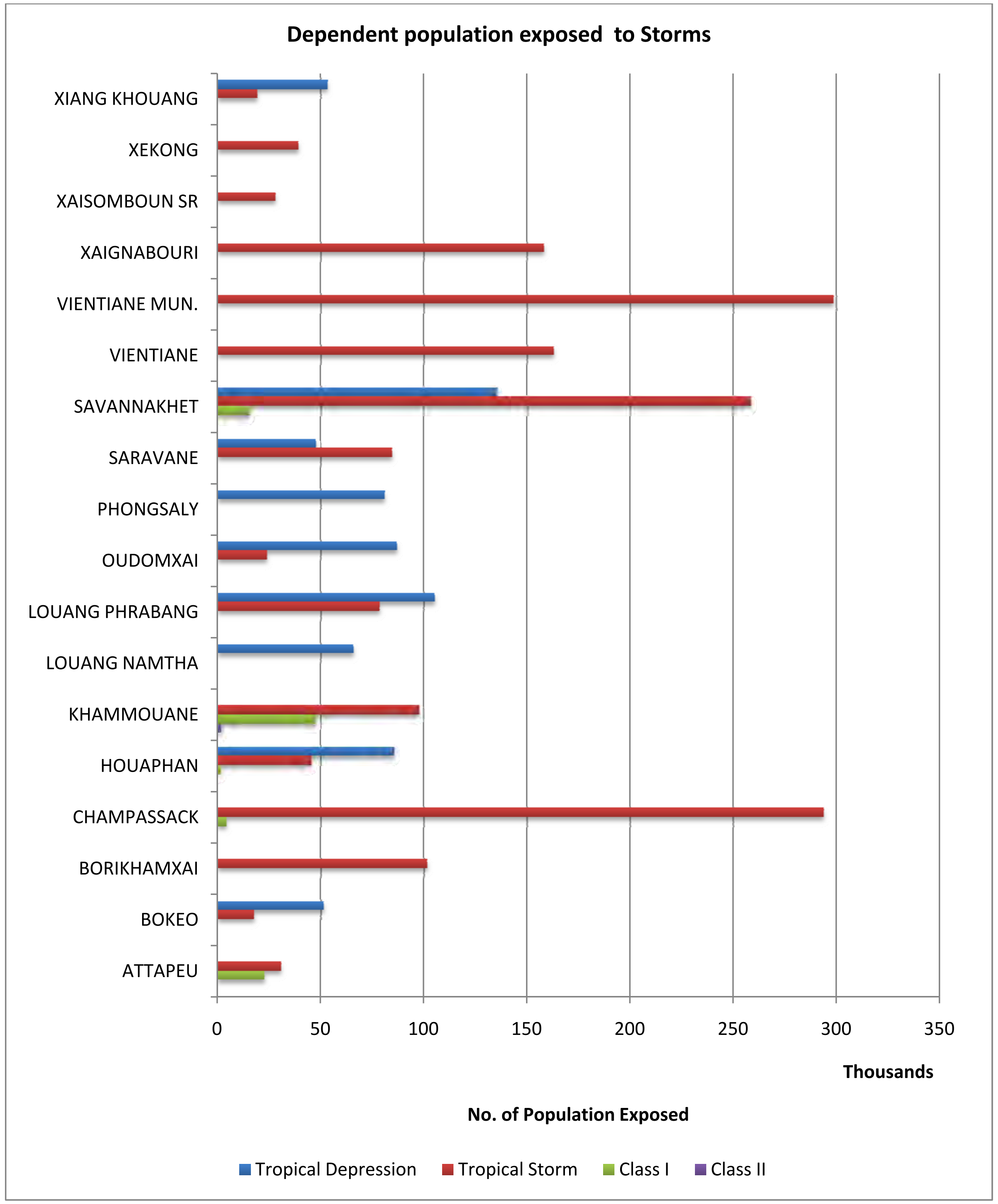


Figure 4.4 Dependent Population Exposed to Storms

4.1.3.2 HEALTH SECTOR

The health sector exposed to storm hazards (50-year return period) is analyzed at the national level. 811 hospitals/ health centers are exposed to storm hazards ranging from tropical depression up to class II (most damaging). Figure 4.5 presents the distribution of hospitals/ health centers at provincial level. Analysis reveals that there is 1 hospital/ health center located in Khammuanne province are exposed to class II storm hazards. 42 of hospitals/ health centers exposed to class I storm hazards are located in Khammuanne, Attapeau, Champassack, Savannakhet, and Champassack.

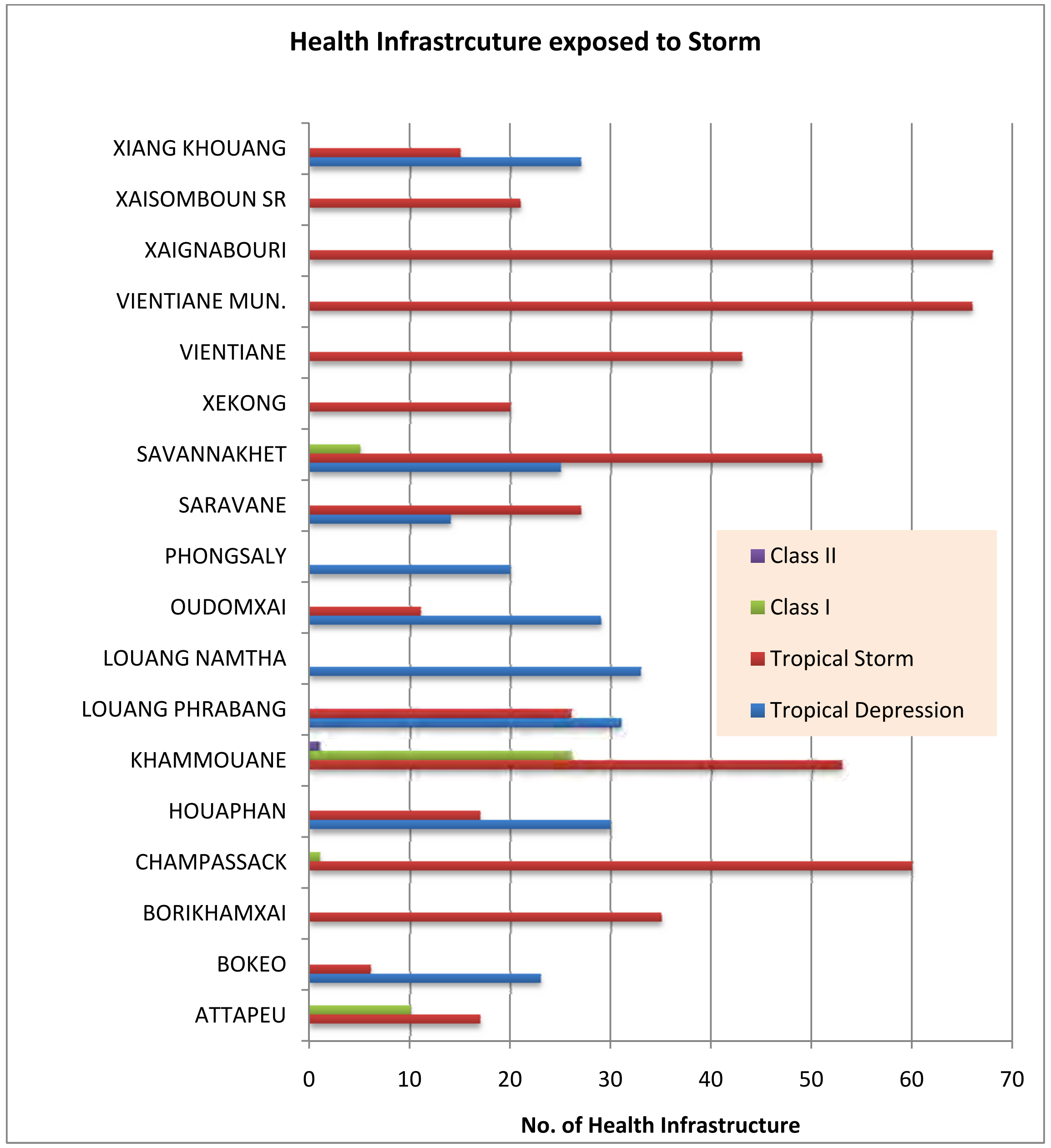


Figure 4.5 Health Infrastructure Exposed to Storms

4.1.3.3 HOUSING SECTOR

An EA for the housing sector was carried out at the national level. Figure 4.6 to Figure 4.9 show the distribution of housing (by wall-type) exposed to different categories of storm hazards based on the wind speed (km/h).

- Figure 4.6 presents the distribution of bamboo housing exposed to storm hazards . It is observed that out of the 535,988 bamboo houses, 0.81% (4,356 houses) of houses fall in storm zone class II, which are located in Khammuane.
- Figure 4.7 shows the distribution of brick/ RCC housing. The figure shows that 47,999 houses are exposed to storm ranging from tropical depression, tropical storm and storm of class I. Out of these houses, 9 houses are exposed to storm of class I which are located in Attapeau province.
- Figure 4.8 depicts the distribution of wooden houses. The analysis reveals that 338,550 houses are exposed to storm hazards with 145 of these houses located in the storm hazard zone with wind speed 154-177 km/h (class II). These 145 houses are located in Khamuanne province.
- Figure 4.9 shows the distribution of other houses exposed to storm hazards. Out of the 15,497 other houses, 1064 are exposed to storm class I, which are located in Khammuane (915 houses) and Attapeu (148 houses) province.

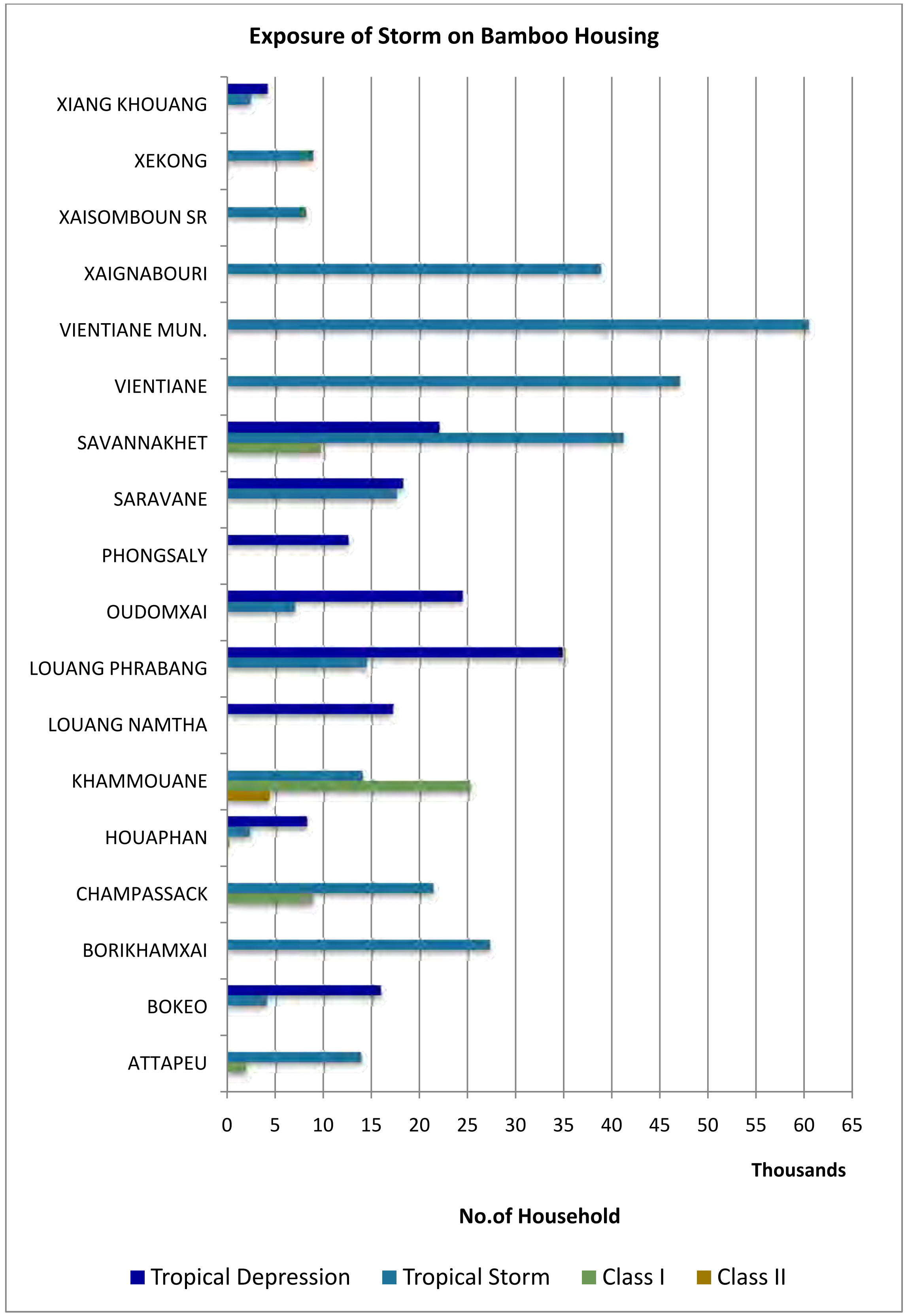


Figure 4.6 Exposure of Storm on Bamboo Housing

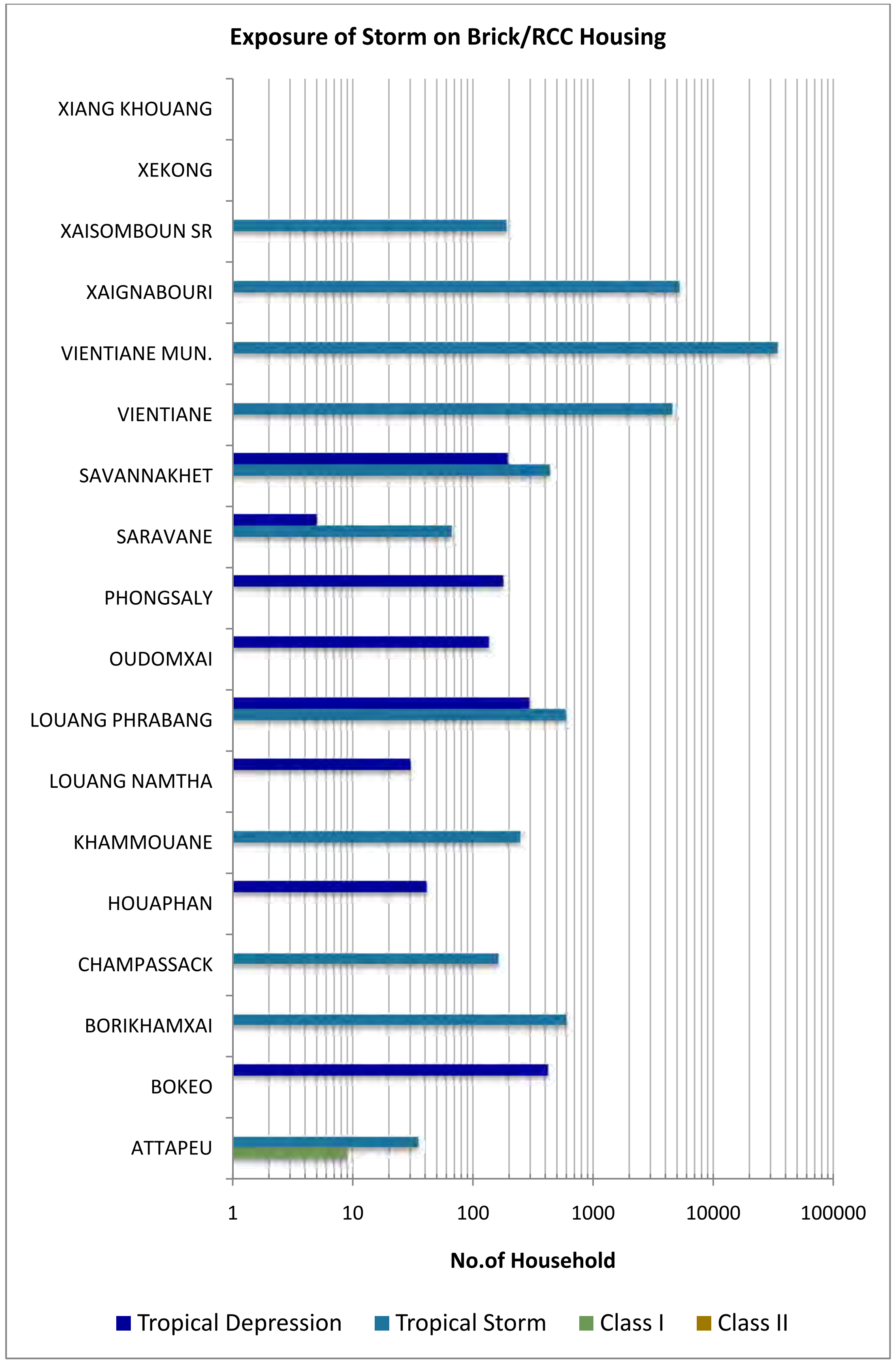


Figure 4.7 Exposure of Storm on Brick/ RCC Housing

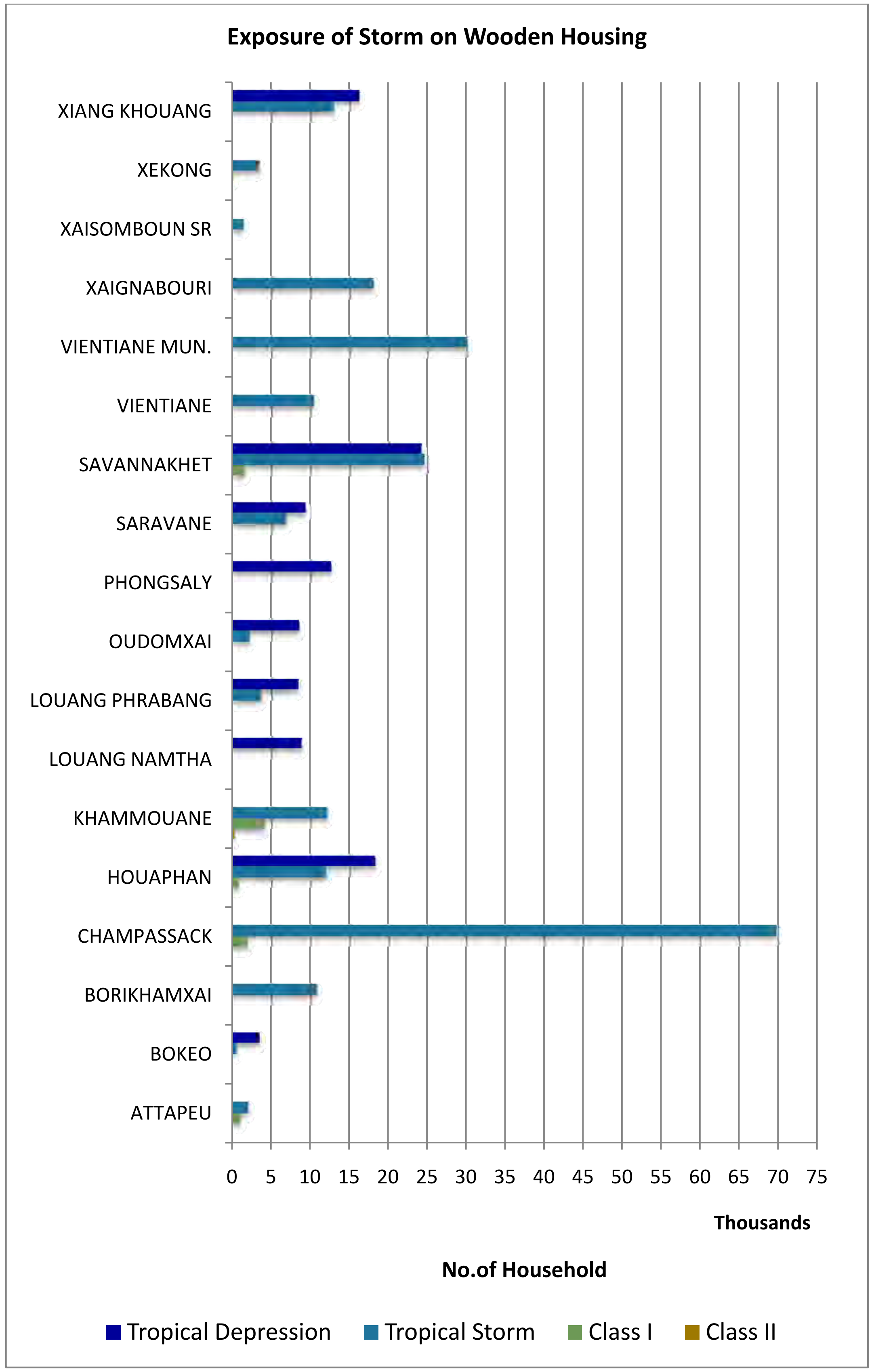


Figure 4.8 Exposure of Storm on Wooden Housing

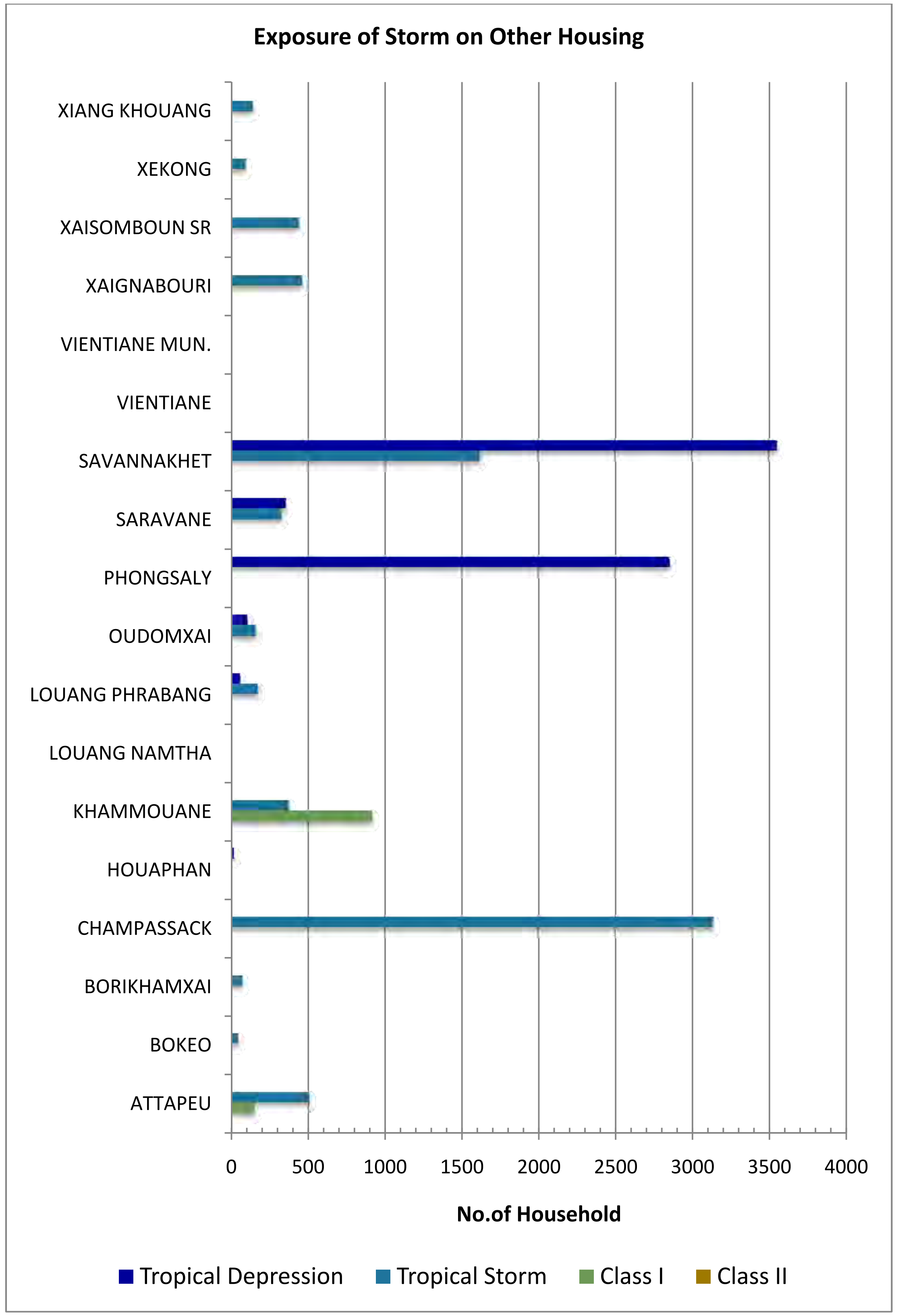


Figure 4.9 Exposure of Storm on Other Housing

4.1.3.4 EDUCATION SECTOR

Figure 4.10 illustrates the education institutions exposed to storm hazards in 18 provinces. Figure 4.10 provides further details on the exposure of school buildings.

