Multi Hazard Risk Assessment in Nargis-affected areas (Ayeyarwady, Bago, Yangon)

Hazard Risk and Vulnerability Assessment Report

United Nations Development Programme, Myanmar

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PREFACE

The United Nations Development Programme in Myanmar commissioned the TARU Leading Edge Private Limited of India to do the study based on the Terms of Reference developed by UNDP. Accordingly, the views and the opinions expressed in this paper are entirely those of TARU and do not necessary reflect the official views of UNDP and the UN.

FOREWORD

On 2 May 2008, Cyclone Nargis struck the coast of Myanmar and moved across the Ayeyarwady Delta and southern Yangon Division (now Region), carving a swathe of destruction along its path. At least 140,000 people died in the storm, with an estimated 7.35 million people affected overall.

Cyclone Nargis highlighted the need for a scientific understanding of the hazards, risks and vulnerabilities that Myanmar faces from natural disasters and what can be done in terms of mitigation, preparedness, response, rehabilitation, recovery and reconstruction when they do occur.

The Government of Myanmar has since established institutional arrangements to respond to disasters, including disaster prevention and preparedness activities. At the same time, the Government, UN agencies and NGOs drafted the Myanmar Action Plan on Disaster Risk Reduction (MAPDRR) to set up a framework for long-term national Disaster Risk Reduction programming. Disaster Risk Assessments of high risk areas in the country has been identified as one of MAPDRR's priorities.

UNDP undertook a Multi Hazard Risk Assessment of the Ayeyarwady Delta, including parts of Yangon and Bago regions that were also impacted by Cyclone Nargis, to investigate the vulnerability of communities to various natural hazards. The study identified what natural disasters could affect the region, and its vulnerabilities in relation to these phenomena.

The assessment also analyzed the likely impacts of processes associated with climate variability and change on key parameters related to changes in temperature and rain, and the likely bearing on the way the hazard/disaster scenario in the region and the country will unfold in coming decades.

The study sought to identify programming gaps and opportunities that will enable the Government and other humanitarian and development agencies to formulate Disaster Risk Reduction plans and strategies.

We hope this report will inform Disaster Risk Reduction programming of the Government, UN agencies, donors and other development organizations, ultimately leaving at-risk communities better prepared in the future.

Bishow Parajuli
Resident Representative
United Nations Development Programme - Myanmar

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We are grateful to all the departments of the Government, administration units and institutions for their cooperation in sharing and collating information, and providing feedback during the course of this study.

We would also like to thank TARU Leading Edge (P) Ltd., India and their partners, the Integrated Natural Resource Management (INRM) and the Myanmar Survey Research (MSR) Company for undertaking this study and producing an important report that will greatly inform Disaster Risk Reduction programming and practice in Nargis-affected areas.

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United Nations Development Programme Myanmar
No. 6, Natmauk Road, P.O. Box 650
Yangon, 11211
Myanmar

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Abbreviations

ANSS	Advanced National Seismic System
AR4	Fourth Assessment Report (IPCC)
ASTER	Advanced Spaceborne Thermal Emission and Reflection
BCCR-BCM2.0	Bjerknes Centre for Climate Research (BCCR), Uni. of Bergen, Norway. Model name, Bergen Climate Model
BIS	Bureau of Indian Standards
CBDRM	Community Based Disaster Risk Mitigation Programmes
CBO	Community Based Organization
CCCMA	Canadian Centre for Climate Modelling and Analysis
CCSM3	Community Climate System Model 3.0
CGCM3	Coupled Global Climate Model
CGCM3.1 (T47)	Canadian Centre for Climate Modelling and Analysis: Coupled Global Climate Model
CNRM-CM3	Global coupled system is the third version of the ocean-atmosphere model initially developed at CERFACS (Toulouse, France)
CSIRO	Commonwealth Scientific and Industrial Research Organization
DFID	Department for International Development
DPE	Direct Position Errors
EWC	Department of Meteorology and Hydrology
EHD	Equivalent Hypocentral Distance
EMS	European Macroseismic Scale
ENSO	El Nono-Southern Oscillation
EPRI	Electrical Power Research Institute
FAO	United Nations Food and Agricultural Organization
FAR	First Assessment Report
FEMA	Federal Emergency Management Agency
GFDL-CM2.0	Geophysical Fluid Dynamics Laboratory Coupled Model
GFDL-CM2.1	Geophysical Fluid Dynamics Laboratory Coupled Model
GHG	Green House Gas
GIS	Geographical Information System
GISS	Goddard Institute for Space Studies
GPS	Global Positioning System
GSHAP	Global Seismic Hazard Assessment Program
GTCC	Global Tropical Cyclone Climatic