- Figure 4.10 shows the number of schools exposed to storm hazards. There are 6545 schools exposed to different storm hazards with wind speeds ranging from 0-62 km/h (tropical depression) up to 154–177 km/h (Class II). Analysis shows that 4 schools are exposed to storm class II which are located in Khammuane provinces.
- 305 schools exposed to class I storm hazards are located Khammouane, Savannakhet, Attapeu, Champassack and Houaphan.
- Most of schools in country Lao PDR (about 6236 schools) are exposed to tropical depressions and tropical storms.

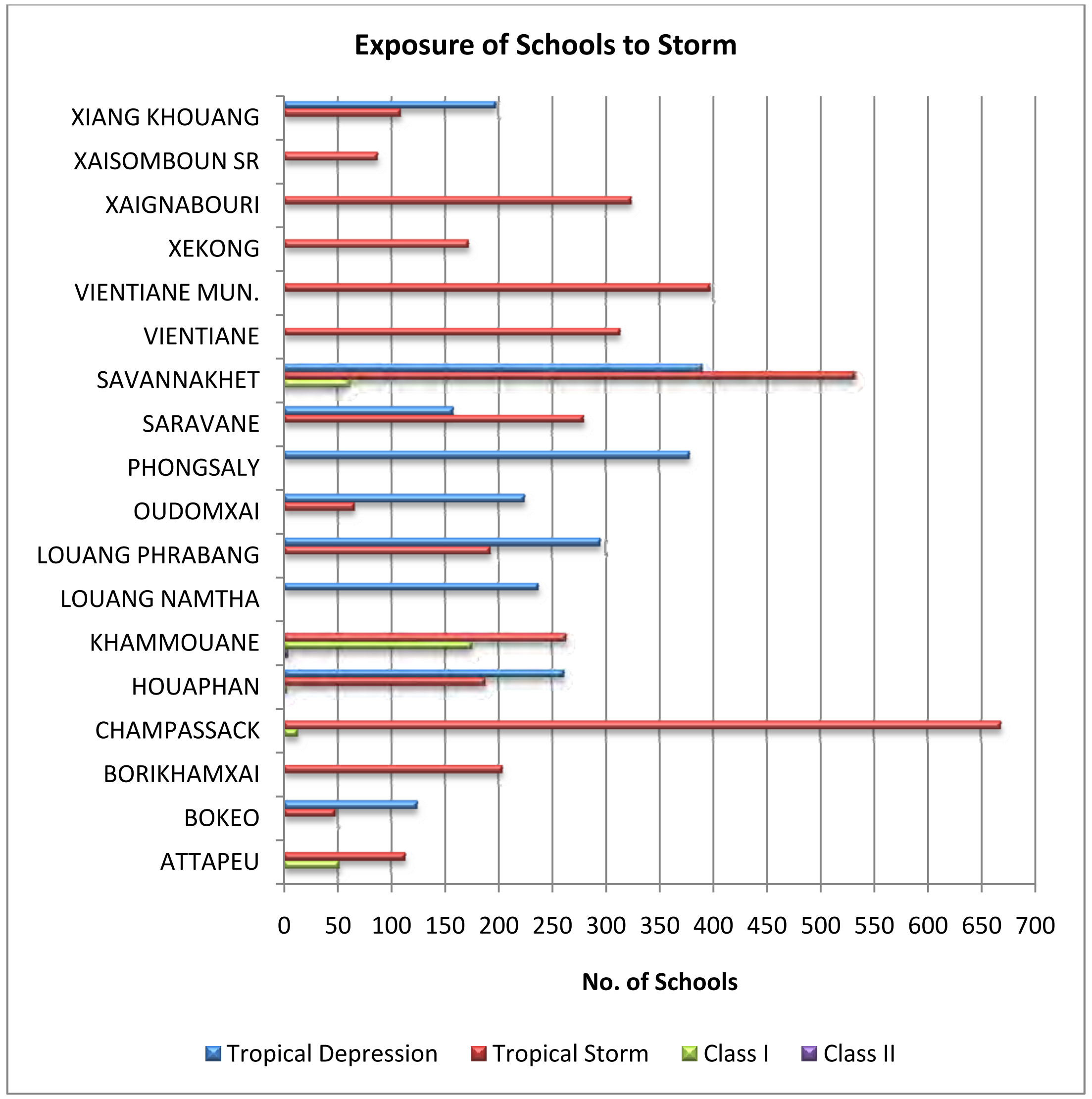


Figure 4.10 Exposure of Schools to Storms

4.1.3.5 HYDROPOWER SECTOR

There are 13 hydropower plants in the country of Lao PDR which are exposed to storm hazards. Eight of these plants are located in Borikhamxai, Champassack, Saravane and Viantiane province. The distribution of hydropower may referred to in Figure 4.11.

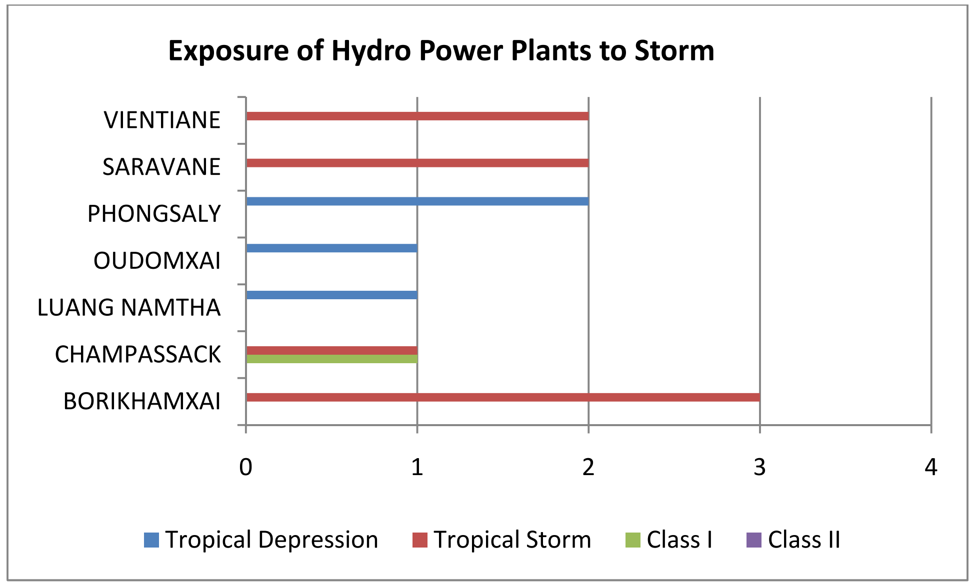


Figure 4.11 Exposure of Hydropower Plants to Storms

4.2 VULNERABILITY AND RISK ASSESSMENT

Storms have greatly impact on physical infrastructure including housing and agriculture. Typhoons impact the community by several means ranging from high torrential wind speed, heavy rain leading to floods, storm surges and flying debris. The VA emphasizes the identification of causative factors which affect the structures. This could include type of material used in building construction, type of roofing for housing, window/ door opening of buildings, location of buildings with respect to topological formation and nearness to coastal areas.

In the case of Lao PDR, typhoons/ storms approach from the South China Sea. These then cross Vietnam and the eastern hills, entering over the plains of Lao PDR. The impacts are largely due to wind forces, heavy precipitation and flooding. Due to obstruction caused by eastern hills and forest vegetation, however, wind speed slows down. Thus storm disaster impacts are reduced substantially.

In current analysis, under the project, the VA is carried out with following assumptions:

- The literature review reveals that there is no methodology available for storm VRAs for existing physical and social infrastructure. Some literature is available on the impacts of various past storms including Ketsana. These papers have focused more on the impacts than causative factors of these storm events. There is a need to develop VAs based on scientific and technical factors.
- The census has not clearly identified the different building types. Largely, residential buildings are classified as RCC/ brick, bamboo, grass, wooden and other types of light materials used for walls and roofs. The storm impacts are largely dependent on types of roofing: sloping or flat. The roof typology is not clear from the existing census database.
- The census categorizes the buildings as households. The household is directly related to families in general. The database, however, does not provide clear understanding on the number of houses. For estimation purposes, households are considered as number of houses with different types of building materials used.
- The buildings typology for schools and health sectors are not clear from the national geography department's database. Thus estimating the vulnerability and risk of such infrastructure buildings is difficult. For simplifying the estimation, it is assumed that all school and health-related infrastructure falls under the brick / RCC category. It is observed that such infrastructure is usually a permanent type of building.
- There are several sectors which need to be considered, however under the project, only housing, population, education and health are considered. There is a need for further detailed scientific studies to include other secondary sectors; to understand their strengths and weaknesses and propose vulnerability and risk functions.

There is several methodology proposed for storm VRAs. The most relevant to the study includes Y.L. Xu et al. (1997), Mark G. Stewart et al. (2002), Jean-Paul Pinelli et al. (2004), Carol J. Friedland (2009) and HAZUS.

Y.L. Xu et al. (1997) have proposed detailed studies on damage estimation of metal roof cladding subject to wind loading. The study analyzes the comparison of fatigue damage caused by the new fatigue loading currently used in Australia and Europe with respect to the design life of roofing sheets, wind return period, annual occurrence of cyclone, and others. The limit fatigue load-bearing capacity of roofing sheets is also obtained.

Mark G. Stewart et al. (2002) discusses risk analysis procedures developed to predict economic risks due to changes to existing housing vulnerability over time. The wind hazard and building vulnerability models are based on exposure of residential construction to cyclones in North Queensland, Australia, which emphasizes the effects of enhanced (post-1980) building standards in North Queensland.

Jean-Paul Pinelli et al. (2004) explains the development of a practical probabilistic model for the estimation of expected annual damage induced by hurricane winds on residential structures. The estimation of the damage is accomplished through establishing basic damage modes for building types and defining possible damage states, whose probabilities of occurrence are calculated as functions of wind speeds from Monte Carlo simulations. The paper describes the conceptual framework for the proposed model and illustrates its application for a specific building type with hypothetical probabilistic inputs. Actual probabilistic input must be based on laboratory studies, post-damage surveys, insurance claims data, engineering analyses and judgment and Monte Carlo simulation methods. The proposed components-based model is flexible and transparent.

Carol J. Friedland (2009) has developed modeling for residential building damage from hurricane storm surges. This has been developed from proto-type housing in the USA.

In view of housing typology in Lao PDR and project scope, it is essential to develop a simple methodology which could be understood and undertaken for further studies by development departments and agencies in the country. The Saffir-Simpson Hurricane Scale provides a clear profile of damage to buildings and other impacts such as flooding on varying hurricane severity. The Saffir Simpson Hurricane Scale, presented in Table 4.1, has been considered as a basis for VRAs with slight modifications. The revised VRA functions are presented in Table 4.2.

Table 4.1 Saffir Simpson Hurricane Scale ("The hurricane disaster-potential scale," 1974)

Category	Maximum Sustained Wind Speed Over Water (mph)	Central Pressure (mb)	Storm Surge (feet)	Probable Property Damage and Evacuation Recommendations	Peak Gust Speed Over Land1, z0=0.1 ft
1	74-95	>980	4-5	No significant damage to building structures. Damage primarily to unanchored mobile homes, shrubbery and trees. Some damage to poorly constructed signs. Some coastal road flooding and minor pier damage.	82-108
2	96-110	965-979	6-8	Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings.	108-130
3	111-130	945-964	9-12	Some structural damage to small residences and utility buildings with a minor amount of curtain wall failures. Damage to shrubbery and trees with foliage blown off trees and large trees blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane. Flooding near the coast destroys smaller structures with larger structures damaged by battering from floating debris. Terrain continuously lower than 5 ft above mean sea level may be flooded inland 8 miles (13 km) or more. Evacuation of low-lying residences with several blocks of the shoreline may be required.	130-156
4	131-155	920-944	13-18	More extensive curtain wall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 ft above sea level may be flooded requiring massive evacuation of residential areas as far inland as 6 miles (10 km).	156-191
5	>155	<920	>18	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be required.	>191

Table 4.2 Storm Vulnerability and Risk Assessment Coefficient

Grade of Storm	Type of building	D1	D2	D3	D4
Category I	Brick / RCC	5 %	-	-	-
	Wooden	5 %	5 %	-	-
	Bamboo & Others	5 %	50 %	-	-
Category II	Brick / RCC	50 %	5 %		
	Wooden	5 %	50 %	5 %	-
	Bamboo & Others	5 %	5 %	75 %	
Category III	Brick / RCC	5 %	50 %	5 %	
	Wooden	5 %	75 %	5 %	
	Bamboo & Others	5 %	5 %	5 %	75 %

4.2.1 HEALTH SECTOR

The VRA for elements at risk in the health sector exposed to storm hazards has been done at the national level. Since the structure of health buildings are not clear from the national database which was obtained from the Geography Department of Lao PDR, estimating the vulnerability and risk of such infrastructure buildings is difficult. For simplifying the estimation, it is assumed that health-related infrastructure falls under the brick/ RCC category of buildings. It is observed that such infrastructure is usually permanent.

A VRA for the health sector (hospitals/ health centers) has been done based on two storm scenarios: class I and class II with the damage levels referred to in Table 4.2.

Scenario 1: (Class 1, 119 – 153 km/h)

Figure 4.12 illustrates the distribution of health infrastructure expected to be damaged under storm hazard class I. There are five hospitals/ health centers that fall in the damage level of D1. These four health infrastructures are located in Khammuanne (2), Champassack (1), Attapeu province (1) and Savannakhet (1).

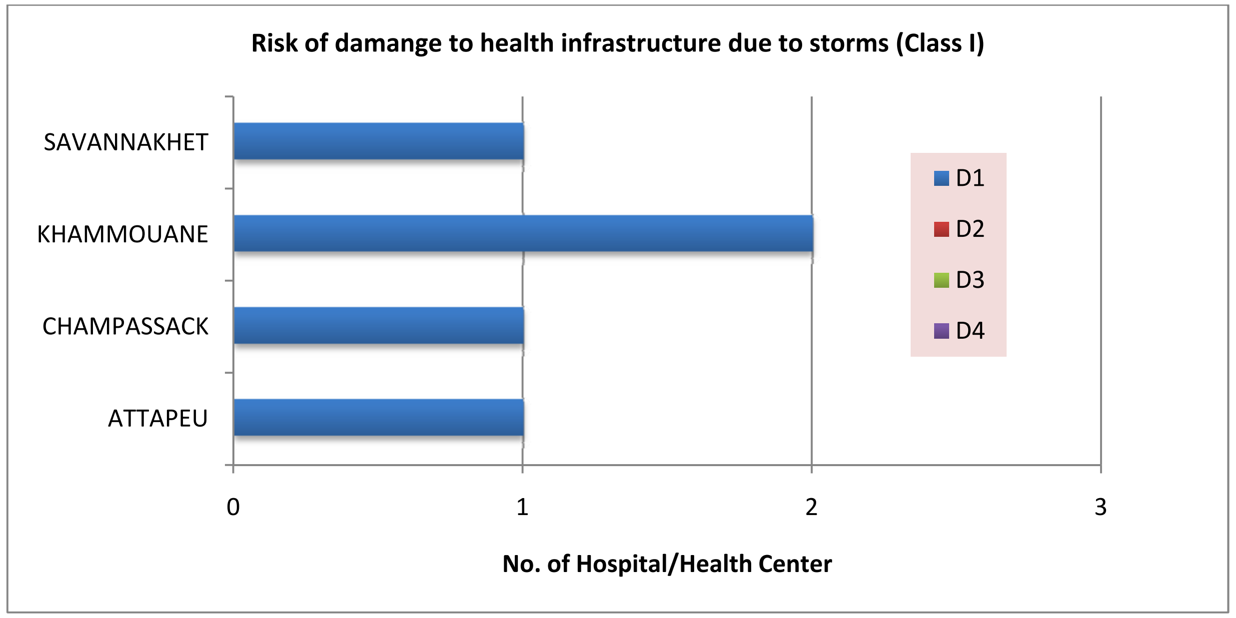


Figure 4.12 Risk of Damage to Health Infrastructure Due to Storms (Class I)

Scenario 2: (Class II, 154 – 177 km/h)

There is only one province estimated to be affected by storm class II, namely Khammuane province. There are two health centers in Khammuane province are expected to fall under the damage level of D1 (1) and D2 (1). Figure 4.13 illustrates the distribution of health infrastructure expected to be damaged under the scenario of storm hazard class II.

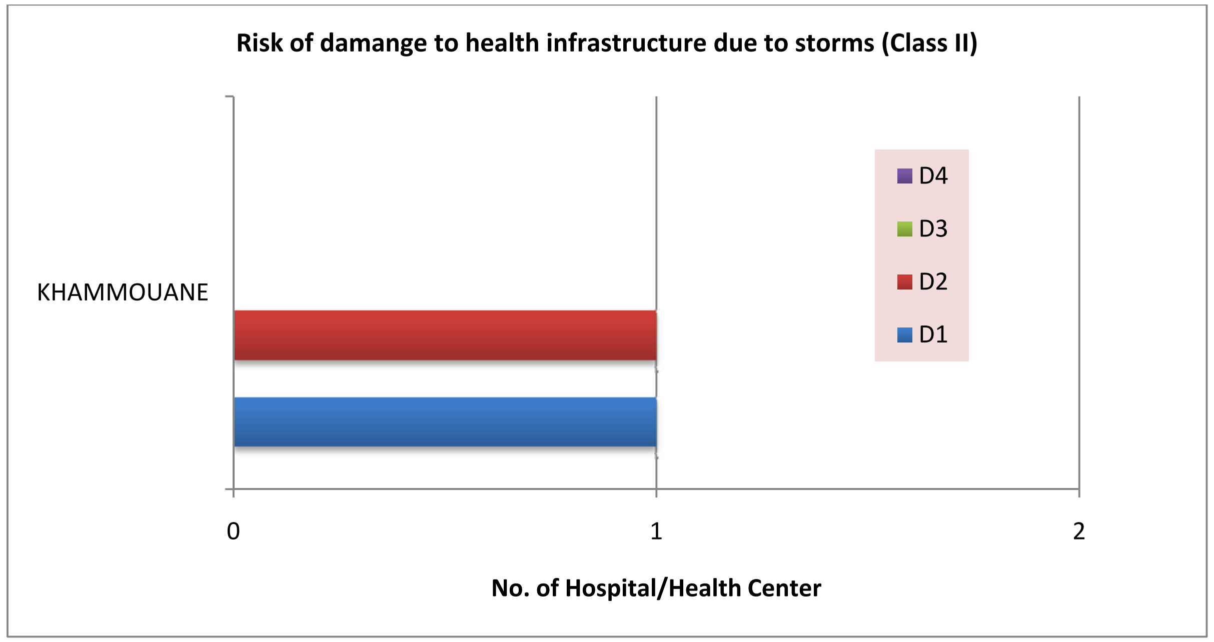


Figure 4.13 Risk of Damage to Health Infrastructure Due to Storms (Class II)

4.2.2 HOUSING SECTOR

As discussed in exposure section, there are four categories of house structures in Lao PDR which has been considered for this study. The VRA for the four types of housing structures has been done based on the storm vulnerability and risk coefficient as mentioned in Table 4.2.

For storm hazards, there are two scenarios which have been considered based on the wind speed of storms: class I (119-153km/h) and class II (154-177 km/h).

Scenario 1: (Class I, 119 – 153 km/h)

Figure 4.14 shows the distribution of houses which are expected to be affected by storm class I, ranging from damage level D1 and D2. It can be seen from the figure that most of the houses are estimated to fall under the damage grade D2 (89.53 %). The detailed number of housing falling under each level of damage in the affected provinces is presented in Appendix I, Table 18.

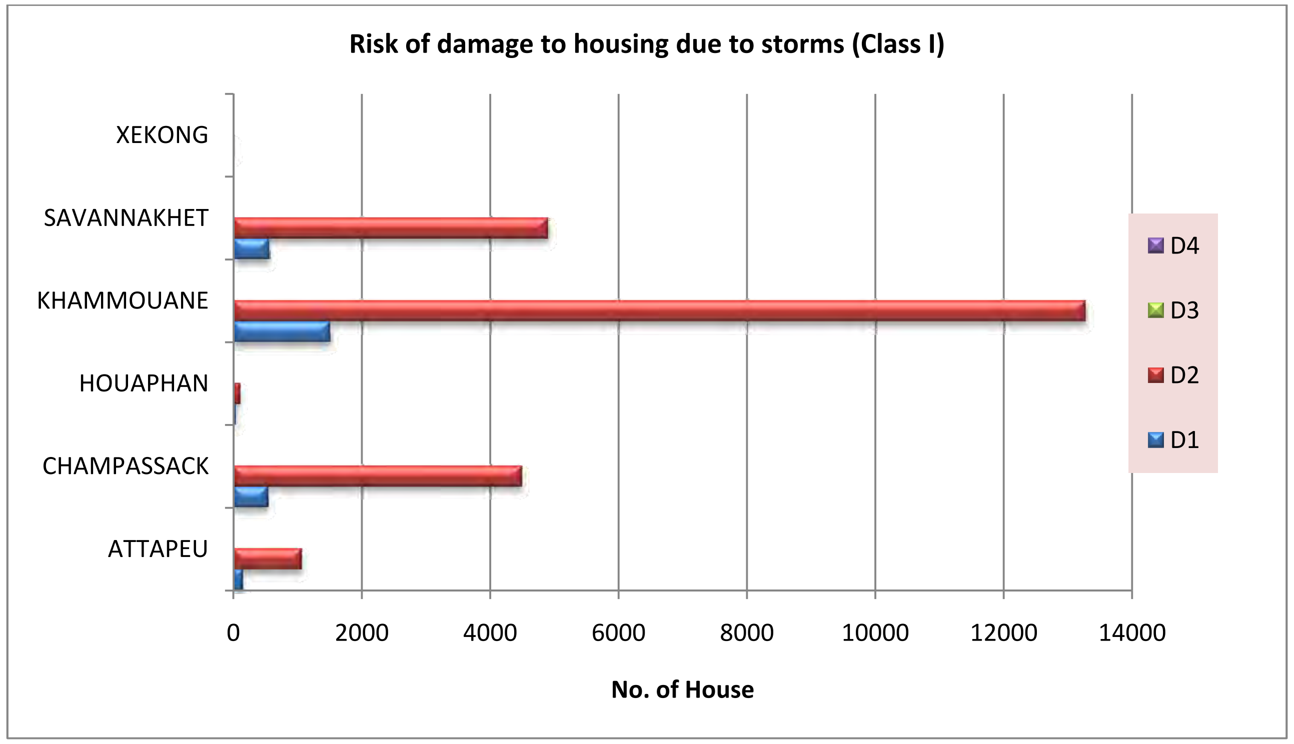


Figure 4.14 Risk of Damage to Housing Due to Storms (Class I)

- **Scenario 2: (Class II, 154 – 177 km/h)**

Figure 4.15 shows the distribution of housing in affected province of Khammouanne. The Khammouanne province is expected to be affected by storm class II, ranging from the damage level D1, D2 and D3. It can be seen from the figure that most of the houses are estimated to fall under the damage level D3 (3274 houses). The detailed number of housing falling in each level of damage in the two provinces is presented in Appendix I, Table 19.

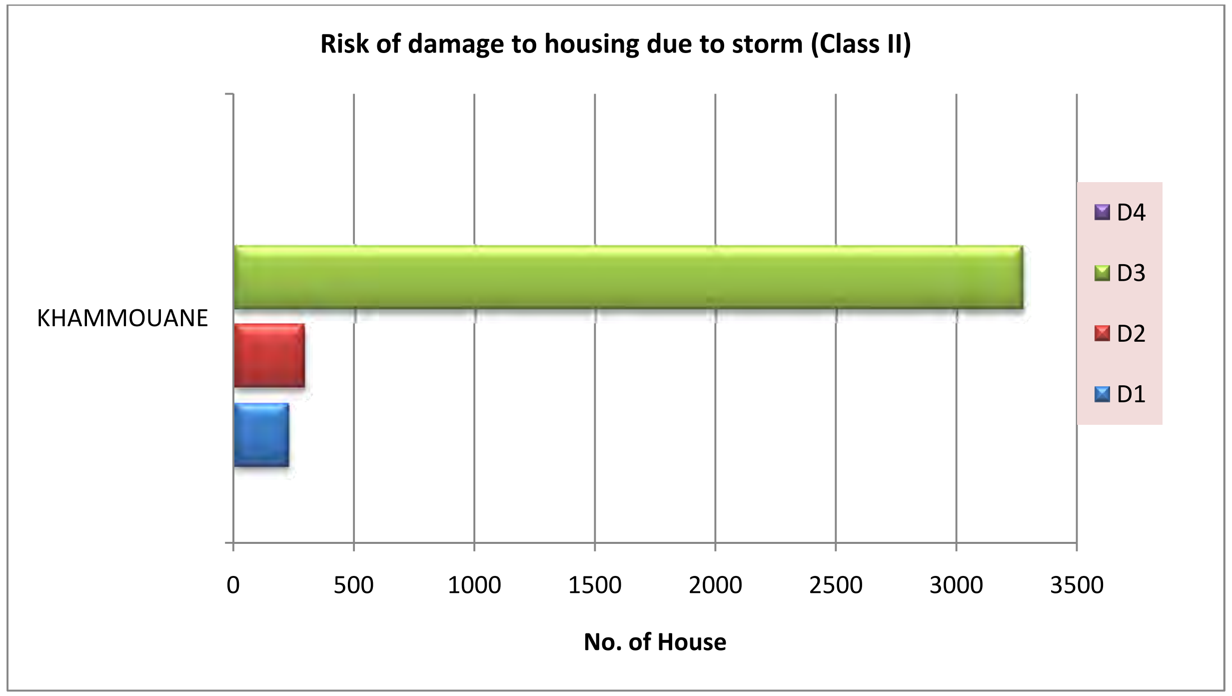


Figure 4.15 Risk of Damage to Housing Due to Storms (Class II)

4.2.3 EDUCATION SECTOR

For the education sector, VRAs for elements at risk exposed to storm hazards has been done at the national level. Similar to the health buildings, estimating the vulnerability and risk of this infrastructure was difficult because the structure of these buildings was not clear from the national database. For simplifying the estimation, it is assumed that education-related infrastructure is permanent and falls under the brick/ RCC category.

Scenario 1: (Class I, 119 – 153 km/h)

Figure 4.16 shows that eighteen school buildings are likely to be affected by the storm class I, with all of these affected schools falling under D1 level of damage. These affected school buildings are located in Houphan, Savannakhet, Khammouanne, Champassack and Attapeu provinces. Appendix I, Table 17 shows the distribution of the affected school buildings in each province.

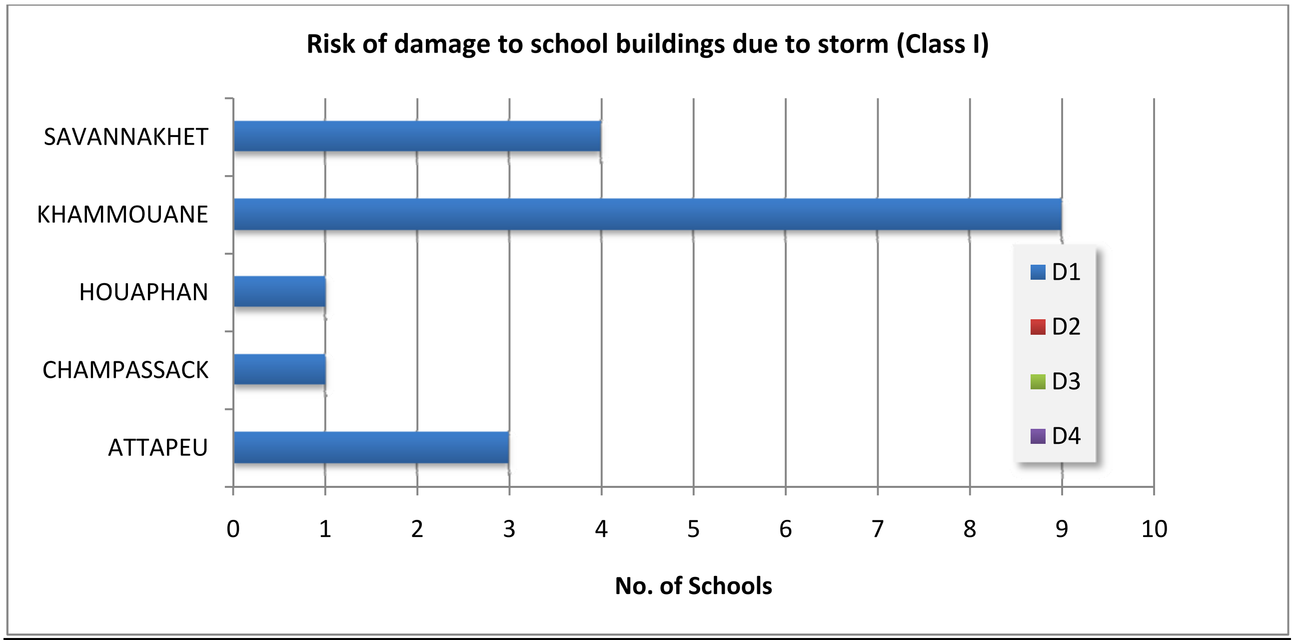


Figure 4.16 Risk of Damage to School Buildings Due to Storms (Class I)

Scenario 2: (Class II, 154 – 177 km/h)

As depicted in Figure 4.17, It is only Khammouane province where several its school buildings are estimated to be affected by storm class II. There are 3 school buildings estimated to fall under a damage level of D1 (2 school buildings) and D2 (1 school building). Appendix I, Table 21 shows the distribution of the affected school buildings in these two provinces.

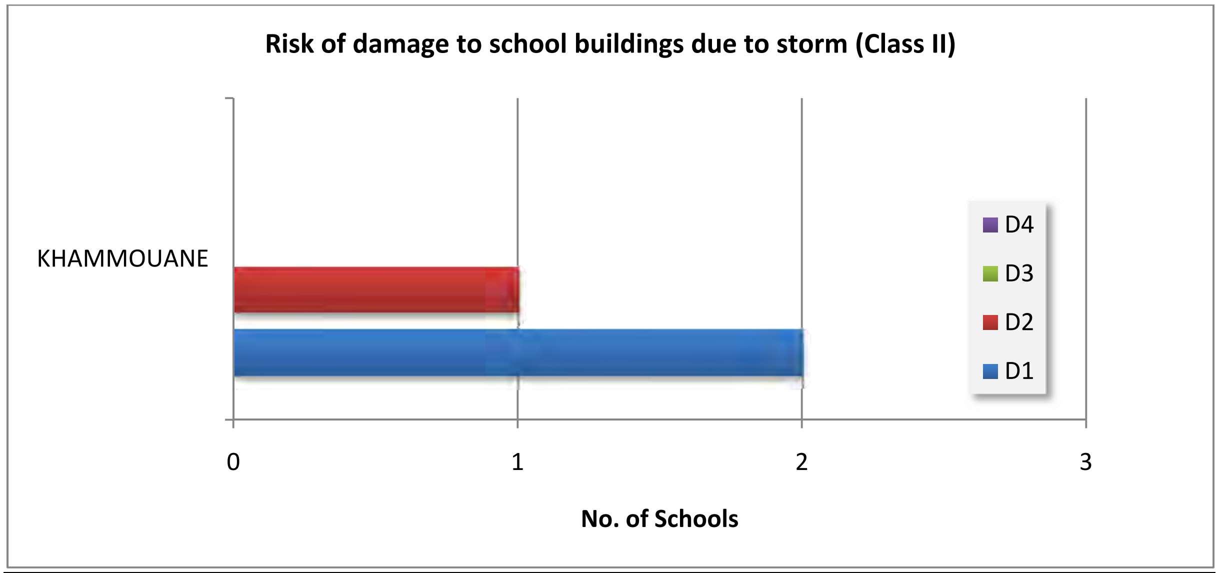


Figure 4.17 Risk of Damage to School Buildings Due to Storms (Class II)

4.3 CONCLUDING REMARKS

- The EVRA for Lao PDR has been done at the national level based on a 50-year return period. As the data used for the EVRA is primarily from the Joint Typhoon Warning Center (JTWC, 2010), the result can only be used as a rough reference for storm prediction in the country of Lao PDR. Since Lao PDR is frequently affected by storms, it is recommended that the results from this study are combined with more detailed data related to past storm events which may be collected from focal departments and organizations in Lao PDR. The detailed storm hazard assessment maps will help policy makers, planners, decision makers and related actors to better plan and implement an effective system related to storm hazard management.
- In order to get a clear and more detailed picture of the storm EVRA in Lao PDR, it is recommended to integrate and utilize the networking system of storm monitoring and observation which include the neighboring countries of Lao PDR, such as: Thailand, Cambodia, Vietnam and China.

It is also recommended to carry out detailed studies and mapping on specific locations where the storms are most likely to happen based on the results and methodology as mentioned above.

5 DROUGHT EXPOSURE, VUNERABILITY AND RISK ASSESSMENT

5.1 EXPOSURE ASSESSMENT

5.1.1 INTRODUCTION

Drought hazard assessment has been discussed in Chapter 3.6, Part 1. The drought hazard assessment has been carried out using SPI). SPI was chosen for this study because of its simplicity and because it is based only on precipitation data. Drought frequency has been computed for different weather periods whilst a variation of droughts at different locations was compared. Spatial and temporal variation of drought has been investigated for different durations. The occurrence of moderate, severe, extreme and moderate-to-extreme droughts in different durations for each year was analyzed at each station. Drought is closely related to disaster management and food security, hence, its analysis and monitoring is indispensable to the safety of the people of Lao PDR

Drought EA aims to identify and quantify sectoral assets which may be affected by severe droughts. The assessment provides information for policy makers, decision makers and planners about sectors which may need drought mitigation interventions. EA initiates the process of drought VRA but does not characterize the performance of assets in varying extremities of drought. The impact of droughts on different sectors is distinctive. Drought tends to have the greatest effect on the agricultural sector, followed by different social sectors. The EA aims to estimate the amount and extent to which agricultural land exists in drought-prone areas. Apart from the direct damage to agriculture, drought often causes food insecurity, livelihood, livestock, water and sanitation problems, and a high rate of migration to urban areas. The majority of these impacts will directly affect a country's national development. For exposure assessment related to the droughts, only the agricultural rice paddy sector exposed to the duration of dry and wet seasons for four types of drought severity (moderate, severe, extreme and moderate-to-extreme) have been analyzed.

5.1.2 METHODOLOGY FOR DOUGHT EXPOSURE ASSESSMENT

This project aims to identify the agricultural sector at risk for EA.

- **Identification of sectors for drought assessment**:
- **Data collection**: Data relating to the agricultural sector is collected from reliable sources. The data is structured in GIS format and is collected at the provincial level.
- **Application of GIS tools for EA**: Chapter 3.6, Part 1 categorizes the drought hazard maps into moderate, severe, extreme and moderate-to extreme drought conditions. The hazard assessments show the varying severities of droughts as they are distribution across the country. The details of the assessment can be found in Chapter 3.6, Part 1 of this report. Using GIS tools it is possible to overlay the drought hazard maps over the agricultural land (rice paddy field) maps. This helps to show the varying susceptibility and vulnerability of the land to droughts, and also helps identify crops that are exposed to drought variability. By using these tools it is possible to quantify the area of agricultural land located in drought-prone areas.
- The EA estimates the area of paddy fields (Ha) affected by various extremities of drought in various seasons.
- **Analysis of EA**: The analysis of the EA provides information about the exposure of agricultural land (paddy field) in drought prone areas. The details of the EA may be found in Appendix I.

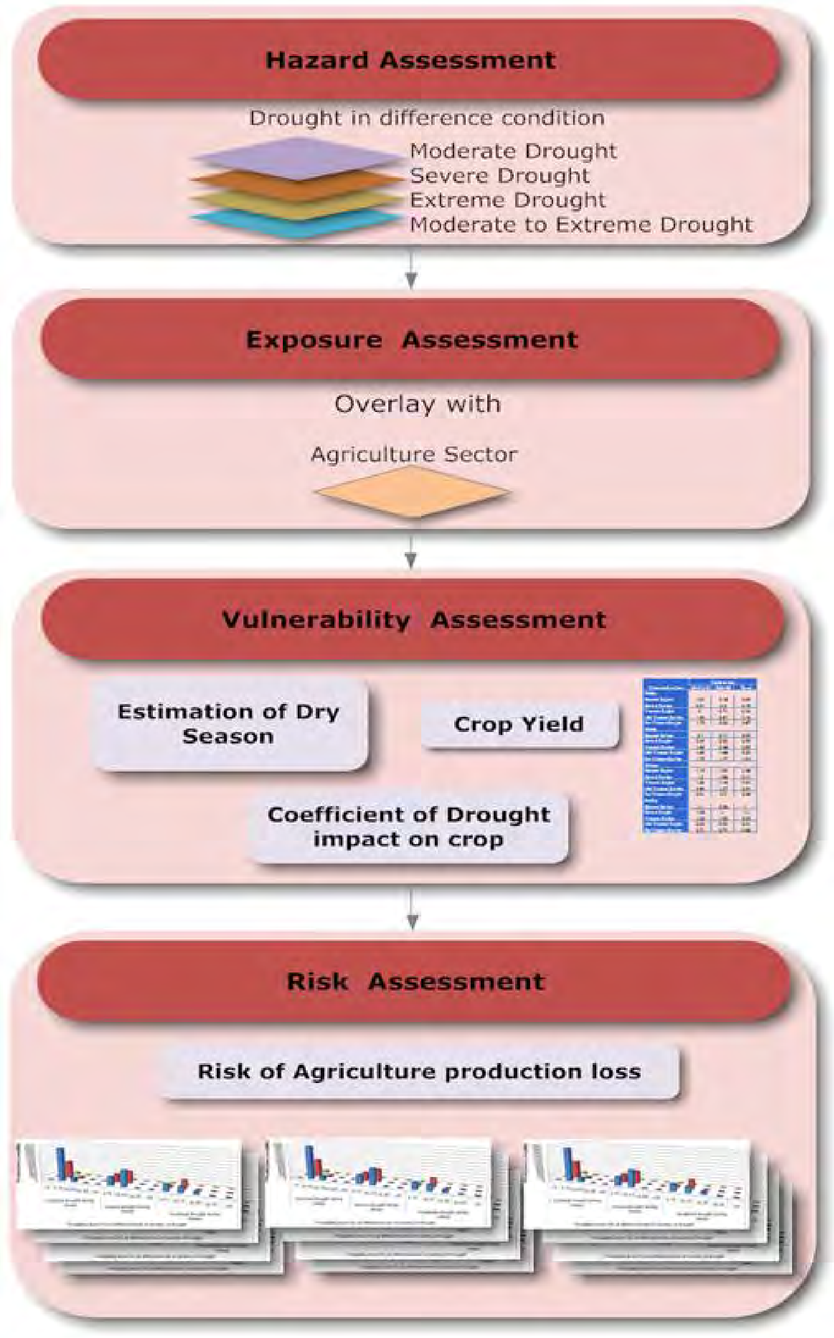


Figure 5.1 Methodology of Drought EVRA

5.1.3 ELEMENTS AT RISK AND EXPOSURE ASSESSMENT

5.1.3.1 AGRICULTURE - PADDY

Agriculture sector (paddy) exposed to drought is carried out for the four categories of drought severity: moderate, severe, extreme and moderate-to-extreme), as well as for both dry and wet seasons.

- The exposure of the agricultural sector has been analyzed in terms of geographical regions. Three regions have been considered: northern, central and southern region. Figure 5.2 to Figure 5.9 show the results of the analysis.
- Figure 5.2 illustrates that in the dry season, during moderate drought conditions, 51 percent of the area of rice paddy in Lao PDR is exposed to a 10-15 percent probability of drought. Around 32.88 percent of the area of rice paddy is exposed to a 5-10 percent probability of drought. Almost 15 percent of the area of rice paddy is exposed to a 10-15 percent drought probability, followed by 1.48 % of rice paddy area exposed to a 15-20 percent probability of drought occurrence.
- Figure 5.3 illustrates that in the dry season, during severe drought conditions, the biggest portion of the area of rice paddy (57.40 %) in Lao PDR is exposed to a 0-5 percent probability of drought, where most of it is located in the central region (Savannakhet, Vientianne Capital, Vientianne, Borikhamxai, and Khammuanne).
- Figure 5.4 illustrates that the in dry season, during extreme drought conditions, about 60.95 percent of the area of rice paddy in Lao PDR is exposed to a 0-5 percent probability of drought, followed by 26.99 percent exposed to a 5-10 percent probability of drought, 4.34 percent exposed to a 10-15 percent drought probability and 7.71 percent having no probability of drought occurrence.
- Figure 5.5 depicts the distribution of the probability of drought occurrence in the dry season, during moderate-to-extreme conditions. Analyses reveals that, during the moderate to extreme drought condition, there are several areas of rice paddy in the central region which will likely suffer from the high probability of drought occurrence (exposed to > 20 % of probability of drought occurrence). These areas of rice paddy are located in Savannakhet, Khammuanne, and Borikhamxai province.
- Figure 5.6 to Figure 5.9 illustrates the rice paddy area exposed during the wet season for the four categories of drought severity. Detailed distribution of the area of rice paddy in each province that is exposed to droughts may be referred to in Appendix I, Table 22 to Table 23.