HAZUS	Hazards United States
HadCM3	Hadley Centre for the Third Assessment Report
HEC-RAS	Hydrologic Engineering Centre – River Analysis System
IF	International Futures
IMD	India Meteorological Department
INM-CM3.0	Instituto Nazionale di Geofisica e Vulcanologia. Italy: Climate Model
IPCC	Inter Governmental Panel on Climate Change
IITM	Indian Institute of Tropical Meteorology
IPSL-CM4	Institute Pierre Simon Laplace
INGO	International Non Governmental Organizations
JTWC	Joint Typhoon Warning Centre
MCE	Maximum Considered Earthquake
MHRA	Multi Hazard Risk Analysis
MIMU	Myanmar Information Management Unit
MIROC3.2 (medres)	Model for Interdisciplinary Research on Climate
MLE	Maximum Likelihood Estimates
MM	Modified Mercalli
MMI	Modified Mercalli Intensity
MPI (ECHAM5)	Max-Planck-Institut für Meteorologie
MRI	Mean Recurrence Interval
MRI-CGCM	Meteorological Research Institute; Japan: Coupled Global Climate Model
MSK	Medvedev-Sponheur-Karnik Scale
MSR	Myanmar Survey Research
NAO	North Atlantic Oscillation
NASA	National Aeronautical & Space Administration
NCMRWF	National Centre for Medium Range Weather Forecasting
NGO	Non Governmental Organization
NHC	National Hurricane Centre
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Productivity
PCM	Parallel Climate Model
PDO	Pacific Decadal Oscillation
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity

PMSS	Probable Maximum Storm Surge
PRA	Participatory Rural Appraisal
PRESIS	Providing Regional Climates for Impacts Studies
PSHA	Probabilistic Seismic Hazard Analysis
PWHA	Probabilistic Wind Hazard Analysis
RMW	Radius of Maximum Wind
RS	Remote Sensing
SA	Spectral Acceleration
SAR	Second Assessment Report
SCR	Stable Continental Region
SPLASH	Special Programme to List Amplitude Surges from Hurricanes
SRG	Self Reliant Groups
SRES	Special Report on Emission Scenarios
SRTM	Shuttle Radar Topography Mission
SST	Sea-Surface Temperature
SWAT	Soil and Water Assessment Tool
SWMM	Storm Water Management Model
TAR	Third Assessment Report
TOR	Terms of Reference
TRMM	Tropical Rainfall Measuring Mission
UBC	Uniform Building Code
UKHO	United Kingdom Hydro graphic Office
UKMO-HadCM3	Met Office weather and climate change forecasts for the UK and Hadley Centre Coupled Model
UNEP	United Nations Environmental Program
UNESCO	United Nations Education Social and Cultural Organization
USGS	United States Geological Survey
VA	Vulnerability Assessment
WCF	West Coast Fault
WG	Work Group
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

The Context

Cyclone Nargis has been one of the cathartic events in the history of Myanmar. The colossal loss of lives and livelihoods, socio-economic development assets and community support structures brought the disaster risk reduction agenda to the fore and underscored the need to imbue greater impetus to DRR activities in Myanmar in general and especially in the Ayeyarwady delta.

South Asia and South-East Asia are among the most vulnerable regions in the world to multiple hazards and disaster risks. Myanmar, situation at the conjunction of both the regions, broadly suffers from a similar set of hazards. In spite of Myanmar's high susceptibility to hazards, relatively infrequent incidents of major disasters in the past did not establish a strong rationale for focused attention to risk reduction and mitigation activities. However, over time, the existing risks have increased and these are getting further exacerbated due to processes attributed to climate change and variability as well as other socio-economic and developmental factors. The increasing exposure to hazards and mounting vulnerabilities are leading to more and more hazards getting translated into disasters and posing greater risks to communities and development assets. Post-Cyclone Nargis, the need to inform the disaster mitigation, preparedness, response, rehabilitation and reconstruction process with a sound and scientific understanding of the hazard, risk and vulnerability profile of the country in general and in Ayeyarwady delta region in particular has been articulated. All these factors have underscored the need for conducting a proper assessment of the hazard profile, the vulnerabilities and the risks posed by various natural hazards and to develop a composite risk assessment for the area.

Scope and Methodology

The present hazard, risk and vulnerability assessment (HRVA) stems from this felt need. The assessment focuses on the Ayeyarwady delta region including Yangon and Bago divisions of Myanmar. The study identifies prevalent natural hazards in the delta region, maps/assesses hazard-specific and multi-hazard risks, analyzes key vulnerabilities and also outlines the future scenarios including impacts on key sectors associated with the national development process and having an intimate bearing on community lives and livelihoods. The assessment also analyzes the likely impacts of processes associated with climate variability and change on key parameters related to change in temperature and precipitation and its likely bearing on the way the hazard/disaster scenario in the region and the country unfold in coming decades.

The assessment takes into account the horizontal as well as the vertical spread of risks. Accordingly, the methodology addresses in-depth analyses of prominent hazards like earthquake, tsunami, cyclone, storm surge, floods and climate change impacts in the region. It also seeks to outline the probabilistic hazard analysis to identify the likely unfolding of hazards. The assessment identifies the key physical, socio-economic and economic elements at risk and strategically assesses the vulnerabilities of these elements. The risks are analyzed for each specific hazard as well as from a multi-hazard perspective to arrive at a better understanding of the composite risk profile of the region. The assessment also takes into account the key sectors of Myanmar's national and socio-economic life. These will provide valuable inputs to the on-going sector-specific recovery interventions as well as to the community-based disaster risk management initiatives.

Key Features-Hazard, Risk and Vulnerability Assessment

The *hazard risk assessment* has been done through analysis of past hazard data, historical pattern of occurrence and trends and desk review of literature and reports including some of the past reports on hazard, risk and vulnerability assessments conducted earlier and the available data. Constrained by the scarce data pool, the study has utilized scientific tools and methods for hazard risk assessment to arrive at a deterministic as well as a probabilistic hazard risk assessment. The hazard risk assessment also takes stock of the likely impacts of climate change and variability on the hazard scenario in the region to analyze possible changes in temperature and precipitation. The hazard risk assessment will provide a better understanding of the way the hazards are likely to unfold in coming years.

Assessing the vulnerability of a region as vast as the Ayeyarwady delta is a complex task as the vulnerabilities remain largely latent and intangible. However, the assessment takes into consideration parameters such as education, occupational profile with all its diversities, income with all the instabilities associated with it, the existing capacity at community and administrative levels and co-relates it with the physical, social and economic vulnerabilities, accessibility of natural resources and the social network support systems as well as the early warning mechanisms. The vulnerability assessment will assist the DRR practitioners and other national and international development and humanitarian organizations to develop vulnerability reduction and capacity building programmes. The recovery and reconstruction interventions will also receive valuable inputs and information so that they do not tend to enhance or accentuate existing vulnerabilities.

Apart from the hazard-specific risk assessment, the Study also provides a *composite risk analysis*. It seeks to identify the principal risks to the region and the communities as well as some key sectors of socio-economic life. The analysis indicates that nearly 60% of the households in the delta region are susceptible to one or the other hazard. The multiple vulnerabilities become further compounded due to lack of all-weather accessibility to the communities hampering even the evacuation efforts. Nearly 50% to 80% of the households being landless are primarily dependent on agriculture and fisheries and any impact on these sectors renders an overwhelming segment of population extremely vulnerable. It indicates high vulnerability of both the buildings and the productive assets like crops to multiple hazards.

The process of risk assessment for key sectors like shelter, livelihoods (viz. agriculture, fisheries, aquaculture, artisans, construction workers etc.) water and sanitation and micro-finance will help analyze sectoral interventions in this context. The sectoral risk assessment will help vertical integration of risks.

In the *urban vulnerability assessment* context, social and economic vulnerability/capacity are closely linked to education, income and occupational diversity of households and skills, health, age and gender of its members. At the same time, the construction practices and materials used also indicate a higher vulnerability of the building stock.

In the *rural vulnerability assessment* context, the locational vulnerability of houses and use of bio-mass based construction materials sharpens the physical vulnerability. Low land holding, inadequate access and communication modes, dependence on single livelihood source make an overwhelming segment of population vulnerable. In brief, the vulnerability of rural populace in delta region is extremely high on all five parameters of the Sustainable Livelihood Framework viz. physical, natural, human, social and financial.

In the context of global debate on likely *impacts of climate change and variability* processes, especially since South Asia and South-east Asia regions have been identified as the likely key hot spots for magnified amplitude of climatic risks, the HRVA process has also assessed the slow and imperceptible changes like sea level rise and temperature/precipitation increase and how these processes are likely to exacerbate the hazard, risk and vulnerability scenario at the national level but also in the specific context of the delta region.

Efforts have also been made to quantify the risks and present future scenarios. The composite risk assessment will help the Government, the policy and decision-makers make informed development choices. The development planning process and programme formulations for the region will benefit from the composite risk assessment. The hazard specific, multi-hazard, composite and sectoral risk assessment will help make the development process more risk averse and resilient. Use of composite risk assessment by development agencies and humanitarian actors will ensure that the proposed programmatic interventions are oriented towards addressing the identified risks and vulnerabilities especially at the community level.

Issues and Constraints

Myanmar possesses a diverse geographical terrain with different features and characteristics. This also imbues the country with a divergent hazard and vulnerability profile. Due to a relatively lesser number of disasters of severe magnitude in the past, efforts towards building a data-set of information on key hazards, their patterns of occurrence, impacts and other indicators has not been maintained. The efforts have primarily been concentrated on undertaking studies focusing on the seismic hazard risk.

For conducting a detailed and intensive HRVA, the availability of data and information on the past disasters etc. is very essential. However, the paucity of primary and secondary data tends to restrict a comprehensive and in-depth analysis. The overall data scarce environment necessitated greater focus on collecting the requisite data and information from multiple sources including community interactions to delve deeper into community's memory. However, this process by itself poses considerable challenges in terms of validating the information and data gathered. The HRVA Team has made utmost efforts to overcome this constraint by seeking to elicit and compile data from various national and international sources to arrive at a comprehensive understanding of the hazard, risk and vulnerability profile of the region.

It was also noticed that in addition to the natural hazards, the fire hazards ranks among the principal hazards for the communities. This is of prime importance across towns and urban settlements in Myanmar as the housing patterns in the country predominantly use wood as one of the major raw materials. However, the Team encountered a challenge in compiling authenticated data in order to undertake fire hazard modeling. Due to non-availability of data, the fire hazard has not been included in the key hazards listed in the Report. It is hoped that with availability of more information and data over the years, it will become feasible to undertake a detailed assessment of the fire hazard and identify suitable mitigation and preparedness measures to address the hazard.

Recommendations

The key recommendations emerging from the hazard, risk and vulnerability assessment indicate that the high hazard-proneness of the region due to a combination of multiple factors makes it imperative that DRR programmes and interventions are oriented to address the key findings emerging from the exercise. Better understanding of the key risks -- existing and emerging, residual and composite -- will help prioritize DRR interventions focusing on risk reduction, mitigation, preparedness, recovery and reconstruction as well as sectoral interventions. This will pave the way for a 'risk averse' development paradigm at national, provincial, institutional and community level.