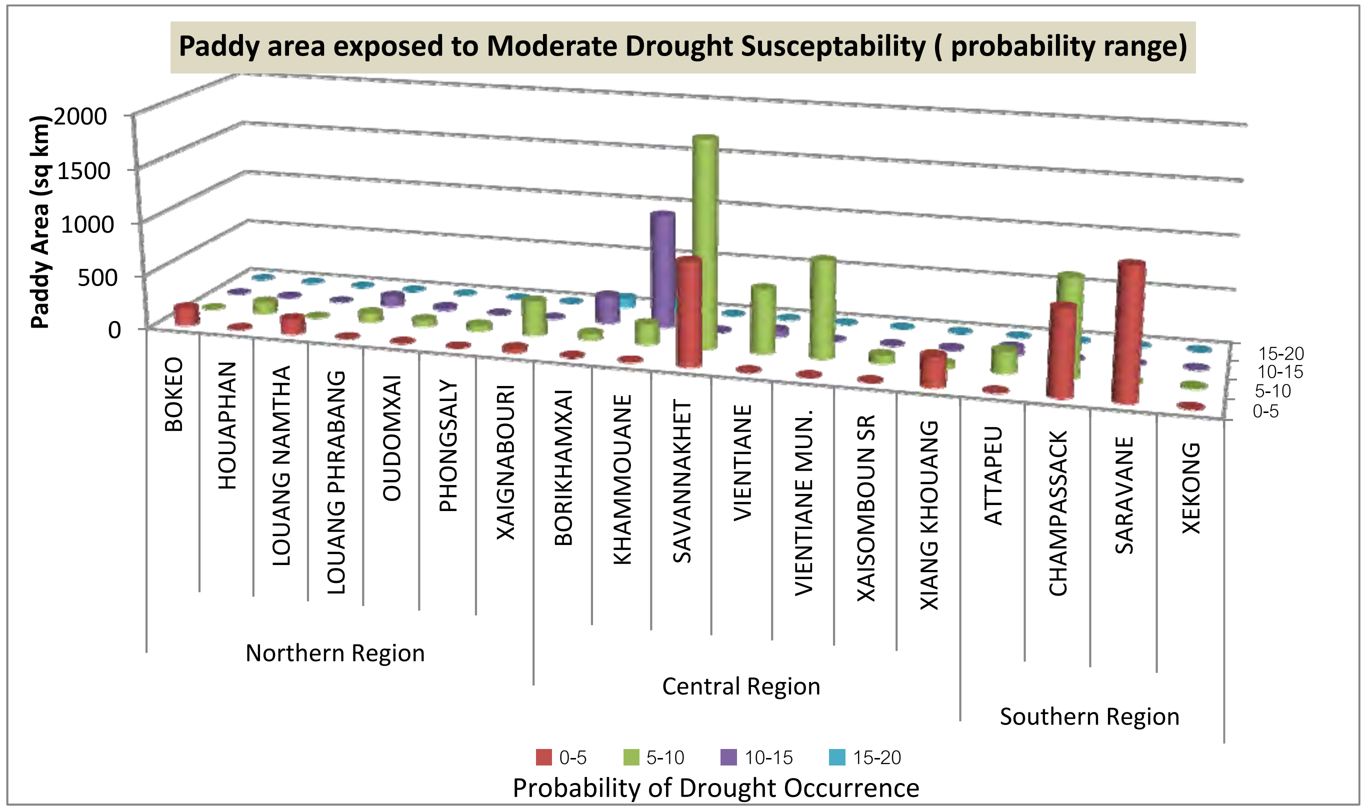


Figure 5.2 Paddy Area Exposed to Moderate Drought Susceptibility (Probability Range Dry season)

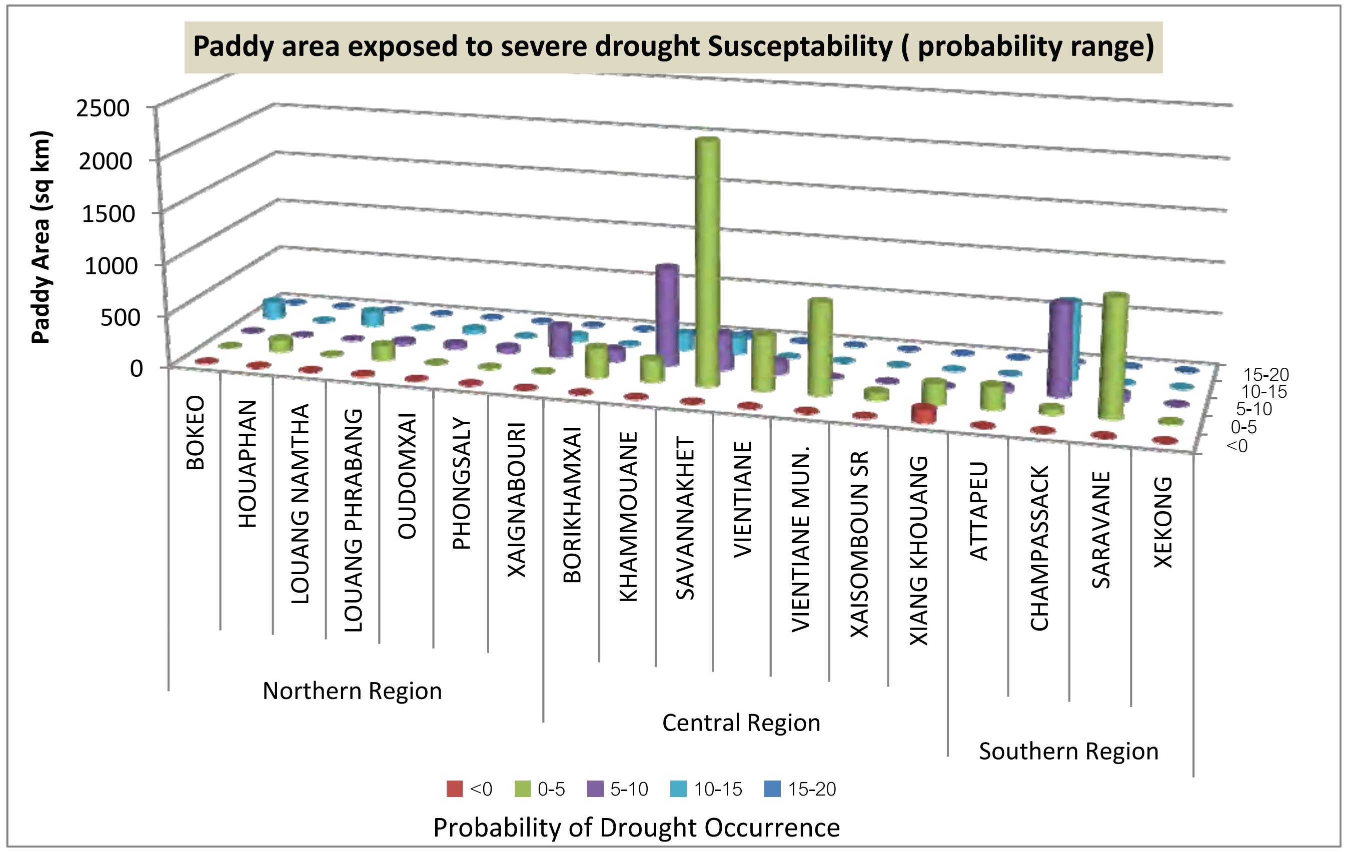


Figure 5.3 Paddy Area Exposed to Severe Drought Susceptibility (Probability Range Dry season)

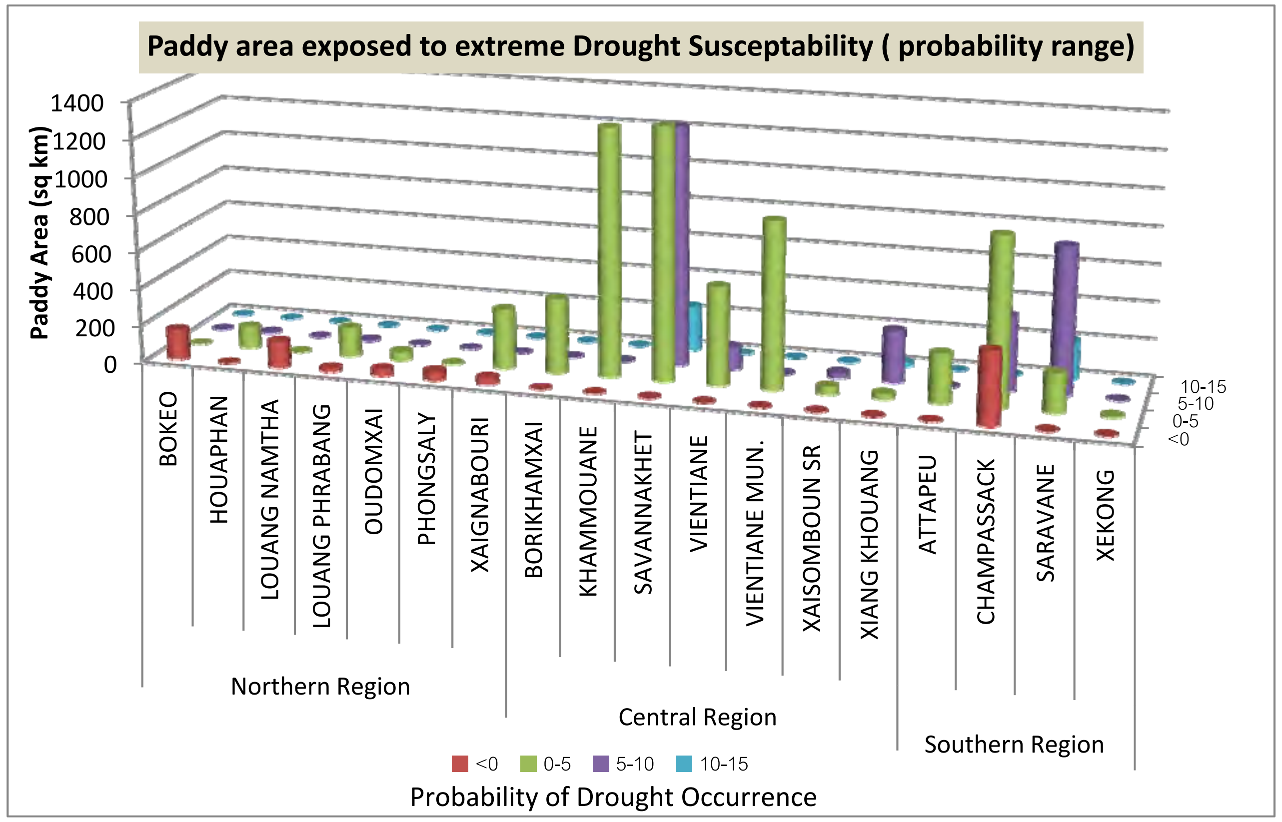


Figure 5.4 Paddy Area Exposed to Extreme Drought Susceptibility (Probability Range, Dry season)

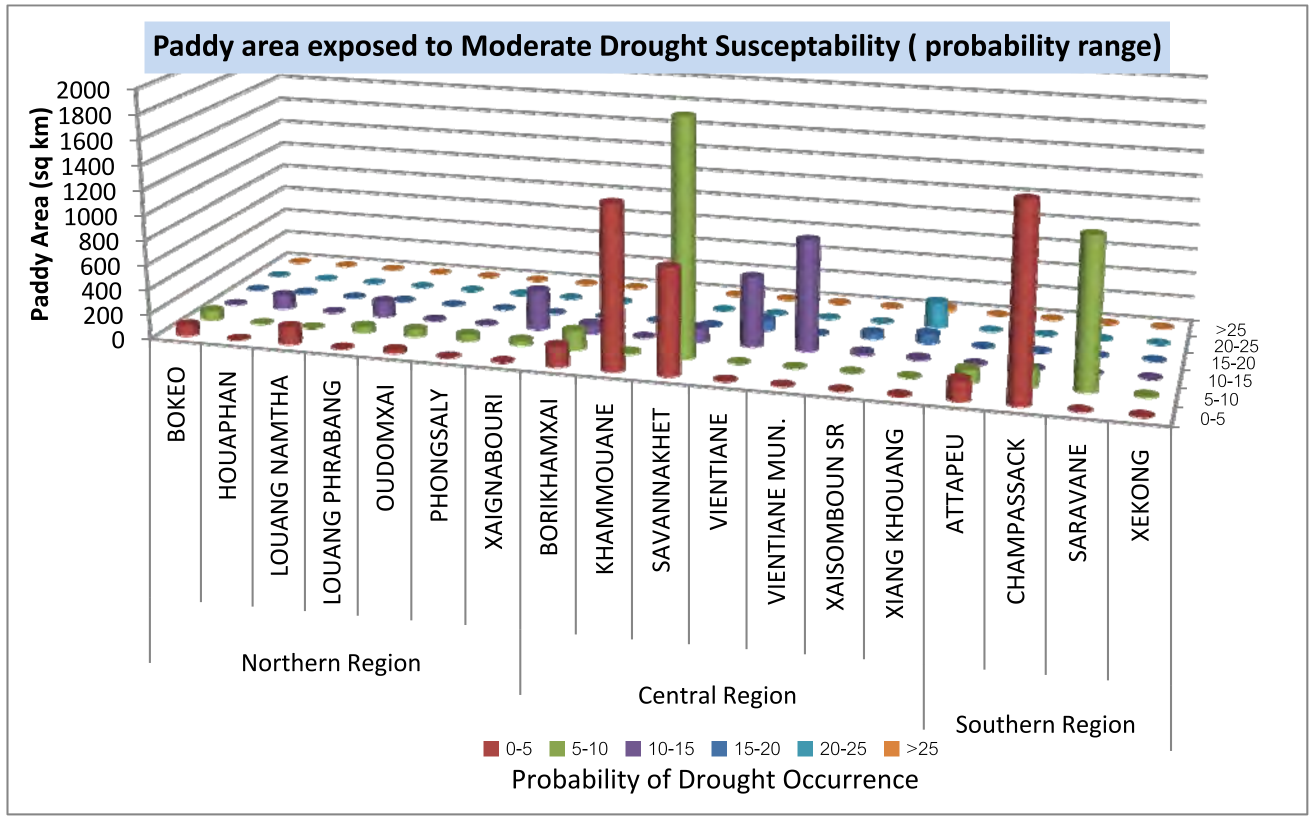


Figure 5.6 Paddy Area Exposed to Moderate Drought Susceptibility (Probability Range, Wet Season)

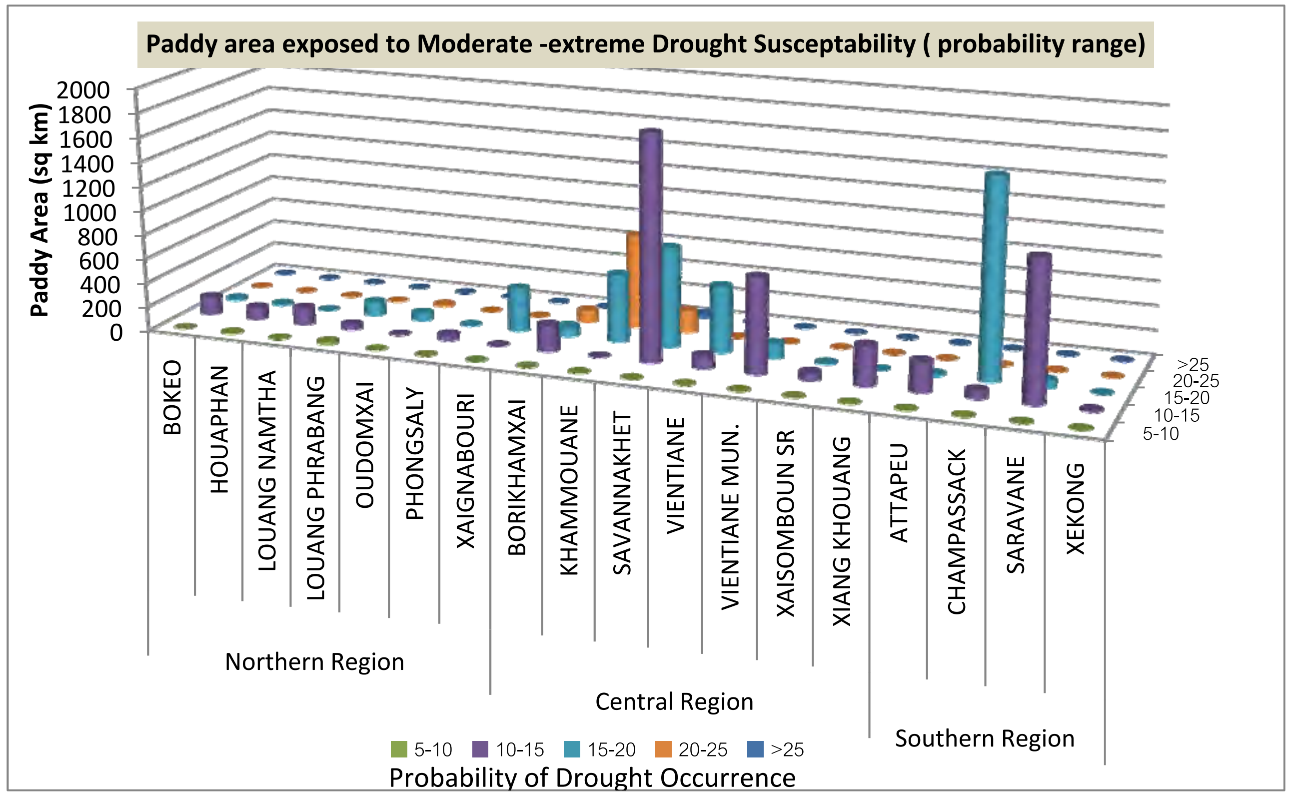


Figure 5.5 Paddy Area Exposed to Moderate-to-Extreme Drought Susceptibility (Probability Range Dry season)

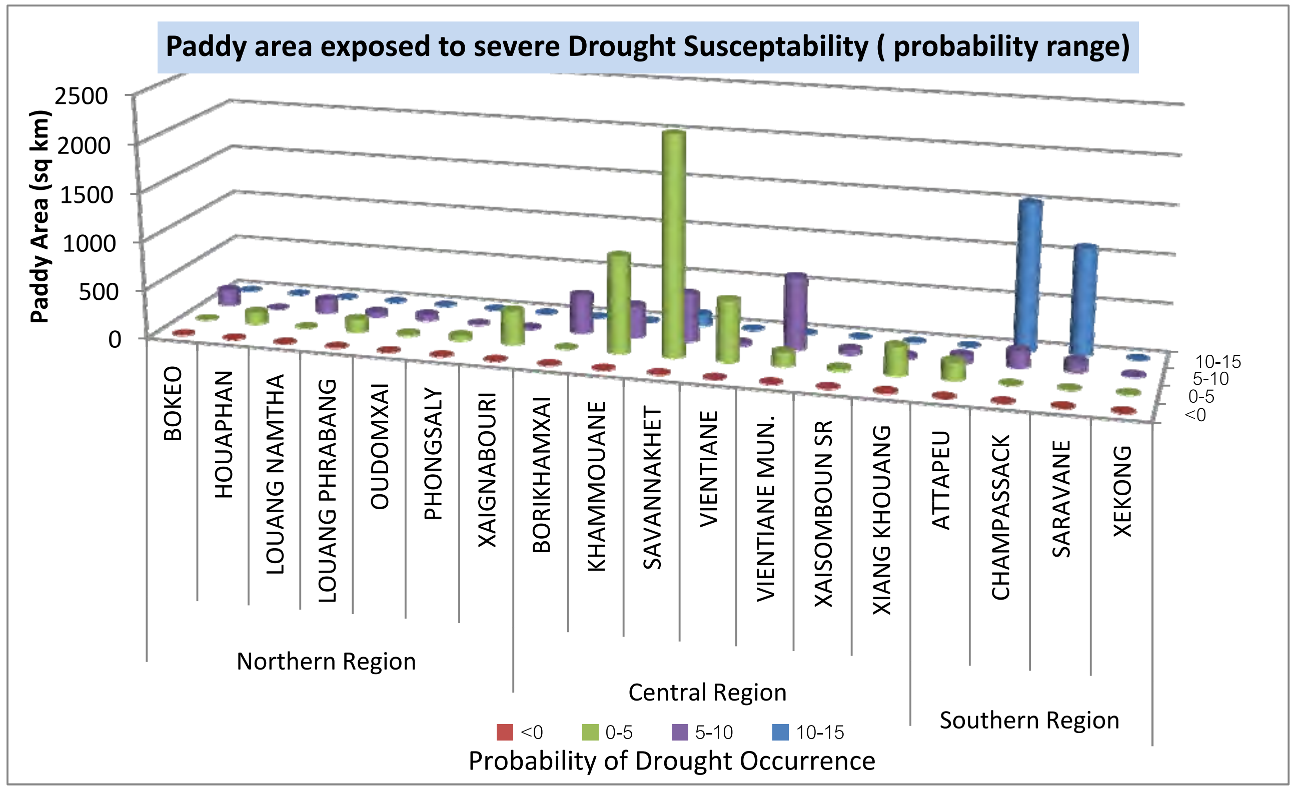


Figure 5.7 Paddy Area Exposed to Severe Drought Susceptibility (Probability Range, Wet Season)

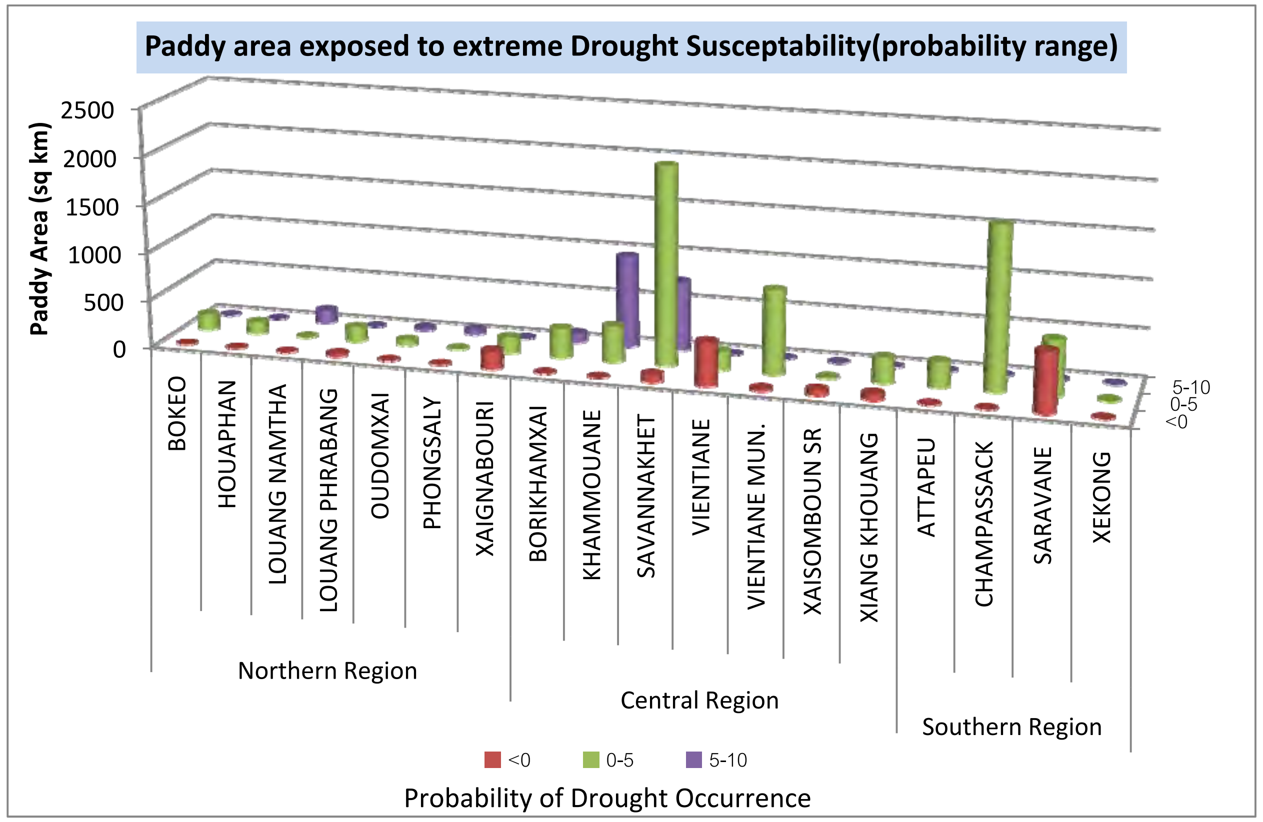


Figure 5.8 Paddy Area Exposed to Extreme Drought Susceptibility (Probability Range, Wet Season)

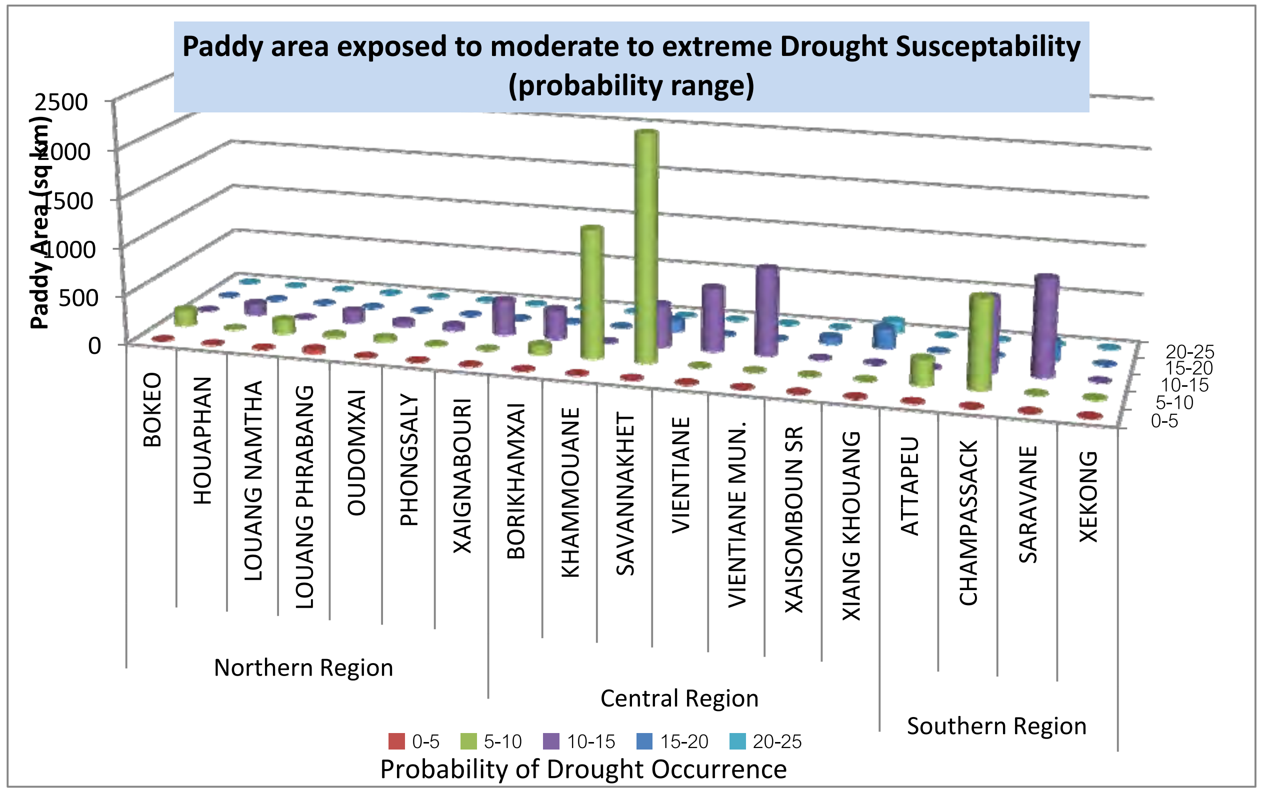


Figure 5.9 Paddy Area Exposed to Moderate-to-Extreme Drought Susceptibility (Probability Range, Wet Season)

5.2 VULNERABILITY AND RISK ASSESSMENT

Drought hazard assessment has been discussed in Chapter 3.6, Part 1 of the project report. The occurrence of moderate, severe, extreme and moderate–to-extreme droughts in different durations for each year was analyzed at each station. The drought VRA primarily defines drought risk as insufficient rainfall in the study area. There are several ways to carry out a drought VA. The scope of this project focuses on agricultural (paddy) VRA. The precision of the VA depends upon the classification of crops cultivated and topological, geographical and climatic characteristics of the region under study. It is challenging to estimate precise VRA for drought due to unavailability of studies on drought impact and the difficulty of defining the vulnerability of various regions in Lao PDR.