With a view to institutionalize the DRM systems and capacities, setting-up and operationalizing an appropriate institutional, policy and legislative framework will be essential. These systems, structures and capacities need to be created at all administrative levels. It will provide direction and guidance to risk reduction, mitigation and preparedness activities across regions, sectors and stakeholders. A well researched strategy needs to be developed to address the requirements.

The HRVA will promote cross-sectoral linkages as well as facilitate greater interface between policy and development planning process and programme design by national and provincial government, bi-lateral and multi-lateral development and humanitarian agencies and civil society players.

The HVRA will facilitate integration of DRR elements into sectoral development plans and policies. A detailed sector-specific assessment, building on the key trends and issues identified through the current HRVA, needs to be conducted to arrive at a thorough understanding of each sector of national economy and community life and to understand the linkages with other walks of socio-economic life. Sectoral experts to address water and sanitation, shelter, livelihood regeneration, agriculture, safer construction practices need to be involved to develop a long-term strategy and mechanisms to integrate DRR into each of the crucial sectors. Guidelines for mainstreaming DRR into sectoral development plans need to be developed along with capacity enhancement of institutions for taking the process forward.

In view of the high vulnerability profile of the Ayeyarwady delta in particular and the country in general, it is felt that the key indicators contributing to increasing vulnerabilities and enhancing the risks need to be addressed to minimize exposure to multiple natural hazards. One such key area is the Shelter sector. It is recommended that guidelines for promoting safer construction practices, to provide sustainable housing construction solutions based on use of natural resources available in the area, developing a housing construction tool-kit, introducing risk resistant construction techniques and technologies and undertaking a feasibility study to develop mechanisms for the same needs to be undertaken. Region-specific techno-legal regime and construction practices/codes need to be developed and training and capacity building initiatives undertaken to enhance enforcement levels and promote greater compliance at community levels.

On the lines of the HRVA for Ayeyarwady delta, it will be also be prudent to take the process forward by focusing on other main vulnerable areas like the Rakhine state and use the lessons learnt to replicate the same at the national level. A composite risk and vulnerability ATLAS for Myanmar will help put disaster risk reduction and climate change adaptation at the centre-stage of national thinking and development process.

Many of the hazards especially the ones induced by climatic processes have a cause and effect relationship. A hazard in one area can lead to a disaster in another one. Moreover, the inter-dependence of socio-economic processes also necessitate closer understanding of hazards, risks and vulnerabilities across provinces to arrive at a comprehensive risk reduction framework.

At the same time, studies to document the likely impacts of climate change (CC) processes on the hazard, vulnerability profile (including social / livelihood patterns), and the key sectors directly contributing to the national gross domestic product needs to be undertaken. This will help design appropriate developmental and policy initiatives to build and strengthen community capacity to cope with adverse impacts of CC and variability over the coming decades much before their adverse impacts become perceptible.

The relevance of the HVRA and its key findings will significantly improve by factoring them into the overall national and regional development process. The national planning and development process should incorporate the risk assessments for designing development projects and programmes for urban and rural areas as also for key sectors and other infrastructure development. It will also be pertinent to disseminate these findings in an easy-to-understand format to the vulnerable communities so that they are able to take greater initiative to secure their lives and livelihoods instead of being dependent on external assistance.

The Way Forward

While the technical HRVA will assist in preparing long-term risk reduction, mitigation and preparedness interventions and incorporation of disaster risk reduction concerns into the national and provincial development planning process, it will be equally pertinent to highlight some of the key preparedness and response planning measures which need to be put in place. This assumes significance in view of the region's high susceptibility to multiple hazards and low coping capacity of communities and socio-economic systems. This will enable the communities and the local administrations to remain in a state of readiness to meet any eventuality brought about by a natural hazard.

Some Interventions need to be initiated in the meanwhile to address some of the key aspects aimed at improving and strengthening disaster preparedness and response mechanisms at local administration and community level viz.

i. Communication -- multi-modal and redundant communication capacity to ensure timely two-way flow of information.

ii. early warning systems -- to ensure effective monitoring and tracking of likely hazards and timely information dissemination to vulnerable communities to provide ample respite time and ensure last-mile connectivity,

iii. transportation network -- create alternative modes of transportation to complement the current dependence on water transport,

iv. drinking water -- with freshwater resources likely to be contaminated in the aftermath of a hydro-met disaster, ensuring supply of safe drinking water through stock-piling of chlorine tablets, raising plinth level of hand-pumps, decontamination tool-kits etc. needs to be accorded priority and pre-positioned,

v. food supply -- stock-piling of essential food items as poorer communities have little or no food security which is further eroded due to loss of crops and damage to the meager food grains stored at household level. Establishing grain banks with capacity to provide at least one week of food supplies and locating them at a higher ground will help address this key requirement,

vi. health and hygiene – setting-up of health and sanitation systems to prevent pollution of local water resources, check open defecation and prevalence of water-borne diseases.

vii. Safe housing technology toolkit – need to improve stability and strength of bio-mass based housing, which is likely to remain the prevalent housing norm in the region, by minimal use of external resources and by promoting safer housing technologies.

viii. Livelihood recovery -- promote availability of catch crop seeds, tools and techniques, develop mechanisms for subsidized credit for recovery and involvement of banking sector. In addition to reviving traditional livelihoods, alternative means of livelihoods through skill-development programmes need to be created.

ix. Community-based DRM – ensure sustainability of disaster risk management initiatives by promoting greater community participation in activities related to DRM. Many of the risk mitigation and preparedness capacity can be developed at community level through involvement of national and international humanitarian and development organizations and civil society actors.

x. DRR action plan – effective DRR requires horizontal and vertical linkages across communities and regions as well as different administrative levels. A concerted action plan to ensure coordinated approach among various sectors and stakeholders needs to be ensured.

xi. Infrastructure maintenance – community infrastructure assets like schools, health centers, cyclone shelters etc need to be accorded due attention to ensure their availability and functionality during an emergency situation.

Conclusions

The Hazard, Risk and Vulnerability Assessment (HRVA) provides a framework which can be improved upon with greater understanding of the risk reduction context in the country. This can also be extended to other areas to scope hazard, vulnerability and risk profile for the concerned area/sector.

Recognizing the complexities and diversities of vulnerabilities and capacities across the region, it is felt that it requires a multi-model approach and not a strait-jacketed intervention. In the absence of a detailed HVRA, the current initiatives primarily remain focused on one model of intervention across the country or even a region. As a result, most of these are not proving effective and capable of addressing the multi-hazard needs.

The sustainability of the programmes and interventions will require development of capacity at various levels viz. administrative, civil society and institutions. A targeted attention to building capacities for sustaining the DRR initiatives will have to be undertaken, especially at the community level.

It is hoped that the technical analysis, the methodology and the findings will assist further hazard-specific analysis and interpretation by technical agencies and the key findings will guide the administration, DRR practitioners and national/international humanitarian and development in focusing their interventions to address the critical factors contributing towards enhancing the vulnerabilities of communities and their productive assets.

The HRVA Report, it is hoped, will meet the objectives it set out to achieve and is commended for review and analysis.

Chapter 1: INTRODUCTION

Cyclone Nargis struck the Southern coast of Myanmar on May 2008 and moved inland across the Ayeyrawaddy or the Irrawaddy Delta and Southern Yangon Division. The event resulted in heavy loss of lives (> 100,000 people died), livelihoods and assets. Aftermath of the event witnessed large scale disruption of both economic activities and social support systems. Despite monitoring of the cyclone and timely warning, the catastrophic impact due to the Cyclone Nargis clearly manifest the lack of any effective form of preparedness at the institutional, community and household level.

Myanmar is exposed to a range of natural hazards such as storm surges, floods, landslides, and earthquakes, Tsunamis, tidal surges and seasonal fire with cyclone identified as a more frequent hazard. Emergency Events Database (EM-DAT) for the period 1981 to 2008 highlights that, about 5,000 people on an average are killed and about 125,000 people are affected every year from natural disasters in Myanmar. The statistics for the said period are mainly of the major natural disasters like cyclones, floods and Tsunamis.

A large number of institutions/actors with the support of the government departments have been working in the cyclone/floods affected region in the Ayeryarwady delta. Post Nargis, United Nations (UN) agencies including United Nation Development Program (UNDP) played a significant role in the recovery process. In the past two years significant progress has been made towards sector specific recovery along with the introduction of the community based disaster risk management initiatives in the Myanmar. UNDP and several other organizations including the INGO's have been working with the communities to build local capacities for the risk reduction. A large number of community based organizations (CBO), non-governmental organizations (NGO) and sectoral recovery groups (SRG) have also been involved in the recovery efforts. A wide range of initiatives in the delta region indicate the awareness as well as efforts to build the resilience of the communities against natural disasters.

As part of pro-active disaster management and mitigation activities in the cyclone affected delta region and beyond; UNDP seeks to undertake the conduct of multi-hazard risk assessment (MHRA) for the delta area of the Myanmar. The conduct and completion of a rapid risk assessment will play a critical role in the prioritization of ongoing preparedness / mitigation / adaptation / resilience building initiatives; hazard risk and vulnerability assessment study to provide insight on current and residual risk in the communities and thereby realign some of the key activities; provide guidance in establishing a policy and planning linkage with ongoing sector recovery and development / Disaster Risk Reduction programmes in the delta region of Myanmar.

1.1 OBJECTIVES OF THE ASSIGNMENT

The key objective of this assignment was to assess the hazard risk and vulnerabilities of communities in Myanmar (delta). The sub-objectives include:

1. Identify and assess the natural hazards in the delta areas - an assessment of the nature, geographic distribution, severity and frequency of natural hazards and production of hazard maps.
2. An assessment of physical, social and economic vulnerability of the community settlements and production of vulnerability maps.

3. Preparation of risk assessment study using hazard specific and composite risk assessment approach. Production of risk assessment maps displaying information of multi hazard risk across varying geographical units.
4. Review sectoral recovery projects on the basis of risk assessed and identify intervention that would require realignment of specific activities; inputs/recommendations to CBDRM programmes.