Intensity of Drought: The severity of drought was classified into three categories: moderate, severe and extreme. The total area affected under each category of drought is estimated in each particular season.

Probability of the Drought Occurrence: The probability of the occurrence of droughts (as described in Part 1 of the report) was taken in the range of five percentage points such as <5, 5-10, 10-15, 15-20, 20-25, and >25.

Vulnerability Coefficients: There is no literature available on crop losses due to drought events in Lao PDR. Through a literature review of vulnerability functions in the region and expert consultations, the effect of drought on major agriculture crops was analyzed while considering the various intensities of drought. Impacts on crops were experienced as a result of delayed planting and a lack of sufficient moisture during crop growth. The vulnerability coefficients for major crops due to various intensities of drought are presented in Figure 5.10.

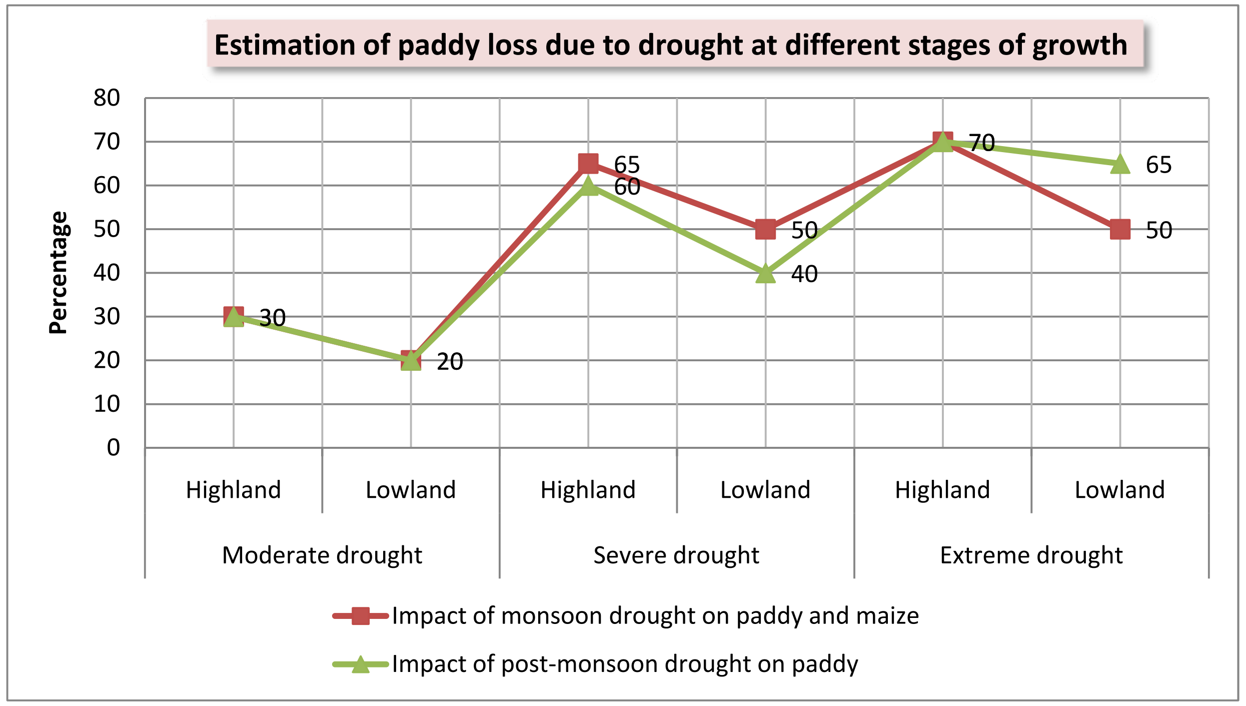


Figure 5.10 Estimation of Paddy Loss Due to Droughts at Different Stages of Growth

Rice Yield

The yield of paddy crops in the country of Lao PDR during the dry season was obtained from the Ministry of Agriculture. A summary of rice paddy crop yield is shown in Table 5.1.

Table 5.1 Summary of Rice Paddy Crop Yield (2000-2008)

Province Name	Unit: Ton/Ha								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Northern Region	**3.52**	**3.60**	**3.76**	**4.03**	**3.98**	**4.11**	**4.10**	**4.10**	**4.04**
Phongsaly	3.54	3.33	3.54	4.01	3.96	4.01	4.50	4.05	4.31
Luangnamtha	3.87	4.00	4.10	4.60	4.53	4.38	4.61	4.00	4.21
Oudomxay	3.20	3.11	3.62	4.46	4.51	4.34	4.00	3.98	3.84
Bokeo	4.11	3.41	3.48	3.81	3.64	3.28	4.00	4.20	4.14
Luangprabang	4.10	4.14	4.17	4.30	4.55	4.51	4.29	4.50	4.26
Huaphanh	3.00	3.10	3.26	3.70	3.60	3.82	3.61	3.42	3.25
Xayabury	3.18	3.31	3.76	3.83	3.15	4.18	4.20	4.34	4.06
Central Region	**4.39**	**4.37**	**4.57**	**4.63**	**4.53**	**4.51**	**4.56**	**4.70**	**4.68**
Vientiane.C	4.60	4.62	4.61	4.71	4.86	4.55	4.60	4.77	4.74
Xiengkhuang	3.50	3.28	3.44	3.00	2.99	3.13	3.41	3.56	3.51
Vientiane	4.25	4.22	4.51	4.36	4.36	4.42	4.39	4.55	4.59
Borikhamxay	4.27	4.23	4.33	4.15	3.64	4.33	4.30	4.84	4.58
Khammuane	4.27	4.23	4.75	5.67	5.11	5.07	5.54	5.03	5.27
Savannakhet	4.33	4.30	4.53	4.35	4.28	4.36	4.37	4.62	4.54
Xaysomboon	4.00	3.90	4.00	3.00	3.50	3.75			
Southern Region	**4.10**	**4.17**	**4.23**	**4.34**	**4.37**	**4.26**	**4.64**	**4.43**	**4.97**
Saravan	4.00	4.11	4.25	4.48	4.50	4.30	5.03	4.50	4.98
Sekong	4.00	4.06	4.10	4.18	4.19	3.99	3.68	4.24	4.38
Champasack	4.12	4.20	4.24	4.29	4.33	4.32	4.42	4.40	5.09
Attapeu	4.10	3.78	4.06	3.79	3.45	3.52	3.90	4.27	4.20
Grand Total	**4.25**	**4.28**	**4.46**	**4.54**	**4.45**	**4.44**	**4.53**	**4.61**	**4.67**

5.2.1 AGRICULTURE SECTOR

Drought VA on agriculture aims to identify and quantify paddy areas which may be affected by droughts. The assessment provides information for policy makers, decision makers and planners about sectors which may need drought mitigation interventions. Apart from the direct damage to agriculture, drought often causes food insecurity, livelihood, livestock, water and sanitation problems, and a high rate of migration to urban areas. The majority of these impacts will directly affect a country's national development.

The drought VRA illustrates the risk of paddy crop prevention loss in various seasons and geographic and development zones of Lao PDR. The drought VRA has been done for a moderate–to-extreme drought during the dry season. Average yield (ton/Ha) of each province obtained from the Ministry of Agriculture was used to estimate the loss production due to droughts during the dry season (moderate–to-extreme droughts).

- Table 5.2 illustrates the risk of production losses of paddy during the dry season (moderate-to-extreme severity of droughts). Paddy is one the most important crops in Lao PDR. The analysis reveals that paddy production is most affected in the central region, followed by the northern and southern regions.
- During the dry season (moderate-to-extreme droughts), it is observed that four provinces in the central region (Borikhamxai, Khammuanne, Savannakhet and Oudomxay) are largely affected by drought conditions (high probability of drought occurrence).
- During the dry season, two provinces in the northern region (Luang Prabang and Huaphanh) has a probability of drought occurrence for its paddy.

Table 5.2 Estimated Paddy Production Loss (ton) During Dry Season (Moderate–to-Extreme Severity of Drought)

Province Name	Estimated paddy loss (ton)				
	Moderate-to-Extreme				
	5-10	10-15	15-20	20-25	>25
Northern Region	**11641.72**	**186130.26**	**223430.66**	**6892.4**	**0**
Phongsaly	0	18350.91	1524.91	0	0
Luangnamtha	0	59473.39	590.38	0	0
Oudomxay	0	0	25251.58	6892.4	0
Bokeo	0	55425.37	6971.28	0	0
Luangprabang	9336.52	18417.47	49074.46	0	0
Huaphanh	2305.2	34463.12	4758.84	0	0
Xayabury	0	0	135259.21	0	0
Central Region	**0**	**1434690.5**	**974832.3**	**503538.13**	**12977.07**
Vientiane.C	0	363422.19	56756.47	0	0
Xiengkhuang	0	107939.53	346.45	0	0
Vientiane	0	45064.56	240823.18	0	0
Borikhamxay	0	93816.78	36356.61	41513.15	0
Khammuane	0	0	277622.45	382194.31	57.01
Savannakhet	0	809026.48	360551.24	79830.67	12920.06
Xaysomboon	0	15420.94	2375.9	0	0
Southern Region	**0**	**636869.39**	**741363.96**	**140.07**	**0**
Saravan	0	507603.93	27553.58	140.07	0
Sekong	0	3654	0	0	0
Champasack	0	28947.33	707605.67	0	0
Attapeu	0	96664.13	6204.71	0	0
Grand Total	**11641.72**	**4329250**	**3655823.2**	**510570.6**	**12977.07**

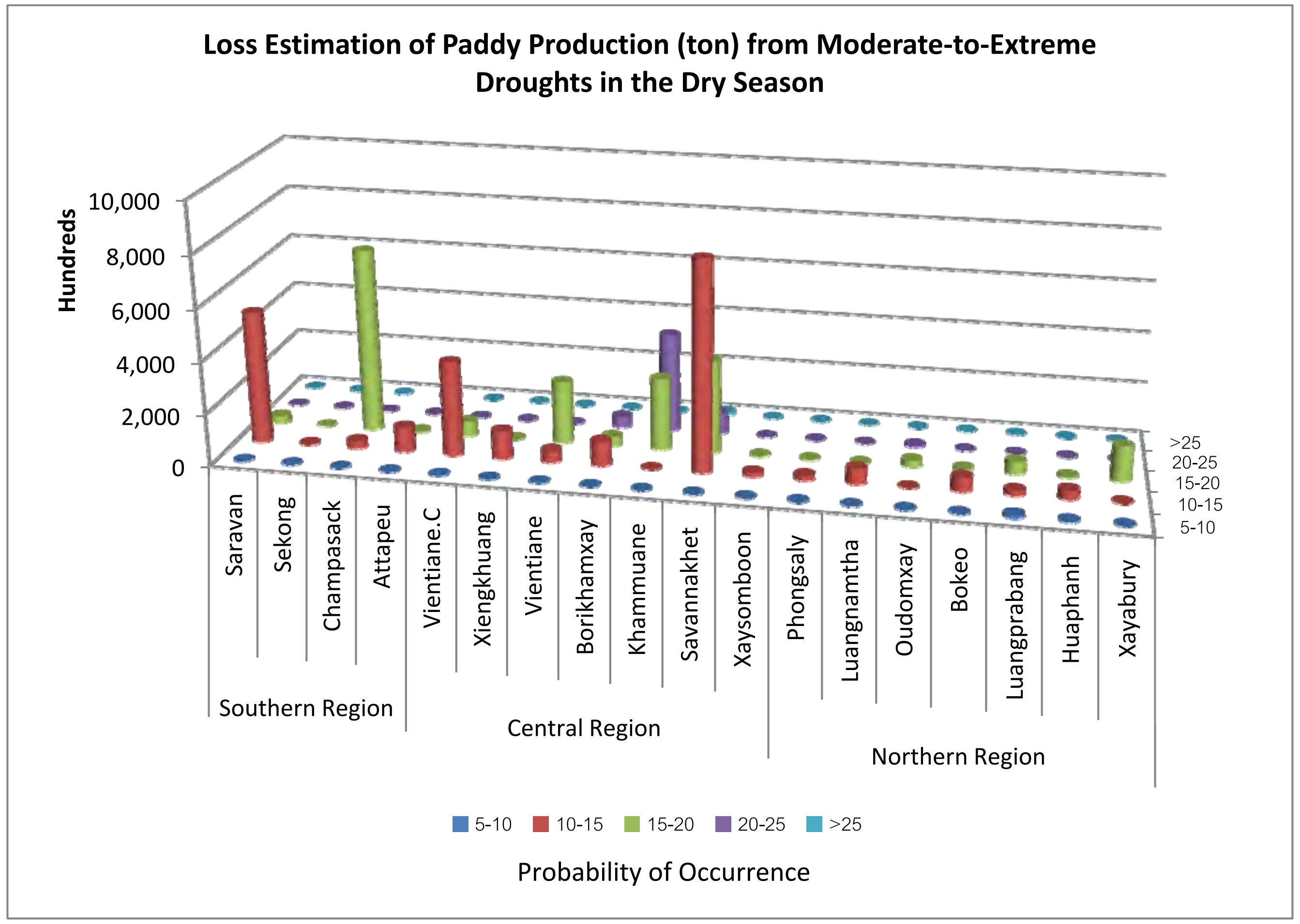


Figure 5.11 Loss Estimation of Paddy Production (ton) from Moderate-to-Extreme Droughts in the Dry Season

5.3 CONCLUDING REMARKS

The drought EVRA determined the estimated agricultural losses caused by various categories of drought severity and probability in Lao PDR. The EVRA analysis has been carried out for paddy to estimate the loss production due to droughts during the dry season. Based on the analysis, the study proposes the following:

- At present, drought hazard assessments have been carried out in pilot study areas by various agencies in the country. There remains a need to study the gross impact of drought for the country in its entirety. There is no report on drought impact on various major crops such as wheat, paddy, barley and maize. It is therefore necessary for national agriculture research organizations to carry out a detailed EVRA study for droughts. It is important to study growth patterns and expected damages resulting from various categories of drought severity.

- The drought assessment here has been carried out at the provincial level. It is necessary to study the impact of drought at the district level as well.

- This analysis pinpoints drought hotspots throughout the country. It is recommended that the most severely affected zones be scaled down for study at the district level.

- EVRA will provide the necessary guidance to stakeholders engaged in agriculture and natural resource development for drought risk reduction. The suggested mitigation strategies include:
    - Setting up a drought early warning system for the country;
    - Modification of the cropping pattern in high drought risk zones;
    - Adequate water resource management;
    - Livelihood management during the drought period for agricultural areas;
    - Adequate supply and maintenance of food and crops during drought conditions;
    - Health surveillance during drought conditions, linking drought risk to the health status of children, women and the elderly.

6 NATIONAL STRATEGY FOR DISASTER RISK REDUCTION IN LAO PDR

6.1 OVERVIEW

Part 1 of this project report provides information on the major hazards found in Lao PDR, detailing the zoning of the different natural hazards including earthquakes, floods, landslides, droughts, storms and other disasters such as epidemics and UXOs. The initial chapters of this report provide the vulnerability and risk profile of the country at the provincial level. Based on the results from this report a set of recommendations have been developed for setting up a national strategy for DRR. These recommendations have been categorized into the following components:

- Policy, institutional mandates and institutional development
- Hazard, vulnerability and risk assessment
- Multi-hazard Early Warning Systems (EWS)
- Preparedness and response planning
- Integration of DRR into development planning
- Community-based disaster risk management (CBDRM)
- Public awareness, education and training

Within each component of the recommendations, a suggested geographical area of project, activity implementation, expected outputs, focal or lead departments and cooperating agencies are provided. This chapter offers the essential structure, but additional work and support is needed from the focal and lead departments for resource mobilization and project implementation.

6.2 POLICY, INSTITUTIONAL MANDATES AND INSTITUTIONAL DEVELOPMENT

The objective of this chapter is to establish a culture of safety within the disaster management field through policy support and the strengthening of institutional mandates and capacities. In order to ensure a coordinated approach to DRR and disaster preparedness, individual institutions have to work in accordance with their current mandates whilst also taking on additional responsibilities. This might require formulating national disaster management acts (NDMA) and legislations, as well as developing institutional capacities across various levels, particularly in high risk areas. To achieve this framework the component will need to enhance capacities through policy support, the institutional development of NDMO and greater involvement of the public in shaping national policies and legislations and strengthening human rights; particularly of women, children, the elderly and other disadvantaged groups.

6.2.1 NATIONAL DISASTER MANAGEMENT ACT

Lao PDR has already developed a national strategy for DRM in close consultation with national and local stakeholders. There is a need to develop an NDMA which will define the roles and responsibilities of various national government and non-governmental organizations (NGOs), departments and offices. This will also help provide the structure of DRM at district and provincial levels. The NDMA will further provide specific executive power to various departments and agencies which will help the system to be more proactive than reactive.

Geographical Area: Whole country

Activities:
- Develop an NDMA through a consultative process
- Develop an expert group that represents various disaster management practitioners, professionals, academics, NGOs, development agencies and so on
- Study the recommendations provided in this report
- Obtain approval from the National Disaster Management Committee (NDMC)
- Prepare disaster management strategies at the national, ministerial and agency levels as required

Output
- NDMA prepared
- Advisory committees established
- National Disaster Management Plan (NDMP) for Lao PDR prepared
- Disaster management strategy for ministries, line agencies and corporations prepared

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.2.2 REVIEW AND FORMALIZE INSTITUTIONAL MANDATES FOR LINE AGENCIES TO PERFORM DISASTER RELATED ACTIVITIES:

DRM requires the support and cooperation of various agencies. There are several institutions which are responsible for disaster related activities; it is important to review their roles and responsibilities and formalize the institutional mandates that detail what their contributions should be.

Geographical Area: Entire Country

Activities:
- Identify relevant functions that are not currently assigned to disaster management institutions
- Identify institutions without appropriate mandates for DRM
- Address the gaps in the institutional functions, by looking at the provision of mandates, issued by the appropriate gazette notifications
- Introduce measures which assign responsibility and accountability for different disaster management functions

Outputs:
- Institutional mandates established or clarified for relevant line agencies
- New regulations implemented as required

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.2.3 DEVELOPING INSTITUTIONAL MANDATES AND CAPACITIES:

There is a concern that the capacity of various disaster management institutions and the resources that they have available is not currently adequate. As a result of this, the NDMO need to enhance the resources available in order to strengthen the present capacity of these institutions.

Geographical Area: Entire Country

Activities:

- The development of an institutional framework that encompasses all the new DRM mandates and strategies for ministries, departments, agencies, and national and international NGOs. This framework will be provided to provincial councils, local government agencies and DM line agencies
- Identification of the needs and gaps in human resources, equipment and offices relating to DRM
- Training and capacity building of different divisions within organizations that function as a disaster management line agency
- Institutionalized cooperation and coordination structures facilitated as needed
- Enhancing the capacity of NDMO. This can be done by building an emergency operations centre (EOC) within the head office, enhancing communications and other necessary facilities, and by training personnel

Outputs:

- Institutional capacities that correspond to the new mandates will be developed and enhanced
- EOC will be set up within the headquarters of NDMO, with the appropriate facilities provided

Contact Ministry / Department / Agency / Institute

- NDMO, Government of Lao PDR
- Other line ministries and departments related to DM

6.2.4 FORMULATION OF CBDRM POLICY

A community's first line of defense to the threat of a disaster is preparation; this is key to reducing a community's vulnerability and increasing their disaster resilience. Having a well-resourced and sustainable program for CBDRM is therefore a key strategy in Lao PDR. The activity recognizes CBDRM as a tool for DRR and capacity building at the local level, enabling the community to play an active role in DRR.

Geographical Area: Whole country

Activities:

- Recognize and provide legal basis for CBDRM groups at the local level
- Clear linkages established and roles identified for CBDRM and NGOs within different disaster management strategies at the province and district levels
- Create national mechanisms for the coordination of the DMC and NGOs in promoting CBDRM
- Development of common approaches and methodologies for CBDRM
- Registration system for disaster response volunteers created

Outputs:

CBDRM recognized as a tool by line agencies and ministries for DRR at the local level

Contact Ministry / Department / Agency / Institute

- NDMO, Government of Lao PDR
- Other line ministries and departments related to DM

6.2.5 ENFORCEMENT OF POLICIES:

DRM is not currently always considered within national projects or strategies, which is posing a challenge for mainstreaming DRR efforts. Nevertheless due to rapid development within the country, it is essential that DRM is mainstreamed in order to ensure that the development does not create new hazards or environmental problems. Integrating DRM into national planning policies will make it mandatory for agencies to include DRM within their projects.