1.2 OVERVIEW OF METHODOLOGY

Based on the TOR, a systematic assessment has been undertaken by a five-staged process:

1. **Hazard Risk Analysis**: The independent analysis of hazard risk across the delta region for earthquake, Tsunamis, cyclone, storm surge and floods. The broader analysis of climate change can't be ignored and therefore climate change related hazards are also touched upon.
2. **Assessment of Elements at Risk**: This will include an enumeration of:
   a. *Physical elements*: housing, community asset, critical buildings and social infrastructure
   b. *Socio-economic elements*: various categories of population, especially the economically and socially vulnerable.
   c. *Economic elements*: economic vulnerability of households and small businesses, productive assets and activities esp. agriculture, fisheries, poultry, livestock, craft, industry and other livelihoods, employment and income.
3. **Strategic Vulnerability Assessment**: The independent analysis of vulnerability (wherever possible) for the above 'elements at risk' were carried out based on the analysis of historical data, field surveys and recall case studies. Given the time constraints, a sample of the settlements were surveyed in detail with a set of tools developed by TARU to get qualitative and semi-quantitative information on different facets of vulnerability. Myanmar Survey Research (MSR) was involved in conduct of field survey.
4. **Risk Assessment**: The mathematical and geographical analysis of composite risk was carried out and the losses were estimated in Myanmar Kyat.
5. **Input to Sectoral Recovery and CBDRM Programmes:** In lines to the risk assessed inputs are provided to address the future design of sectoral recovery programmes and CBDRM.

The practical application of these principles in an operational environment is more complex and challenging. In keeping with the objectives of the assignment, the activities were broken down into five major clusters comprising of 24 sub-tasks (TARU Technical proposal, 2009):

Component/Activity I: Scoping and methodology development for risk assessment

Component/Activity II: Indicative hazard risk assessment and strategic vulnerability assessment report

Component/Activity III: Composite risk assessment

Component/Activity IV: Report sighting recommendations to CBDRM and sectoral recovery plan

Component/Activity V: Project management

Availability and robustness of the data have been identified as the primary constraint. This report has been prepared despite constraints related to availability of social, economic and environmental data; mainly due to restrictions or limited availability at the scale of enquiry, delay in permission/access to field for data validation and discussions with stakeholders. Further, some of the data that were made available, these data sets could not be used for modeling since they were regarded as classified information. Inspite of the above constraints, sincere attempt has been made to ensure that village level analysis as desired in the technical proposal, but data quality may limit the usage in its current form.

The methodology for this study was finalized based on review of available data with the potential sources within the country including the government departments, UN agencies based in Myanmar, and other public domain secondary sources (both national and international). Any form of restricted data sources (as discussed during the subsequent missions undertaken by TARU) have been excluded from the ambit of this assignment. Data sources that are irregularly updated, difficult to access and ambiguous were reduced to minimum while fulfilling respective tasks. The focus was to use publicly or officially available information streams that are robust, reliable and could be validated (including key working/research papers). The data constraint on vulnerability aspects has been practically limited through conduct of extensive survey in the field.

The method suggested towards the assessment aims to deliver a set of functioning tools that can facilitate decision making. The analysis methods are built on works which were undertaken by several institutions/agencies in Myanmar as well as refers to standard methods applicable for analysis. Given the limited data availability/quality of hazard risk catalogues (storm surge, Tsunami, flood and climate change); vulnerability and loss functions (for earthquake and Tsunami, cyclone and storm surge, flood), working assumptions were made to estimate both hazard risk and specific vulnerability. These assumptions are documented to provide a scientific basis for review when better and more recent data and research becomes available.

Please note that the assessment of socio-economic and economic vulnerability did not follow the strict dictates of probabilistic risk assessment. This is partially because of lack of data and also the complex and intangible nature of vulnerability, resilience and coping capacity. Alternate methods for assessing those risks are presented in the relevant chapters ahead. Nevertheless, this report provides a conceptual framework which can be extended further to carry out similar analysis in other regions of the country (Myanmar). The results from this analysis can also be improved upon as detailed data becomes available.

Chapter 2: HAZARD RISK

2.1 EARTHQUAKE

2.1.1 Objectives

To map the earthquake hazard risk and prepare the PGA maps of the study area for 25, 50, 100, 200 years recurrence intervals for the study area which includes Ayeyarwady, Yangon and Bago divisions of Myanmar based on earthquake catalogue.

2.1.2 Seismic Hazard Analysis

Seismic risk assessment involves, estimating the expected loss from probabilistic seismic hazard exposure or deterministic earthquake scenarios and assists in hazard risk mitigation and disaster management (Reiter, 1968; Schneider, 1999; Field, 2000). It begins examining the interaction of earthquake ground shaking with local site effects (amplification due to soil conditions, local geology and topography) and vulnerability factors (e.g. material and quality of construction, age and value of buildings and lifeline infrastructure, population densities and time of day) (Giardini & Bochi, 1993; Giardini et al., 1999).

Seismic hazard risk is typically measured in terms of Modified Mercalli Intensity (MMI), Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV) and Spectral Acceleration (SA) or Response Spectrum. The output of this process can be represented as an intensity or risk value for location; or in the form of a macro seismic hazard risk map or a hazard curve (Lama et al., 2002).

There are two approaches towards seismic risk assessment: Deterministic and Probabilistic methods. Deterministic models were first used in engineering seismology to address issues for the design of critical structures such as nuclear reactors. This typically takes into account abnormal intensity distributions, linear and non-linear site effects and anisotropic attenuation functions. Probabilistic methods are now being extended into risk macro-zoning (Zhongxia, 2003). In addition, integration of new advanced techniques including the use of GIS, RS and GPS technology has enabled to prepare the integrated seismic models (e.g. FEMA's HAZUS) that address both primary and secondary (e.g. liquefaction and slope stability) impacts. (Schneider, 1999) (Also see: www.fema.gov/hazus)

a) Deterministic Seismic Hazard Assessment

Deterministic methods are based on earthquake catalogue and do not usually consider the probability of seismic events. The most common form uses the largest known earthquake in a region, i.e. the historical maximum earthquake to derive the scenario event (Veneziano et al., 1984). This approach is based on the premise that an earthquake of the same magnitude can reoccur, if it has occurred once. Deterministic approach is used to calculate the expected maximum ground motion at a particular location based on seismogenic potential (Zhongxia, 2003). The typical steps involved in a deterministic hazard risk assessment include:

- A seismotectonic study of the region based on seismogenic faults and the historical seismic record to define the scenario earthquake
- Estimation of maximum rupture dimension of seismogenic faults or potential event intensity of a historical maximum event

- Estimation of expected ground motion at the site of interest from the scenario

b) Probabilistic Seismic Hazard Assessment

Probabilistic seismic hazard assessment methods integrate both; the intensity of seismic hazards and their temporal probability over specified recurrence period into the analysis (Field, 2000). This approach is accepted globally as the better informed method for seismic hazard assessment (Cornell, 1968; McGuire, 1987, 1995; EPRI, 1989). The method of Probabilistic Seismic Hazard Analysis (PSHA) involves following approach:

- Preparation of an earthquake catalogue of Myanmar and its immediate neighborhood.
- Identification of earthquake producing zones to create a master seismic source model to explain the spatial and temporal dimensions of regional seismology. This is undertaken by mapping the active faults, geodetic measurements of crustal deformation, and remote sensing methods to define earthquake zones.
- Estimation of seismic strong motion as a function of earthquake magnitude and distance. This is usually carried out by, drawing upon existing attenuation models and matching it to the regional structural, geomorphologic and tectonic framework and instrumental values of ground acceleration from strong motion arrays.
- Estimation of the probability of Peak ground acceleration at specified recurrence intervals to produce maps of seismic hazard risk at appropriate scales. Typical engineered buildings are usually designed using a 50 years return period; critical infrastructure over 100years and the nuclear plants would be designed for a risk corresponding to 500-2,000 period (Zhongxia, 2003, EPRI, 1989).

For this present study, the probabilistic method was adapted. A statistical model of seismogenic sources was developed to estimate seismicity through return period distribution methods. Spatio-temporal analyses were carried out to analyze the seismic risks.

Study Area:

The overall tectonic set up of the Myanmar region indicates that the present study area falls to the proximity of the Sagaing fault, which is an active fault of the region also passes East of Yangon city and is in the vicinity of the subductive Indian plate and the Burma platelet. The seismotectonic set up of the Delta region and its neighborhood is quite complex with a series of Thrust and strike-slip faults, often changing the relative slip over their length. Towards South an active spreading zone is located under the ocean. These tectonic attributes indicate that the region is seismically active. The historical seismicity of the region suggests that the earthquake activity in both the Divisions i.e. Yangon & Bago (West) is high compared to Ayeyarwady Division. Thus, the eastern deltaic region of Myanmar is prone to higher seismic hazard risk compared to Western delta.

Topography, Geomorphology, Soils:

The topographical set up, soils and the landforms present in the region are very important to understand the seismic risk of the region. The soil of the region (*loose, stiff, sandy, clayey etc.*) and their thickness of these soils over the basement rocks are important aspects, which contributes towards the seismic vulnerability of the region for high or medium magnitude earthquake. Although, study of subsurface data (borehole information, geomorphologic mapping at large scale) was beyond the scope of the present study, they have been referred here as a background information for the seismic hazard assessment of the Southern Myanmar region especially the delta region. i.e. Yangon, Ayeyarwady & Bago (East & West).

Geo-morphologically, the Southern Myanmar region can be broadly grouped in to three divisions i.e. Eastern and Western hill ranges, Central basin and Coastal zones. The Irawaddy River, which flows almost North-South, bisects the Southern Myanmar region into two divisions separated by Arakan Yoma (~3100m) and Pegu Yoma (~800m) hills and forms deltaic conditions from Prome. The deltaic region has an average elevation of 4 to 8m and forms swampy and marshy conditions, wherein there are several islands covered with Mangroves. The soils of the Southern Myanmar are broadly classified in to the alluvial, swampy & also of coastal sands.

2.1.3 Calculation of Risk and Return Period[1]

In the current study return periods were used to outline the risk due to both seismic and cyclonic hazards. The relation between the risk and return period can be examined using the below list method.

Annual Exceedance Probability (P) is the probability that an event level will be met or exceeded during a one-year interval. General Exceedance Probability (P_0) is the probability that an event will be met or exceeded during a interval of n years. Return Period (mean recurrence T) is a function of exceedance probability and is defined as 1/P, e.g. an annual exceedance probability P of 0.1 (10%) implies a return period T of ten years.

The probability that an event will be exceeded during the return period is 1.0 minus the probability that it won't be exceeded during the return period. The probability that it won't be exceeded during the T-year return period is $(1 - P)^T$

Example: for a 100-year earthquake, T = 100 and P = 0.01.