Geographical Area: Whole country

Activities:

- Review existing ordinances, acts and regulations
- Identify the gaps and causes of the current inadequate enforcement
- Clarify and resolve areas of overlap or contradiction
- Develop capacities or resources needed for effective enforcement

Outputs:

- Implement and optimize existing DRR policies
- Enforcement of relevant existing ordinances, acts and regulations

Contact ministry / department / agency / institute

- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.3 HAZARD, VULNERABILITY AND RISK ASSESSMENT (HVRA)

Information on the Hazard, Vulnerability and Risk Assessment (HVRA) has been provided in Part 1 and previous chapters of this report. The project has developed HVRA at the national scale; nevertheless there is a need to develop HVRA at the provincial level and most hazard-prone district levels. By considering the results and outcomes of this project, it will be possible to identify the issues and gaps in disaster management which will need to be addressed in order to achieve safer and more sustainable development. These could include:

- Natural & human-induced hazards within the HVRA
- Database management systems for HVRA
- HVRA capacity-building for focal agencies
- Science and technology in HVRA

6.3.1 NATURAL HAZARD, VULNERABILITY AND RISK ASSESSMENT

Flood Risk Assessment

Geographical Area: Flood-prone areas, major flood-prone river basins (please also refer back to the flood hazard zoning information found in Part 1 of this project report)

Activities:

- Development of digital elevation models (DEM) including data collection
- Rainfall data analysis
- Development of appropriate simulation models (as in the past modeling has predominantly been one dimensional)
- Enhance prediction and early warning (EW) capacity
- Digitization of topographic data into DEM
- Development of GIS mapping for the most vulnerable urban areas
- Assess the performance of existing flood protection works in order to establish what improvements could be made
- Develop scientific and field validated vulnerability curves for buildings and other physical infrastructures
- Assess the characteristics of various crops grown within different seasons that are vulnerable to flooding

Outputs:

- Flood hazard mapping in flood plain areas (digital and hard copies)

Contact Ministry / Department / Agency / Institute

- Department of Meteorology and Hydrology (DMH), Government of Lao PDR
- Department of Water Resource, Department of Agriculture (DoA), NDMO and other disaster management line ministries and departments

Earthquake Risk assessment

Geographical Area: Whole country (please refer back to the earthquake hazard zoning information found in Part 1 of this project report)

Activities:

- Identification and mapping of active faults
- Development of extensive macro and micro level earthquake catalogues (available at reasonable cost for research and development)
- Development of geological maps at lower scale for seismic risk assessment
- Large scale seismic-tectonic mapping for the country
- Development of scientific and field validated vulnerability curves for buildings and other physical infrastructures with respect to the earthquake severity

Outputs:

- Detailed seismic zoning maps for the very high seismic prone areas

Contact Ministry / Department / Agency / Institute

- Department of Meteorology and Hydrology (DMH), Government of Lao PDR
- Department of Geology and Mines , NDMO and other disaster management line ministries and departments

Landslide Risk Assessment

Geographical Area: Whole country (please refer back to the landslide hazard zoning information found in Part 1 of this project report)

Activities:

- Field mapping and collection of field data
- Acquisition of satellite data development from GIS mapping for the delineation of vulnerable areas
- Upgrading of computer hardware and software used for GIS mapping
- Development of GIS databases and the delineation of vulnerable areas
- Dissemination of map information
- Geological and geo-technical investigation for the collection of necessary field data
- Data analysis and delineation of associated risks
- Development of risk maps and disaster response maps
- Dissemination of maps and proposed mitigation measures

Outputs:

- Provide landslide hazard maps for the urban areas and other highly populated areas as mentioned in the landslide hazard zoning chapter found in Part 1 of this report.

Contact Ministry / Department / Agency / Institute

- Department of Meteorology and Hydrology (DMH), Government of Lao PDR
- Department of Roads, Department of Housing and Urban Planning, DMH, NDMO and other disaster management line ministries and departments

Drought Risk Assessment

Geographical Area: Whole country (please refer back to the drought hazard zoning information found in Part 1 of this project report)

Activities:
- Based on the information on the drought hazard assessment provided in Part 1 of this report, a detailed study should be carried out for the most drought prone areas
- Development of a drought catalogue that considers, at the minimum, the past 30 years
- Development of a better drought modeling and ground validation system
- Development of a robust rainfall database management system
- Defining a rainfall threshold for the identification of drought conditions
- Identifying the drought vulnerability characteristics of various existing crops

Output
- Comprehensive meteorological and climatic database available for drought hazard and risk assessment
- Precise methodology for drought risk assessment defined

Contact Ministry / Department / Agency / Institute
- Department of Meteorology and Hydrology (DMH), Government of Lao PDR
- DoA, Department of Irrigation, NDMO and other line ministries and departments related to DM

Storm Risk Assessment

Geographical Area: Whole country (please refer back to the storm hazard zoning information found in Part 1 of this project report)

Activities:
- Based on the information on the storm hazard assessment provided in Part 1 of this report, a detailed study should be carried out for the most storm prone areas
- Development of a storm catalogue that considers, at the minimum, the past 50 years
- Development of a better storm modeling
- Identifying the storm vulnerability characteristics

Output
- Comprehensive meteorological and climatic database available for storm hazard and risk assessment
- Precise methodology for storm risk assessment defined

Contact Ministry / Department / Agency / Institute
- Department of Meteorology and Hydrology (DMH), Government of Lao PDR
- NDMO and other line ministries and departments related to disaster management

Epidemics and UXO Risk Assessment

Geographical Area: Whole country (please refer back to the epidemic and UXO hazard zoning information found in Part 1 of this project report)

Activities:
- Based on the information on the epidemic and UXO hazard assessment provided in Part 1 of this report, a detailed study should be carried out for the most epidemic and UXO-prone areas
- Development of a epidemic catalogue that considers, at the minimum, the past 50 years
- Development of a better epidemic modeling and ground validation system

Output
- Comprehensive database for epidemic and UXO events
- Precise methodology for epidemic and UXO risk assessment defined

Contact Ministry / Department / Agency / Institute
- Department of Health, UXO-NRA, Government of Lao PDR
- NDMO and other line ministries and departments related to disaster management

6.3.2 DATABASE MANAGEMENT SYSTEMS

Geographical Area: Whole country

Activities
- Housing categories identified, based on the type of building materials and load paths used in order to help achieve a more precise vulnerability and risk assessment
- Development of a database identifying the class of educational buildings and health institutions
- Development of GIS-based mapping of various industries, including trade and mining
- Update databases so that they provide current information and status of road and power lines
- Develop GIS-based mapping of the arable and temporal changes to cropping

Output
- Database management system: GIS-based mapping for all major infrastructures, which will then be compatible for sectoral risk assessment

Contact Ministry / Department / Agency / Institute
- Department of Survey, Government of Lao PDR
- Lao Statistics Bureau, NDMO and other line ministries and departments related to disaster management

6.3.3 HVRA CAPACITY BUILDING FOR FOCAL AGENCIES

Geographical area: Whole country

Activities:

- Identification of focal agencies for HVRA, taking into consideration natural and human-induced hazards
- Encouraging technical and scientific institutions to build their capacity to carry out hazard assessments using up-to-date techniques and tools
- Establish links between scientific institutions and departments with user agencies
- The development of precise site specific drought models which can be used for crop production management by the agricultural and irrigation departments
- Establish a system to support access to the departmental data collected through VRA
- Regular and consistent training and capacity building on HVRA for stakeholders and the appropriate allocation of resources for such activities

Output

- Strategy paper on capacity building for HVRA
- Identifying focal agencies and targets for HVRA training
- Allocation of funds from respective departments and for above stated activities

Contact Ministry / Department / Agency / Institute

- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.3.4 SCIENCE AND TECHNOLOGY IN HVRA

Geographical Area: Whole country

Activity

- Identification of institutions and departments that will be able to help develop a center of excellence for HVRA
- Provision of additional funds for developing center of excellence
- Collaboration of national and international institutions to help develop a center of excellence for HVRA

Output

- Strategy paper for creating center of excellence
- Identification of Institutions suitable for the center of excellence
- Defining the research and development mandate for HVRA by the Government of Lao PDR
- Regular allocation of funds for the center of excellence

Contact ministry / department / agency / institute

- NDMO, Government of Lao PDR
- Department of Geology and Mines, DMH, and other line ministries and departments related to disaster management

6.4 ESTABLISHMENT OF A NATIONAL EARLY WARNING CENTER IN LAO PDR

As a result of the various hydro-meteorological and geological hazards that occur in the country, it is necessary to establish a national EWS in Lao PDR. In order to do so, meteorological observation and prediction capacities need to be improved, the hydrometric network for enhancing flood monitoring and forecasting capability needs to be improved, landslide prediction and EW capabilities need to be refined and long- and short-term drought forecasting and an effective monitoring system for agriculture and associated sectors need to be established.

6.4.1 ESTABLISHMENT OF A NATIONAL EW CENTER IN LAO PDR

Geographical Area: Whole country

Activity

- Establish a multi-hazard EW division of NDMO at DMH premises
- Institutionalize inter-agency arrangements for national EW with the relevant lead agencies
- Establish a coordinating mechanism that incorporates an effective communication system for the dissemination of EW
- Formalized dissemination arrangements through parallel local radio communication

Outputs:

- Establishment of the EW centre

Contact Ministry / Department / Agency / Institute

- DMH, Government of Lao PDR
- Department of Geology and Mines, and other line ministries and departments related to disaster management

6.4.2 IMPROVEMENT OF METEOROLOGICAL OBSERVATIONS AND PREDICTION CAPABILITIES

Geographical area: Whole country

Activities:

- Develop new automatic weather observation stations with a data processing and display system at DMH, Vientiane linked with a real-time communication system
- Enhance the prediction capabilities for floods

Outputs:

- Improved meteorological observation and prediction capabilities

Contact Ministry / Department / Agency / Institute

- DMH, Government of Lao PDR
- Department of Geology and Mines, DWIDP, and other line ministries and departments related to disaster management
- Improve the hydrometric network for enhancing flood monitoring and forecasting capabilities

Geographical area: Whole country

Activity
- Establish new gauging stations
- Upgrade existing gauging stations
- Procurement of new measuring and communication equipment
- Establish an effective communication network to help communicate data from the field
- Upgrade the data processing units
- Make improvements to the data processing system and develop a well organized database system
- Improve the existing flood forecasting system or develop a suitable flood forecasting model
- Train engineer and operational staff on the modern hydrological applications and instruments that are used

Outputs

Real time forecasting system established to mitigate flood hazards comprising of
  - Well-established hydrometric networks for the country
  - Well-organized database systems
  - Well-established data analysis and forecasting systems

Contact Ministry / Department / Agency / Institute
- DMH, Government of Lao PDR
- Department of Geology and Mines, Department of Irrigation and other line ministries and departments related to disaster management

6.4.3 IMPROVEMENTS IN LANDSLIDE PREDICTION AND EW CAPABILITIES

Geographical area: Whole country

Activities
- Updating and up-scaling of the already prepared landslide hazard forecasting system
- Collection of data and soil parameters to be added as an additional layer to hazard maps
- Identification and installation of automatic rain gauge stations in landslide prone areas
- Installation of suitable instruments to measure precipitation rates
- Analysis of historical data on rainfall and the occurrence of landslides in order to obtain threshold limits for the initiation of landslides
- Develop a proper data exchange network system among relevant institutions and communities at risk
- Develop an EWS and disseminate information down to the grass-root level
- Enhance training and capacity building

Outputs

Properly established EWS to protect at-risk communities and their property from landslides

Contact Ministry / Department / Agency / Institute
- DMH, Government of Lao PDR
- Department of Geology and Mines, Department of Roads and other line ministries and departments related to disaster management

6.4.4 DEVELOP LONG- AND SHORT-TERM DROUGHT FORECASTING AND MONITORING SYSTEMS FOR AGRICULTURAL AND ASSOCIATED SECTORS

Geographical Area: Whole country

Activities
- Upgrading of agro-meteorological observation networks in the country
  - Procurement of new equipment
  - Provision of communication links to each agro-meteorological stations with email facilities
- Upgrading of the agro-meteorology division of the DoA
  - Procurement of high-capacity computers
  - Dedicated communication links leased to the internet lines
- Establishment of a crop-forecasting unit at the DoA headquarters
  - Building construction
  - Procurement of computers, office and furniture
  - Establish a database on weather and crop information
  - Formulate a crop-weather watch group from relevant agencies that meet for a bi-monthly meeting
  - Publish a seasonal news bulletin
  - Issue a yield forecast of the major food crops one month before the end of each growing season

Outputs
- Establish an end-to-end early drought forecasting network
- The agro-meteorological observation network
- Real-time database on agro-meteorology covering the entire country
- Database on crops and other related data with seasonal updating
- Seasonal newsletter
- Yield forecast of major crops in each growing season with a sufficient lead time

Contact Ministry / Department / Agency / Institute
- DMH, Government of Lao PDR
- DoA, Department of Irrigation and other line ministries and departments related to DM

6.5 PREPAREDNESS AND RESPONSE PLAN

The objective of a disaster preparedness and response plan is to minimize the adverse effects of a hazard through effective precautionary actions whilst preparing adequate responses to ensure the timely and coordinated delivery of relief and assistance following a disaster. The recommendations include hazard-specific response plans, national rapid response teams, EOCs, hazard-specific contingency plans, emergency service networks, knowledge-management systems, health sector preparedness and response mechanisms, private sector preparedness for disaster response, capacity building of the local government, provision of storage facilities for emergency reserves and resources needed, construction of multi-purpose shelters and the establishment of a nation-wide emergency communication system.

6.5.1 HAZARD SPECIFIC RESPONSE PLANS

Geographical Area: Whole country

Activities

- Set up technical advisory committee and standard operating procedure (SOP) for each type of hazard
- Facilitate meetings to develop the risk-profile and risk management approaches or strategies to be used
- Share guidelines for the development of a draft response plan at the different district, divisional and local authority levels
- Develop a draft plan, linking response plans at the various levels (village, district, provinces and local authorities) and link with the working group developing the SOPs
- Field-test and finalize the plans

Outputs

- Hazard specific response plans are in place at the national level, with appropriate links to the provincial, district, and village level
  - Community-level plans for earthquakes, floods, landslides, droughts, lightning and thunderstorms

Contact Ministry / Department / Agency / Institute

- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.2 NATIONAL RAPID RESPONSE TEAM

Geographical Area: Whole country

Activities:

- Identification of specialized skill-sets required and establish a team that hold a legal mandate
- Training and capacity-building of team members
- Standard command and control procedures developed Which are then linked with the contingency plans
- Public dissemination of the availability of these teams
- Develop a telephone directory for these team members

Outputs:

- Specialized national rapid -response teams operational for deployment during a disaster

Contact Ministry / Department / Agency / Institute

- DMH, Government of Lao PDR
- Department of Geology and Mines, and other line ministries and departments related to disaster management

6.5.3 EMERGENCY OPERATION CENTER (EOC)

Geographical area: Whole country

Activities

- Specific role for the EOC and the incident command system (ICS)to be defined and adopted
- Infrastructure to be provided
- SOPs and institutional tools to be made available to the center
- Field-testing and regular drills to be established
- Provision of financial resources to activate any response or contingency plans, followed by continuous monitoring
- Hiring of consultants and subject experts for the SOPs
- Establish EOCs at NDMO and all provinces
- Office equipment for EOC and other provinces provided
- Communication equipment for the EOC provided
- Study tours and exposure visits to EOCs in the region
- Identify agencies with adequate material and human resources for emergency response
- Design and operationalize the resource networks for emergency response

Outputs

- Setting up of ICS – an institutional framework for a response operation. This will provide unified command and structure of disaster response through existing ministries / departments / agencies
- EOCs at the district level form a decentralized mechanism for response operations, whilst maintaining a standard approach to emergency operations. This will emphasize the development of standing orders, whilst providing legal status to concerned agencies to carry out tasks whilst working under EOCs.

Contact Ministry / Department / Agency / Institute

- NDMO, Government of Lao PDR
- Other line ministries and departments related to DM

6.5.4 HAZARD SPECIFIC CONTINGENCY PLANNING

Geographical Area: Whole country

Activities

The capacity of people and the risk exposure to the hazard is mapped by each ministry, department and agency, whilst:

- Developing institutional safety plans to protect or limit the damage to its own infrastructure and facilities
- Developing contingency plans to maintain its organizational preparedness, so as to be in a position to offer services as and when required
- Developing public warning and awareness systems for each type of contingency plan

- Providing a legal-base detailing their own self-compliance to the contingency plans
- Establishing and strengthening monitoring capacities of the responsible governments or private sector entities
- Improve social protection or a safety-net through insurance

Outputs
- Hazard specific contingency plans are put in place by various line ministries, departments and government agencies, as required
  - National Industrial and chemical hazard management permits
  - Forest-fire management plans
  - Dam-related hazard management plans
  - Biological-hazard management plans
  - Urban-fire suppression and management plans
  - Road traffic accident management plans
  - Epidemic management plans
  - Explosion and bomb blasts management plans

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.5 EMERGENCY SERVICE NETWORKING

Geographical Area: Whole country

Activities
- Set up emergency services, in order of priority, in all areas not currently covered
- Upgrade existing services (skills, equipment and human resources) to meet the risks faced
- Set up a technical advisory committee to identify the scale and type of needs of the community at risk under different emergency scenarios whilst also considering the focal departments or bodies that will help carry out or provide services under these sectors
- Identify team leaders for each sectoral service agency or department at the national and district level
- Establish operational links and mechanisms of the EOC and DMC roles under the response and contingency planning
- Disseminate information about the existence of such focal bodies, respective mandates and operational mechanisms

Outputs
- Emergency service networks (warning, evacuation, mass care, disaster victim identification (DVI), tracing and family reunion, health and medical care, public warning and so on) in place at provincial, district, municipal and urban council levels

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.6 KNOWLEDGE MANAGEMENT SYSTEMS

Geographical Area: Whole country

Activities
- Organize a multi-stakeholder national-level workshop to:
  - Develop an institutional mechanism to carry out a workshop on the lessons-learned after every disaster response operation, based on a standard methodology
  - Develop a mechanism to record, interpret and transfer such knowledge into disaster response and mitigation planning in the country
  - Review and renegotiation the institutional framework as required
- Organize provincial level meetings that enable different stakeholders to communicate and establish local mechanisms to operationalize such measures
- Publish and disseminate lessons learned, suggest improvements for mitigation measures and decide on changes to the institutional framework after every disaster or every year, depending on what occurs first

Outputs
- Knowledge management systems established to update the national response plans and incorporate the lessons learned
- Institutional framework established to record, analyze, interpret and act upon the knowledge generated through lessons learned after every disaster
- Lead agency identified to carry out this task at the provincial and national level, depending upon scale of disaster
- Communication protocol established to ensure the incorporation of the knowledge management system into the disaster management framework at all levels

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- National Geography Department , other line ministries and departments related to disaster management

6.5.7 HEALTH SECTOR PREPAREDNESS AND RESPONSE MECHANISM

Geographical Area: Whole country

Activities
- Establish health sector disaster management committees and action groups
- Review and update laws, regulations and by-laws relating to the health sector preparedness strategies
- Improve the resilience and response capacity of health institutions
- Train health staff
- Compile an inventory of resources for the health sector disaster management
- Network with other relevant agencies
- Establish an emergency operation room at all levels
- Strengthen the risk analysis process relating to the health sector preparedness and response strategies
- Prepare disaster management plans at all sub-national levels
- Prepare disaster or emergency preparedness plans and response plans at the institutional level

- Conduct community-based awareness programs
- Conduct research relating to the health sector disaster preparedness and response plans and activities

Disaster response
- Preparation of SOPs for emergency response and relief
- Establish special teams for rapid deployment
- Preparation of plans for mass-casualty management at the hospital level
- Network among relevant agencies on disaster response and relief

Outputs
- Health sector disaster management committees and action groups at all levels established
- Laws, regulations and by-laws on the health sector disaster management complied and regularly updated
- Capacity of health sector institutions and staff at all levels improved for disaster preparedness and response
- Inventory of resources for health sector disaster management compiled and updated
- Emergency operation rooms at the national and district-level established
- Disaster preparedness plans and monitoring and evaluation mechanisms prepared
- Community-level action groups help assist health services

Contact Ministry / Department / Agency / Institute
- Department of Health Services, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.8 PRIVATE SECTOR PREPAREDNESS FOR DISASTER RESPONSE

Geographical Area: Whole country

Activities
- Identify and establish contacts within the existing national and local level trade or business organizations
- Where they do not exist, form new relationships between business communities at the local and national levels
- Organize meetings and workshops to improve awareness and provide guidance and assistance to help business units establish their own plans for responding to disasters and for rapid recovery after a disaster
- Provide assistance to businesses to help them set up and provide a forum for exchanging information exchange which will help enhance emergency preparedness and contingency planning within the business community
- Monitor disaster preparedness whilst updating the plans so that businesses remain prepared for any future hazards that may occur

Outputs
- New associations formed among business communities at the local and national level
- Existing associations among businesses identified
- Guidance and assistance provided to businesses so that they have their own plans for responding to disasters and for rapid recovery after a disaster
- Assistance provided to businesses so that they are able to organize themselves to provide a forum for information exchange to enhance emergency preparedness

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.9 CAPACITY BUILDING OF LOCAL AUTHORITIES FOR EMERGENCY RESPONSE

Geographical Area: Whole country

Activities
- Assessment of the response requirements
- Recruitment and training of staff by relevant municipal councils (MCs) and major urban councils (UCs)

Outputs
- Equipment provided for selected local authorities
- Recruitment of staff and training provided

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.10 PROVISION OF FACILITIES FOR STORAGE OF EMERGENCY RESERVES AND RESOURCE NEEDS

Geographical Area: Whole country

Activities
- Selection of locations
- Identification of type of storage materials used
- Design of facilities of 2000 M^2 each, in selected locations

Outputs
- Storehouse for emergency resources needed in the selected locations

Contact Ministry / Department / Agency / Institute
- NDMO, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.5.11 ESTABLISH A NATION-WIDE EMERGENCY COMMUNICATION SYSTEM

Geographical Area: Whole country

Activities
- Identify exact requirements of the regional, district, and local authorities, with NDMO and EOC as the main focal points
- Supply the required equipment, in order of priority

Outputs
- A nation-wide radio communication system in place

Contact Ministry / Department / Agency / Institute

- Ministry of Communications, Transport, Post and Construction, Government of Lao PDR
- Other line ministries and departments related to disaster management

6.6 INTEGRATION OF DRR INTO DEVELOPMENT PLANNING

Planning department under the Ministry of Planning and Investment is a focal point to develop a national development plan. It is necessary to include all DRR components in respective projects and plans. NDMO should coordinate with the planning department and review the current status of mainstreaming DRR into development programs and projects.

6.7 COMMUNITY BASED DISASTER MANAGEMENT

Communities are affected by the primary impacts of disasters and are consequently the first to respond. Preparing communities for disasters is the first step and first line of defense against different hazards and is therefore key to reducing vulnerability and increasing disaster resilience. Having a well-resourced and sustainable program will help communities better prepare and manage disasters; CBDRM is therefore a key strategy for helping to achieve a safer Lao PDR. Nevertheless so far there has been insufficient coordination between the efforts of the government at the district and divisional level and action planning and the interventions of NGOs at the community level. After the devastating tsunami, there has been significantly greater acceptance within the country (and among international donors) of the country's relatively high vulnerability to disasters. Consequently there is a greater willingness to invest resources in pre-disaster preparedness and mitigation, especially at the community level; this provides a significant opportunity for the government to help initiate a national program on CBDRM. Under the CBDRM theme the following activities are recommended:

a. **Community DRM Teams at All Levels:** This sub-component seeks to establish a community team for DRM in all at-risk communities in the country. These community DRM teams will be responsible for EW, preparedness, response and mitigation. The sub-component will support the establishment of these teams, provide initial orientation and training, support the undertaking of village-level hazards, vulnerability and capacity assessment, preparation of response and evacuation plans, and the identification of micro-projects on mitigation. The teams will provide periodic training and will be expected to conduct periodic drills and rehearsals.

b. **An Effective National Network of Local Volunteers for DRM:** There is a need to establish a national scheme for community-based disaster response volunteers. These volunteers will support the dissemination of EW, assist in evacuation, search and rescue, provide first aid and medical response, and support the running of camps. They will be active members of the CBDRM groups. The components will record the registration of volunteers in a database and this will be made available at the province, district and community levels. A scheme for providing recognition of volunteers needs to be established in the form of certificates and identify cards. A standard curriculum and large-scale training for these volunteers will be provided and is to be undertaken by all who want to volunteer.

c. **Establishing a CBDRM Resource Center in Each District:** This component will establish CBDRM resource centers in each district. Members of staff in the resource centers will act as facilitators for the CBDRM teams and activities in the district, provide technical support, support the district commissioners with regards to the maintenance of the database, as well as undertake documentation and dissemination of CBDRM experiences. The aim is to identify agencies at the district level that are willing to take on this role and then to support them in strengthening their capacity to serve this function.

d. **Small Grants Program:** There is a plan to create a CBDRM Small Grants Program to support the implementation of priority community preparedness and mitigation projects by community DRM teams for EW, preparedness, response and mitigation projects.

e. **Applied Research Grant Schemes for Government Agencies to Implement Community Level Risk Management Programs:** The aim is to establish a fund in the DMC to award annual applied research grants to implement mitigation and risk management programs at the community-level, in partnership with at-risk communities; this fund will be made available to government institutions, universities, academic institutions and professional bodies.

f. **Develop a Micro-Finance Scheme to Reduce Community Vulnerability at the Household Level and To Help Promote Alternative Livelihood Options:** This sub-component will work with a number of Lao micro-finance institutions to support the establishment of schemes that help enable vulnerable communities, in hazard prone locations, to identify and take up alternative and additional livelihood options, as well as invest in mitigation measures to improve the disaster resilience of household and livelihood assets.

g. **Training of Key State and Non-State Actors at the Local Level:** This sub-component will help strengthen the capacity of key actors at the local level such as volunteers from specified villages and the local citizens' committees to help in the area of conflict resolution and peace keeping through specific training.

h. **Promoting Mechanisms for Communities to Seek Accountability and Express Grievances:** An independent and effective redress mechanism for complaints and grievances in relation to disasters will be created in close collaboration with the UN human rights commission.

6.8 PUBLIC AWARENESS, EDUCATION AND TRAINING

An important aspect of any DRM program is to anticipate the requirements for disaster-related public awareness, education and training. The planning process will only be effective if those who are the ultimate beneficiaries know how to mitigate disasters, respond in times of disasters and develop capacities to cope in their aftermath. For this reason, an essential part of DRM planning is the education of those who may be at risk of potential disaster events. At present, many government organizations, NGOs and community-based organizations (CBOs) conduct DRM related training. Nevertheless efforts are often being duplicated or training is being conducted without the appropriate resources.

The main programs identified under the theme of public awareness, training and education are:

- Promote public awareness at the national level: this can be done though effective implementation of a national public awareness program for disaster preparedness.
- Promote awareness within schools: this can be achieved through the introduction of disaster management-related subjects in the school curriculum, and through awareness campaigns and publications produced in Lao language.
- Promote awareness and train university students by incorporating DRR into the university curriculum: the integration of information on disaster management within different subjects at university, such as urban planning, civil engineering and architecture would help promote awareness and will help with DRR planning in the future. This has already been implemented in some universities, but needs to be addressed on a larger scale.
- Increased awareness of DRM within the school curriculum: disaster management would not be a new subject area in the curriculum, but instead should be integrated into existing subjects.
- Promote awareness among professional groups and key decision makers through training: this would involve training on disaster preparedness and reduction at a number of different levels, including entry level, refresher training and in service training of government staff at various levels.
- Increase capacity among key institutions through the training of officials and the provision of training tools and resources.
- Integrate DRM training within development and educational initiatives: Professionals who are involved in planning, implementation, financial management and so on need to understand the implications of DRM and the positive impact it will have on sustaining development efforts.
- National awareness campaigns on public safety in disasters.

REFERENCES

1. Arya A.S. and TEAC Consult (1994) 2. Development of Alternative Buildings Material and Technology for Nepal: Seismic Vulnerability Analysis (Appendix C). In: UNDP (1994) His Majesty's Govt. of Nepal, Ministry of Housing and Physical Planning, UNDP/UNCHS (Habitat), Subproject NEP/88/054/21.03.
2. Bhattarai, D. and Chhetri, M. B. (2001). Mitigation and Management of Floods in Nepal, Ministry of Home Affairs, HMG/Nepal.
3. Bragga, F., Dolce, M. and Liberatore, D. (1986) Assessment of the Relationship between Macroseismic Intensity Type of Building and Damage, based on the Recent Italy Earthquake Data. In: Proceedings of the 8th European Conference on Earthquake Engineering, Lisbon.
4. Carol J. Friedland (2009); Residential Building Damage From Hurricane Storm Surge: Proposed Methodologies to Describe, Assess and Model Building Damage ; A Dissertation Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Civil and Environmental Engineering
5. Coburn, A. and Spence, R. (1992) Earthquake Protection. Chichester, West Sussex: John Wiley & Sons Ltd.
6. Coburn,A., Pomonis,A., Sakai, S., and Spence, R.(1992). Reducing Human Casualties in Building Collapse, Methods of Optimising Disaster Plans to Reduce Injury Levels. The Martin Centre for Architectural and Urban Studies, University of Cambridge, 6 Chaucre Road, Cambridge CB2 2EB, United Kingdom.
7. CRED (2010). EMDAT. The OFDA/CRED International Disaster Database, www.em-dat.net - Université catholique de Louvain - Brussels – Belgium.
8. Czarneck, R.M., Scholl, R.E. and Malik, L.E. (1986) Techniques for Estimating Earthquake Probable Loss for Buildings and Contents. In: Techniques for Rapid Assessment of Seismic Vulnerability. American Society of Civil Engineers, Structures Congress 1986, New Orleans Conference Proceeding Paper: 67-78.
9. Dong, W., Shah, H., Klun, J. and Green, S. (1995) Estimating Residential Dwelling Losses: The California Residential Earthquake Recovery Fund (CRERF) Experience. In: Proceedings of the 10th European Conference on Earthquake Engineering. Vienna: 28 August - 2 September 1994.
10. Dutta, D., Herath, S. and Musiake, K. (2003) A Mathematical Model for flood loss estimation. Journal of Hydrology 277 (1-2) 24-49.
11. Exposure assessment and models, website reference http://www.epa.gov/opptintr/exposure/ referred on 4th August 2010
12. Federal Emergency Management Agency [FEMA] (1999) Chapter 5: Direct Physical Damage - General Building Stock. HAZUS99 Technical Manual. National Institute of Building Sciences (NIBS).
13. GeoHazards International and UNCRD (2001) Final Report, GESI: Global Earthquake Safety Initiative Pilot Project. Geneva: United Nations.
14. Guragain, R., Warakanchana, K., Mayourca, P. and Meguro, K. (2006) Numerical Simulation of Masonry Structures under Cyclic Loading Using Applied Element Method. Seisen Kenkyu 58(6) 531-534. Institute of Industrial Science, University of Tokyo.
15. Hamada, M. (1991) Damage Assessment of Lifeline Systems in Japan. In: Proceedings of the 4th US-Japan Workshop on Earthquake Disaster Prevention for Lifeline System. National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, Maryland, pp. 321-333.
16. IDNDR Secretariat and UNISDR (1999) RADIUS: Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters. Geneva: United Nations.
17. Jain, S.K., Tripathi, R.P and Agrawal, A.K (1991) Geotechnical Damage due to Bihar Earthquake of August 1988. In: Proceedings of the 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics. St. Louis: 11-15 March 1991, Paper No. 3.44, pp. 519-524.
18. Jean-Paul Pinelli , Emil Simiu, Kurt Gurley , Chelakara Subramanian , Liang Zhang , Anne Cope , James J. Filliben , and Shahid Hamid (2004) : Hurricane Damage Prediction Model for Residential Structures.
19. Kalevras, V.C. (1986) RC Building Earthquake Capacity / Vulnerability Evaluation Based on Approximate Analysis and Correction Factors. In: Proceedings of the 8th European Conference on Earthquake Engineering, Lisbon.
20. Kang, J.L., Su, M-D. and Chang, L-F. (2005) Loss functions and framework for regional flood damage estimation in residential areas. Journal of Marine Science and Technology 13(3) 193-199.
21. Kiremidjian, A.S., ed. (1990) Recent Lifeline Seismic Risk Studies. In: Proceedings of the 1990 Annual Civil Engineering Convention and Exposition. San Francisco: 5 November 1990. American Society of Civil Engineers.
22. Klien, D., Schalk, M. and Woelfel, H. (1985) Seismic Failure Probabilistic of PWR Components. In: Proceedings of the 8th International Conference on Structural Mechanics in Reactor Technology. Brussels: August 1985.
23. Krimgold, F. (1988) Search and Rescue in Collapsed Reinforced Concrete Buildings. In: Proceedings of 9th World Conference on Earthquake Engineering. Tokyo-Kyoto: 2-9 August 1988, Volume VIII. College of Architecture and Urban Studies, Virginia Polytechnic Institute and State University.
24. Kumar, A., and Bose P.R (2000) Cost Benefit Analysis of Earthquake Protection Programme Through Retrofitting of Non Engineered Buildings. In: Proceedings of the 12th World Conference on Earthquake Engineering. Auckland: 30 January - 4 February 2000.
25. Lofti, H.R. and Shing, P.B. (1991) An appraisal of smeared crack models for masonry shear wall analysis. Computers & Structures 41(3) 413-425. Elsevier Ltd.
26. Manual for Estimating the Socio-Economic Effects of Natural Disasters, Website reference www.eclac.cl/publicaciones/xml/8/7818/partone.pdf downloaded on 15th August 2010
27. Mark G. Stewart (2002) Cyclone damage and temporal changes to building vulnerability and economic risks for residential construction. Centre for Infrastructure Performance and Reliability, School of Engineering, The University of Newcastle, Rankin Drive, Callaghan, New South Wales, 2308, Australia
28. Mayorca, P. and Meguro, K. (2004) Proposal of an Efficient Technique for Retrofitting Unreinforced Masonry Dwellings. In: Proceedings of the 13th World Conference on Earthquake Engineering. Vancouver: 1-6 August 2004.
29. McBean, E.A., Gorrie, J., Fortin, M., Ding, J. and Moulton, R. (1998) Flood Depth-Damage Curve by Interview Survey. Journal of Water Resources Planning and Management 114 (6) 613-634.
30. Meguro, K. and Tagel-Din, H. (2001) Applied Element Simulation of RC Structures under Cyclic Loading. Journal of Structural Engineering 127(11) 1295-1305. American Society of Civil Engineers.
31. Mooney, K. (1977) The Valuation of Human Life. London: Macmillan.
32. M. Pelling, A. Maskrey, P. Ruiz, L. Hall, eds(2004). Reducing Disaster Risk: a challenge for development. A global report ; UNDP, John S. Swift Co., USA, 146 pp.
33. National Society of Earthquake Technology. (2007). National Strategy for Disaster Risk Management in Nepal. National Society of Earthquake Technology (NSET)

34. Noji, E.K., Jones, N.P., Smith, G.S. and Krimgold, F. (1989) Use of Quantitative Measures of Injury Severity in Earthquake Research for Mitigation and Response. In: Proceedings of The Johns Hopkins University, International Workshop on Earthquake Injury Epidemiology. Baltimore: 10 - 12 July 1989.

35. OAS (1991). Primer on Natural Hazard Management in Integrated Regional Development Planning. Washington DC, Organization of American States.

36. Ohta, Y., Ohashi, H. and Kagami, H (1986) A Semi Empirical Equation for Estimating Occupants Casualty in an Earthquake. In: Proceedings of the 8th European Conference on Earthquake Engineering, Lisbon. European Association for Earthquake Engineering, 2(3) 81-8.

37. Pandey, B.H. and Meguro, K. (2004) Simulation of Brick Masonry Wall Behavior under Inplane Lateral Loading Using Applied Element Method. In: Proceedings of the 13th World Conference on Earthquake Engineering. Vancouver: 1-6 August 2004.

38. Peter J. Vickery, Peter F. Skerlj , Jason Lin; Lawrence A. Twisdale Jr., Michael A. Young , and Francis M. Lavell (2006): HAZUS-MH Hurricane Model Methodology. II: Damage and Loss Estimation.

39. Rojahn, C. and Sharpe, R.L. (1985) ACT-13: Earthquake damage evaluation data for California. Applied Technology Council, California, USA.

40. Schick, A.and Polackova Brixi, H. (eds.) (2004). Government at Risk. World Bank and Oxford University Press, Washington DC.

41. Shiono K. and Krimgold K. (1989) A Computer Model for the Recovery of Trapped People in a Collapse Building: Development of a Theoretical Framework and Direction for Future Collection. In: Proceedings of The Johns Hopkins University International Workshop on Earthquake Injury Epidemiology. Baltimore: 10 - 12 July 1989.

42. Shipp, J.G. and Johnson, M.W. (1990) Seismic Loss Estimation for Non Structural Components in High-Rise Buildings. In: Proceedings of the 4th U.S. National Conference on Earthquake Engineering Volume 3, pp. 61-70. Palm Springs: 20-24 May 1990.

43. Smith, D.I. (1994) Flood damage estimation - A review of urban stage-drama curves and loss functions. Center for Resource and Environmental Studies 20(3) 231-238.

44. Terminology: Basic terms of disaster risk reduction, Web reference http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm

45. Tkach, R.J. and Simonovic, S.P. (1997) A New Approach to Multi-criteria Decision Making in Water Resources. Journal of Geographic Information and Decision Analysis 1(1) 25-44.

46. Vulnerability Assessment, Website reference http://www.cdera.org/projects/champ/mitiplcy/vulnerb.shtml downloaded on 15 August 2010

47. Vulnerability Assessment Techniques and Applications (VATA), web reference: http://www.csc.noaa.gov/vata/rvas.html referred on 15th August 2010

48. Whitman R.V., Reed J.W. and Hong S.T. (1974) Earthquake Damage Probability Matrices. In: Proceedings of the 5th World Conference on Earthquake Engineering. Rome: 25-29 June 1973, Volume II, pp. 2531-2540.

49. WMO, 2005. World Meteorological Organization, 2005. Meteoworld (Weather Climate Water).

50. Whitman R.V., Vanmarcke E.H., de Neufville R.L., Brennan III J.E., Cornell C.A. and Biggs J.M. (1975) Seismic Design Decision Analysis. Journal of the Structural Division 101(5) 1067-1084.

51. Y.L.Xu (1997) Fatigue Damage Estimation on metal roof cladding subject to wind loading . Journal on Wind Engineering and Industrial Aerodynamics 72 (1997) 379-388. Department of Civil and Structural Engineering , The Hong Kong Polytechnic University, Hung Hom,Kowloon, Hong Kong, China

Appendix I

Appendix of Earthquake EVRA

Table 1 Hospitals / Health centers exposed to earthquake hazard zone

Province Name	No. of Hospital exposed for each MMI Intensity		
	Intensity I-V	Intensity VI	Intensity VII
ATTAPEU	27	0	0
BOKEO	0	4	25
BORIKHAMXAI	34	1	0
CHAMPASSACK	61	0	0
HOUAPHAN	0	47	0
KHAMMOUANE	80	0	0
LOUANG PHRABANG	0	20	37
LOUANG NAMTHA	0	0	33
OUDOMXAI	0	0	40
PHONGSALY	0	2	18
SARAVANE	41	0	0
SAVANNAKHET	81	0	0
VIENTIANE	0	43	0
VIENTIANE MUN.	58	8	0
XAIGNABOURI	0	32	36
XEKONG	20	0	0
XAISOMBOUN SR	0	21	0
XIANG KHOUANG	0	42	0

Table 2 Transportation sector exposed to earthquake hazard zone

Province Name	Road length (km) exposed for each MMI Intensity		
	Intensity I-V	Intensity VI	Intensity VII
ATTAPEU	305	0	0
BOKEO	0	0	86
BORIKHAMXAI	535	19	0
CHAMPASSACK	580	0	0
HOUAPHAN	0	454	0
KHAMMOUANE	430	0	0
LOUANG PHRABANG	0	181	356
LOUANG NAMTHA	0	0	278
OUDOMXAI	0	0	283
PHONGSALY	0	23	428
SARAVANE	408	0	0
SAVANNAKHET	584	0	0
VIENTIANE	2	393	0
VIENTIANE MUN.	175	52	0
XAIGNABOURI	0	237	331
XAISOMBOUN SR	0	354	0
XEKONG	178	0	0
XIANG KHOUANG	0	388	0

Table 3 Distribution of housing exposed to earthquake hazard zone

Province Name	Intensity I-V					Intensity VI					Intensity VII				
	Bamboo	Brick/RCC	No Data	Other	Wood	Bamboo	Brick	No Data	Other	Wood	Bamboo	Brick	No Data	Other	Wood
ATTAPEU	15780	44	383	651	2885	0	0	0	0	0	0	0	0	0	0
BOKEO	0	0	0	0	0	963	17	0	0	441	18938	406	1466	40	3414
BORIKHAMXAI	25346	598	468	69	10603	1896	0	0	0	176	0	0	0	0	0
CHAMPASSACK	30169	163	177	3137	71598	0	0	0	0	0	0	0	0	0	0
HOUAPHAN	0	0	0	0	16	10599	40	1260	12	30510	0	0	0	0	0
KHAMMOUANE	43574	247	8	1287	16259	0	0	0	0	0	0	0	0	0	0
LOUANG NAMTHA	0	0	0	0	0	0	0	0	0	0	17175	29	74	0	8796
LOUANG PHRABANG	0	0	0	0	0	27938	13	5349	75	5977	21366	871	1948	144	5994
OUDOMXAI	0	0	0	0	0	0	0	0	0	0	31353	136	332	257	10549
PHONGSALY	0	0	0	0	0	467	0	16	0	196	12040	178	95	2853	12377
SARAVANE	35800	71	236	674	16101	0	0	0	0	0	0	0	0	0	0
SAVANNAKHET	72818	632	2265	5166	50208	0	0	0	0	0	0	0	0	0	0
VIENTIANE	87	36	0	0	572	41417	4581	530	0	9818	5590	0	0	0	0
VIENTIANE MUN.	27708	31413	0	0	25793	32754	3039	101	0	4124	0	0	0	0	0
XAIGNABOURI	0	0	0	0	0	11999	3516	0	0	11570	26795	1771	7	460	6427
XAISOMBOUN SR	208	0	0	0	0	7867	189	134	436	1305	0	0	0	0	0
XEKONG	8892	211	90	3398	0	0	0	0	0	0	0	0	0	0	0
XIANG KHOUANG	0	0	0	0	0	6430	0	284	135	27627	0	0	0	0	0

Table 4 Education exposed to earthquake hazard zone

Province Name	No of School exposed for each MMI Intensity		
	Intensity I-V	Intensity VI	Intensity VII
ATTAPEU	166	0	0
BOKEO	0	17	156
BORIKHAMXAI	197	7	0
CHAMPASSACK	682	0	0
HOUAPHAN	0	453	0
KHAMMOUANE	444	0	0
LOUANG PHRABANG	0	199	290
LOUANG NAMTHA	0	0	238
OUDOMXAI	0	0	291
PHONGSALY	0	7	372
SARAVANE	438	0	0
SAVANNAKHET	981	0	0
XEKONG	173	0	0
VIENTIANE	2	306	6
VIENTIANE MUN.	362	36	0
XAIGNABOURI	0	141	183
XAISOMBOUN SR	1	87	0
XIANG KHOUANG	1	306	0

Table 5 Number of casualties due to experience a 250 years return period of earthquake (day-time and night-time scenario)

Province Name	Day time Population				Night time Population			
	Dead	Life threatening	Hospitalized injury	Light injury	Dead	Life threatening	Hospitalized injury	Light injury
BOKEO	2087	3130	3130	2087	4955.58	7433.37	7433.37	4955.58
LOUANG PHRABANG	4225	6338	6338	4225	10035.268	15052.902	15052.902	10035.268
LOUANG NAMTHA	2322	3483	3483	2322	5515.016	8272.524	8272.524	5515.016
OUDOMXAI	4230	6345	6345	4230	10046.098	15069.147	15069.147	10046.098
PHONGSALY	2578	3867	3867	2578	6122.446	9183.669	9183.669	6122.446
VIENTIANE	56	85	85	56	133.798	200.697	200.697	133.798
XAIGNABOURI	2984	4475	4475	2984	7086.012	10629.018	10629.018	7086.012
Total	**18482**	**27723**	**27723**	**18482**	**43894.218**	**65841.327**	**65841.327**	**43894.218**

Appendix of Flood EVRA

Table 6 Population exposed in a flood 100 year return period

Province Name	Total Population Exposed	No. of Population exposed for each depth (m.) of Flood				No. of people in working age exposed for each depth (m.) of Flood				No. of children and elder exposed for each depth (m.) of Flood			
		< 0.30	0.30-1.00	1.01-2.00	>2.00	< 0.30	0.30-1.00	1.01-2.00	>2.00	< 0.30	0.30-1.00	1.01-2.00	>2.00
ATTAPEU	46789	0	2746	1789	27122	0	1433	934	14158	0	1313	855	12964
BORIKHAMXAI	14161	1971	1132	1693	5021	1099	631	944	2799	872	501	749	2222
CHAMPASSACK	17241	2964	3989	461	4159	1512	2035	235	2122	1452	1954	226	2037
KHAMMOUANE	37985	0	1363	1693	23398	0	769	955	13199	0	594	738	10199
LOUANG PHRABANG	38337	0	2364	1534	22414	0	1284	833	12171	0	1080	701	10243
PHONGSALY	8998	0	0	0	6027	0	0	0	3056	0	0	0	2971
SARAVANE	20124	4212	2398	1234	6451	2494	1420	731	3820	1718	978	503	2631
SAVANNAKHET	120766	1900	4085	7315	67455	959	2061	3691	34034	941	2024	3624	33421
VIENTIANE	19992	812	1969	1761	9211	444	1076	962	5032	368	893	799	4179
VIENTIANE MUN.	34367	4362	1947	2332	15328	2470	1102	1320	8679	1892	845	1012	6649
XAISOMBOUN SR	322	0	0	0	226	0	0	0	130	0	0	0	96
XEKONG	3429	0	0	130	2220	0	0	70	1201	0	0	60	1019

Table 7 Housing exposed in a flood 100 year return period

Province Name	Bamboo				Brick/RCC				Other				Wood			
	< 0.30	0.30-1.00	1.01-2.00	>2.00	< 0.30	0.30-1.00	1.01-2.00	>2.00	< 0.30	0.30-1.00	1.01-2.00	>2.00	< 0.30	0.30-1.00	1.01-2.00	>2.00
ATTAPEU	5	7	10	52	0	1	1	2	1	1	2	11	3	9	11	59
BORIKHAMXAI	1	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0
CHAMPASSACK	0	0	0	1	0	0	0	0	0	0	0	0	2	1	1	3
KHAMMOUANE	1	3	4	55	0	0	0	3	0	0	0	2	1	3	4	56
LOUANG PHRABANG	0	1	1	17	0	0	0	2	0	0	0	0	0	0	0	5
PHONGSALY	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
SARAVANE	2	1	1	3	0	0	0	0	0	0	0	0	8	7	6	16
SAVANNAKHET	5	13	18	234	0	0	0	0	0	3	3	45	7	22	29	402
VIENTIANE	1	1	1	5	3	3	3	16	0	0	0	0	1	1	1	6
VIENTIANE MUN.	23	23	22	121	14	14	12	53	0	0	0	0	22	22	20	110
XAISOMBOUN SR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XEKONG	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0

Table 8 School exposed in a flood 100 year return period

Province Name	No of School exposed for each depth (m.) of Flood			
	< 0.30	0.30-1.00	1.01-2.00	>2.00
ATTAPEU	1	1	2	30
BORIKHAMXAI	1	0	1	5
CHAMPASSACK	1	1	0	5
KHAMMOUANE	0	2	1	28
LOUANG PHRABANG	0	2	1	34
PHONGSALY	0	0	0	14
SARAVANE	7	5	2	8
SAVANNAKHET	4	4	7	91
XEKONG	0	0	1	9
VIENTIANE	1	2	0	7
VIENTIANE MUN.	4	1	3	13
XAISOMBOUN SR	0	0	0	1

Table 9 Hospital/ Health Center at risk

Province Name	No. of Health Infrastructure at risk			
	D1	D2	D3	D4
ATTAPEU	0	1	2	1
KHAMMOUANE	0	1	1	1
LOUANG PHRABANG	0	2	3	1
PHONGSALY	0	1	1	0
SAVANNAKHET	1	2	4	2
VIENTIANE	0	1	1	0
Total	**1**	**8**	**12**	**5**

Table 10 Housing (Bamboo and Others type) at Risk

Province Name	No .of Housing at Risk			
	D1	D2	D3	D4
ATTAPEU	2	5	20	46
BORIKHAMXAI	0	0	1	2
CHAMPASSACK	0	0	0	0
KHAMMOUANE	1	1	13	37
LOUANG PHRABANG	0	0	4	12
PHONGSALY	0	0	0	1
SARAVANE	0	0	1	2
SAVANNAKHET	3	7	65	184

Province Name	No .of Housing at Risk			
	D1	D2	D3	D4
VIENTIANE	0	0	1	3
VIENTIANE MUN.	5	8	33	79
XAISOMBOUN SR	0	0	0	0
XEKONG	0	0	0	1
Total	**11**	**22**	**139**	**368**

Table 11 Housing (Brick/RCC and Wooden type) at Risk

Province Name	No. of Housing at risk			
	D1	D2	D3	D4
ATTAPEU	6	15	28	14
BORIKHAMXAI	0	0	0	0
CHAMPASSACK	1	1	1	1
KHAMMOUANE	5	15	27	14
LOUANG PHRABANG	1	2	3	2
PHONGSALY	0	0	0	0
SARAVANE	3	4	7	4
SAVANNAKHET	33	101	181	93
VIENTIANE	2	6	10	5
VIENTIANE MUN.	19	41	73	37
XAISOMBOUN SR	0	0	0	0
XEKONG	0	0	0	0
Total	**70**	**184**	**332**	**170**

Table 12 Number of school at risk

Province Name	No. of School at Risk			
	D1	D2	D3	D4
ATTAPEU	2	8	14	7
BORIKHAMXAI	1	1	2	1
CHAMPASSACK	0	1	2	1
KHAMMOUANE	2	7	13	6
LOUANG PHRABANG	3	9	15	8
PHONGSALY	1	4	6	3
SARAVANE	2	2	4	2
SAVANNAKHET	8	23	41	21
XEKONG	1	2	4	2
VIENTIANE	1	2	3	2
VIENTIANE MUN.	1	3	6	3
Total	22	62	110	56

Table 13 Estimated production losses

Province Name	Production	Production Loss at Plantation Stage					Production Loss at Booting Stage					Production Loss at Head and Flowering Stage					Production Loss at Ripening Stage				
		Number of days of inundation (submergence)					Number of days of inundation (submergence)					Number of days of inundation (submergence)					Number of days of inundation (submergence)				
		4	8	12	16	20	4	8	12	16	20	4	8	12	16	20	4	8	12	16	20
ATTAPEU	24814	2978	5211	11166	13648	24814	4218	9926	14889	21837	24814	3474	7196	16129	24814	24814	2481	7444	18611	24814	24814
BORIKHAMXAI	3554	426	746	1599	1955	3554	604	1422	2132	3128	3554	498	1031	2310	3554	3554	355	1066	2666	3554	3554
CHAMPASSACK	15405	1849	3235	6932	8473	15405	2619	6162	9243	13557	15405	2157	4468	10013	15405	15405	1541	4622	11554	15405	15405
KHAMMOUANE	67746	8130	14227	30486	37261	67746	11517	27099	40648	59617	67746	9485	19646	44035	67746	67746	6775	20324	50810	67746	67746
LOUANG PHRABANG	2235	268	469	1006	1229	2235	380	894	1341	1966	2235	313	648	1453	2235	2235	223	670	1676	2235	2235
SARAVANE	41524	4983	8720	18686	22838	41524	7059	16610	24915	36542	41524	5813	12042	26991	41524	41524	4152	12457	31143	41524	41524
SAVANNAKHET	161776	19413	33973	72799	88977	161776	27502	64710	97065	142363	161776	22649	46915	105154	161776	161776	16178	48533	121332	161776	161776
VIENTIANE	36352	4362	7634	16359	19994	36352	6180	14541	21811	31990	36352	5089	10542	23629	36352	36352	3635	10906	27264	36352	36352
VIENTIANE MUN.	77796	9336	16337	35008	42788	77796	13225	31118	46678	68461	77796	10891	22561	50567	77796	77796	7780	23339	58347	77796	77796
XAISOMBOUN SR	110	13	23	49	60	110	19	44	66	97	110	15	32	71	110	110	11	33	82	110	110
XEKONG	1	0	0	0	0	1	0	0	0	1	1	0	0	1	1	1	0	0	1	1	1

Appendix of Storm EVRA

Table 14 Population exposed to Storm

Province Name	Total Population	Total population exposed to Storm				working age population exposed to Storm				Dependent population exposed to Storm			
		Tropical Depression	Tropical Storm	Class 1	Class 2	Tropical Depression	Tropical Storm	Class 1	Class 2	Tropical Depression	Tropical Storm	Class 1	Class 2
ATTAPEU	111881	0	64491	47390	0	0	33665	24738	0	0	30826	22652	0
BOKEO	145660	108752	36908	0	0	57482	19508	0	0	51270	17400	0	0
BORIKHAMXAI	229145	0	229145	0	0	0	127751	0	0	0	101394	0	0
CHAMPASSACK	608379	0	600098	8281	0	0	306202	4225	0	0	293896	4056	0
HOUAPHAN	277050	179602	94849	2599	0	93928	49604	1359	0	85674	45245	1240	0
KHAMMOUANE	336749	0	224517	108784	3448	0	126656	61368	1945	0	97861	47416	1503
LOUANG NAMTHA	145132	145132	0	0	0	79446	0	0	0	65686	0	0	0
LOUANG PHRABANG	401268	229840	171428	0	0	124803	93085	0	0	105037	78343	0	0
OUDOMXAI	264371	207579	56792	0	0	120843	33062	0	0	86736	23730	0	0
PHONGSALY	164415	164415	0	0	0	83375	0	0	0	81040	0	0	0
SARAVANE	323329	116270	207059	0	0	68858	122626	0	0	47412	84433	0	0
SAVANNAKHET	825355	273111	521664	30580	0	137795	263200	15429	0	135316	258464	15151	0
VIENTIANE	358887	0	358887	0	0	0	196071	0	0	0	162816	0	0
VIENTIANE MUN.	688218	0	688218	0	0	0	389669	0	0	0	298549	0	0
XAIGNABOURI	339163	0	339163	0	0	0	181002	0	0	0	158161	0	0
XAISOMBOUN SR	66068	0	66068	0	0	0	38018	0	0	0	28050	0	0
XEKONG	84853	0	84853	0	0	0	45896	0	0	0	38957	0	0
XIANG KHOUANG	228630	168253	60377	0	0	114993	41265	0	0	53260	19112	0	0

Table 15 Hospital / Health Center exposed to Storm

Province Name	No. of Hospital/Health Center exposed to Storm			
	Tropical Depression	Tropical Storm	Class 1	Class 2
ATTAPEU	0	17	10	0
BOKEO	23	6	0	0
BORIKHAMXAI	0	35	0	0
CHAMPASSACK	0	60	1	0
HOUAPHAN	30	17	0	0
KHAMMOUANE	0	53	26	1
LOUANG PHRABANG	31	26	0	0
LOUANG NAMTHA	33	0	0	0
OUDOMXAI	29	11	0	0
PHONGSALY	20	0	0	0
SARAVANE	14	27	0	0
SAVANNAKHET	25	51	5	0
XEKONG	0	20	0	0
VIENTIANE	0	43	0	0
VIENTIANE MUN.	0	66	0	0
XAIGNABOURI	0	68	0	0
XAISOMBOUN SR	0	21	0	0
XIANG KHOUANG	27	15	0	0

Table 16 Number of housing exposed in a storm 50 year return period

Province Name	Bamboo				Brick				Other				Wood			
	Tropical Depression	Tropical Storm	Class1	Class2	Tropical Depression	Tropical Storm	Class1	Class2	Tropical Depression	Tropical Storm	Class1	Class2	Tropical Depression	Tropical Storm	Class1	Class2
ATTAPEU	0	13887	1894	0	0	35	9	0	0	504	148	0	0	1997	889	0
BOKEO	15873	4029	0	0	424	0	0	0	0	41	0	0	3389	467	0	0
BORIKHAMXAI	0	27242	0	0	0	598	0	0	0	69	0	0	0	10780	0	0
CHAMPASSACK	0	21366	8803	0	0	163	0	0	0	3137	1	0	0	69771	1827	0
HOUAPHAN	8167	2298	135	0	41	0	0	0	12	0	0	0	18240	11876	732	0
KHAMMOUANE	0	13986	25234	4356	0	247	0	0	0	373	915	0	0	12079	4036	145
LOUANG NAMTHA	17176	0	0	0	30	0	0	0	0	0	0	0	8796	0	0	0
LOUANG PHRABANG	34832	14473	0	0	294	591	0	0	53	167	0	0	8402	3570	0	0
OUDOMXAI	24383	6971	0	0	136	0	0	0	101	157	0	0	8433	2117	0	0
PHONGSALY	12508	0	0	0	179	0	0	0	2853	0	0	0	12573	0	0	0
SARAVANE	18236	17566	0	0	5	67	0	0	351	323	0	0	9266	6836	0	0
SAVANNAKHET	21993	41162	9666	0	196	436	0	0	3552	1616	0	0	24194	24558	1457	0
VIENTIANE	0	47095	0	0	0	4618	0	0	0	0	0	0	0	10390	0	0
VIENTIANE MUN.	0	60462	0	0	0	34453	0	0	0	0	0	0	0	29917	0	0
XAIGNABOURI	0	38794	0	0	0	5287	0	0	0	460	0	0	0	17998	0	0
XAISOMBOUN SR	0	8075	0	0	0	190	0	0	0	437	0	0	0	1305	0	0
XEKONG	0	8872	20	0	0	0	0	0	0	91	0	0	0	3380	19	0
XIANG KHOUANG	4067	2367	0	0	0	0	0	0	0	136	0	0	16221	12890	0	0

Table 17 Education Sector exposed to Storm

Province Name	School exposed to Storm			
	Tropical Depression	Tropical Storm	Class 1	Class 2
ATTAPEU	0	114	52	0
BOKEO	125	48	0	0
BORIKHAMXAI	0	204	0	0
CHAMPASSACK	0	669	13	0
HOUAPHAN	262	188	3	0
KHAMMOUANE	0	264	176	4
LOUANG NAMTHA	238	0	0	0
LOUANG PHRABANG	296	193	0	0
OUDOMXAI	225	66	0	0
PHONGSALY	379	0	0	0
SARAVANE	158	280	0	0
SAVANNAKHET	390	533	61	0
VIENTIANE	0	314	0	0
VIENTIANE MUN.	0	398	0	0
XEKONG	0	173	0	0
XAIGNABOURI	0	324	0	0
XAISOMBOUN SR	0	88	0	0
XIANG KHOUANG	198	109	0	0

Table 18 Housing risk profile for Class 1 of Storm in a 50 year return period

Province Name	Class 1			
	D1	D2	D3	D4
ATTAPEU	147	1065	0	0
CHAMPASSACK	532	4493	0	0
HOUAPHAN	43	104	0	0
KHAMMOUANE	1509	13276	0	0
SAVANNAKHET	556	4906	0	0
XEKONG	2	11	0	0

Table 19 Housing risk profile for Class 2 of Storm in a 50 year return period

Province Name	Class 2			
	D1	D2	D3	D4
KHAMMOUANE	225	290	3274	0

Table 20 Education risk profile for class 1 of Storm in a 50 year return period

Province Name	Class 1			
	D1	D2	D3	D4
ATTAPEU	3	0	0	0
CHAMPASSACK	1	0	0	0
HOUAPHAN	1	0	0	0
KHAMMOUANE	9	0	0	0
SAVANNAKHET	4	0	0	0

Table 21 Education risk profile for class 2 of Storm in a 50 year return period

Province Name	Class 2			
	D1	D2	D3	D4
KHAMMOUANE	2	1	0	0

Appendix of Drought EVRA

Table 22 Paddy area exposed to drought susceptibility for dry season

Province Name	Province Area	Paddy Area (sq km) Exposed to Drought Susceptibility for dry season																	
		Moderate				Severe					Extreme				Moderate to Extreme				
		0-5	5-10	10-15	15-20	<0	0-5	5-10	10-15	15-20	<0	0-5	5-10	10-15	5-10	10-15	15-20	20-25	>25
ATTAPEU	9551.39	0.0	199.0	65.1	0.0	0.0	217.7	46.3	0.0	0.0	0.0	264.0	0.0	0.0	0.0	248.1	15.9	0.0	0.0
BOKEO	6989.33	162.5	0.0	0.0	0.0	0.0	0.0	0.0	160.9	0.0	162.1	0.0	0.0	0.0	0.0	146.4	18.4	0.0	0.0
BORIKHAMXAI	15710.8	0.0	54.9	256.9	87.0	0.0	282.7	109.3	0.0	0.0	0.0	397.5	0.0	0.0	0.0	218.3	84.6	96.6	0.0
CHAMPASSACK	14981.5	783.6	897.3	0.0	0.0	0.0	51.0	876.8	749.3	0.0	386.3	893.0	400.3	0.0	0.0	66.1	1615.7	0.0	0.0
HOUAPHAN	17522.2	4.7	109.2	7.5	0.0	2.3	119.1	0.0	0.0	0.0	0.0	116.1	5.3	0.0	6.7	100.8	13.9	0.0	0.0
KHAMMOUANE	16723.8	0.0	187.6	1062.0	72.1	0.0	210.1	950.9	158.7	0.0	0.0	1321.6	0.0	0.0	0.0	0.0	556.1	765.6	0.1
LOUANG NAMTHA	9605.16	140.8	0.1	0.0	0.0	0.0	0.0	0.0	141.0	0.0	140.9	0.0	0.0	0.0	0.0	139.8	1.4	0.0	0.0
LOUANG PHRABANG	19970.9	0.4	83.4	94.4	0.0	5.5	143.3	29.3	0.0	0.0	18.3	154.5	5.4	0.0	21.7	42.7	113.8	0.0	0.0
OUDOMXAI	11794.4	0.0	59.4	23.1	0.0	0.0	1.3	41.5	39.8	0.0	36.3	46.3	0.0	0.0	0.0	0.0	64.8	17.7	0.0
PHONGSALY	15470.4	0.0	50.7	0.0	0.0	0.0	2.2	48.5	0.0	0.0	48.7	2.0	0.0	0.0	0.0	46.9	3.9	0.0	0.0
SARAVANE	10163.3	1187.0	12.7	0.0	0.0	0.0	1127.9	71.4	0.4	0.0	0.0	207.5	784.6	207.6	0.0	1137.7	61.8	0.3	0.0
SAVANNAKHET	21399.8	950.6	1910.6	1.8	0.0	0.0	2318.2	349.0	165.9	28.6	1.2	1342.2	1280.3	239.3	0.0	1834.9	817.7	181.1	29.3
VIENTIANE	12591.3	0.0	594.5	54.6	0.0	0.0	529.6	119.5	0.0	0.0	0.0	526.5	122.5	0.0	0.0	102.3	546.7	0.0	0.0
VIENTIANE MUN.	3586.78	0.0	892.3	0.0	0.0	0.0	883.3	0.0	0.0	0.0	0.0	889.6	0.0	0.0	0.0	777.6	121.4	0.0	0.0
XAIGNABOURI	15540.5	35.7	320.5	1.2	0.0	0.0	0.0	302.5	54.4	0.0	36.6	320.5	0.0	0.0	0.0	0.0	358.0	0.0	0.0
XAISOMBOUN SR	7709.37	0.0	72.3	0.0	0.0	0.0	72.3	0.0	0.0	0.0	0.0	42.2	30.1	0.0	0.0	62.7	9.7	0.0	0.0
XEKONG	8396.53	0.0	8.9	0.0	0.0	0.0	7.5	1.4	0.0	0.0	0.0	8.9	0.0	0.0	0.0	8.9	0.0	0.0	0.0
XIANG KHOUANG	12715	276.2	40.0	10.7	0.0	125.2	201.6	0.0	0.0	0.0	0.0	28.8	277.4	20.6	0.0	325.8	1.0	0.0	0.0

Table 23 Paddy area exposed to drought susceptibility for wet season

Province Name	Province Area	Paddy Area (sq km) Exposed to Drought Susceptibility for wet season																	
		Moderate						Severe				Extreme			Moderate to Extreme				
		0-5	5-10	10-15	15-20	20-25	>25	<0	0-5	5-10	10-15	<0	0-5	5-10	0-5	5-10	10-15	15-20	20-25
ATTAPEU	9551.39	161.2	102.8	0.0	0.0	0.0	0.0	0.0	184.0	80.1	0.0	0.0	264.0	0.0	0.0	264.0	0.0	0.0	0.0
BOKEO	6989.33	85.8	75.2	0.0	0.0	0.0	0.0	0.0	0.0	162.1	0.0	0.0	162.2	0.0	0.0	161.9	0.2	0.0	0.0
BORIKHAMXAI	15710.8	166.4	155.5	76.1	0.0	0.0	0.0	0.0	0.0	398.0	0.0	0.4	302.2	95.3	0.0	89.7	301.7	6.7	0.0
CHAMPASSACK	14981.5	1539.0	141.2	0.0	0.0	0.0	0.0	0.0	0.0	170.9	1510.0	0.0	1680.2	0.0	0.0	915.9	764.3	0.0	0.0
HOUAPHAN	17522.2	0.0	0.0	112.2	9.2	0.0	0.0	0.0	121.5	0.0	0.0	0.0	121.5	0.0	0.0	1.9	116.2	3.3	0.0
KHAMMOUANE	16723.8	1307.1	14.5	0.0	0.0	0.0	0.0	0.0	993.9	327.8	0.0	0.0	370.8	950.9	0.0	1318.3	3.4	0.0	0.0
LOUANG NAMTHA	9605.16	140.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.8	0.0	0.0	2.7	138.1	0.0	140.8	0.0	0.0	0.0
LOUANG PHRABANG	19970.9	0.0	47.2	127.5	3.2	0.3	0.0	0.0	130.7	47.4	0.0	27.1	151.1	0.0	35.5	23.3	119.0	0.3	0.0
OUDOMXAI	11794.4	22.6	56.5	3.5	0.0	0.0	0.0	0.0	20.1	62.4	0.0	0.0	54.3	28.2	0.0	34.9	47.6	0.0	0.0
PHONGSALY	15470.4	0.5	50.3	0.0	0.0	0.0	0.0	0.0	45.7	5.1	0.0	0.0	4.3	46.4	0.0	4.0	46.8	0.0	0.0
SARAVANE	10163.3	0.0	1199.7	0.0	0.0	0.0	0.0	0.0	0.0	107.4	1092.3	624.3	575.4	0.0	0.0	0.0	993.4	206.3	0.0
SAVANNAKHET	21399.8	849.5	1896.9	116.5	0.0	0.0	0.0	0.0	2251.0	493.0	119.0	76.4	2060.3	726.3	0.0	2310.4	434.7	117.9	0.0
VIENTIANE	12591.3	0.0	0.0	559.8	89.2	0.0	0.0	0.0	625.7	23.3	0.0	456.4	192.6	0.0	0.0	0.0	649.0	0.0	0.0
VIENTIANE MUN.	3586.78	0.0	0.0	889.6	0.0	0.0	0.0	0.0	142.0	747.7	0.0	20.2	869.5	0.0	0.0	0.0	889.6	0.0	0.0
XAIGNABOURI	15540.5	0.0	39.0	318.1	0.0	0.0	0.0	0.0	350.3	6.8	0.0	188.5	168.5	0.0	0.0	1.1	355.9	0.0	0.0
XAISOMBOUN SR	7709.37	0.0	0.0	23.8	48.5	0.0	0.0	0.0	25.4	46.9	0.0	58.2	14.1	0.0	0.0	0.0	4.8	67.5	0.0
XEKONG	8396.53	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.2	8.7	0.0	0.0	8.9	0.0	0.0	4.7	0.0	0.0	0.0
XIANG KHOUANG	12715	0.0	0.0	10.7	76.8	206.5	32.8	7.1	293.6	26.0	0.0	64.6	262.3	0.0	0.0	0.0	0.0	203.0	118.3