Probability of non-exceedance during the return period => $(1 - 0.01)^{100} = 0.37$

The probability that it will be exceeded during the T-year return period is 1 minus the probability of non-exceedance => $1- (1 - P)^T \sim= 0.63$

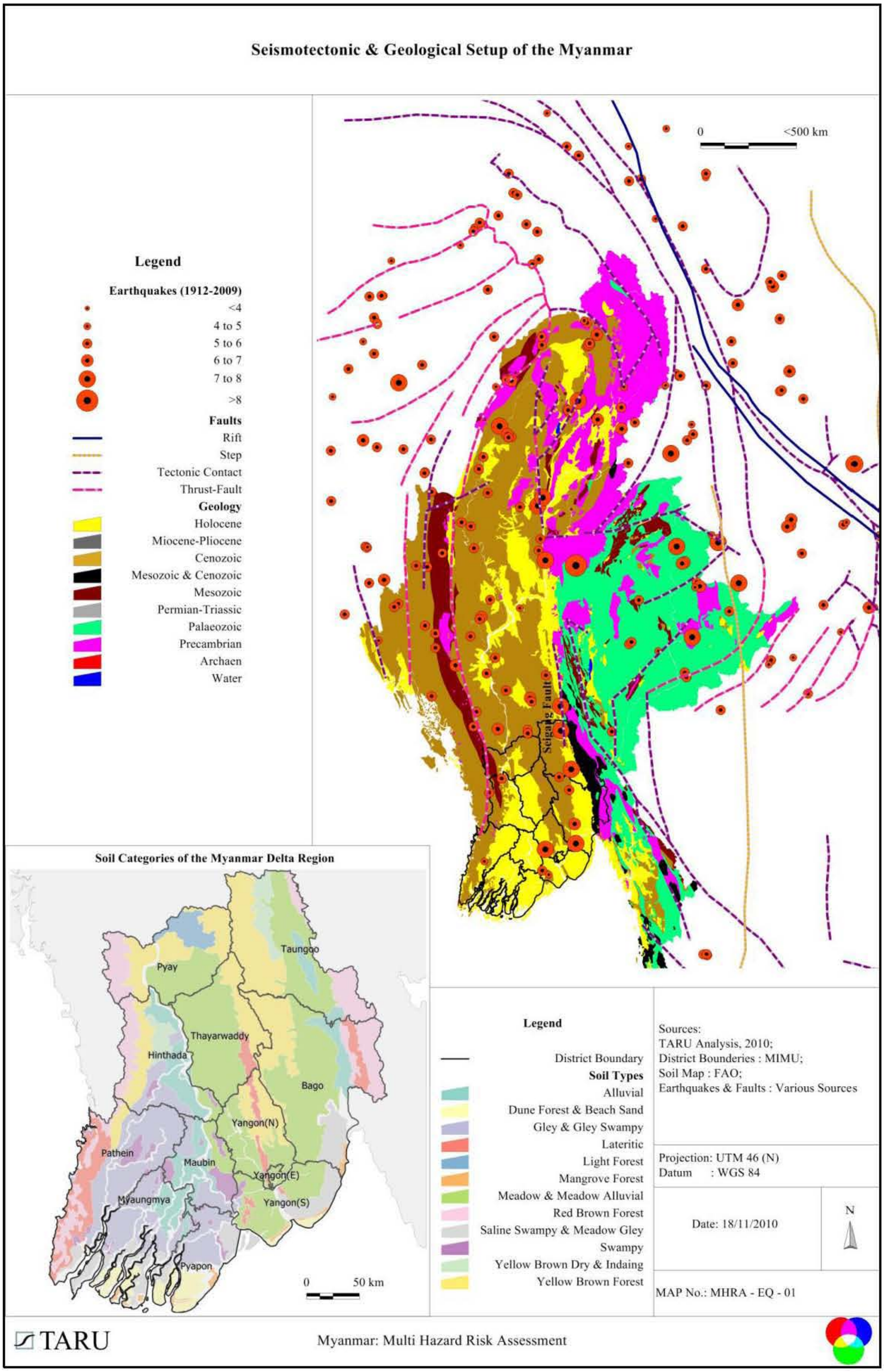
The value 0.37 and 0.63 infers that there is a 37% chance that the 100-year earthquake will not occur during a 100-year period or in other words there is a 63% probability that an event with a 100-year return period will be exceeded during a 100-year interval.

The probability that an event with return period T will be exceeded during a period of n years (P_0) is 1.0 minus the probability that it won't be exceeded during that interval i.e. $(1 - P)^n$. The probability that the event will be exceeded during the n-year interval can be calculated using the following equation:

$$\mathbf{P_0 = 1 - (1 - P)^n}$$

[1] Modified from Structural design for dynamic loads, Department of Architecture, University of Virginia. Last accessed on November, 2010. http://www.arch.virginia.edu/~km6e/arch721/home.html#toc

Figure 2-1: Seismotectonic Features & Geology of Myanmar



Seismotectonic Profile:

Tectonically, Myanmar lies in one of the two main earthquake belts of the world, known as the Alpide Belt and thus is prone to an earthquake hazards. Seismotectonic processes in the Myanmar region are very complex as it is bounded by an Indian plate in the West and in the South is the Burma platelet (part of Eurasian plate). These two tectonic domains exhibit different rates of plate movements. In South-West of Myanmar, the nature of Indian plate is subductive with plate velocity of 5.5 cm/yr. Further, there is also an active spreading zone in the South of Myanmar which makes the region vulnerable to seismic hazard. Referring to seismogenically active in nature, the Sagaing fault passing through Northern to Southern Myanmar is important. This fault roughly trends along north-South direction (Swe & Tun, 2006). This fault is the major source of destructive earthquakes in Myanmar. It is also due to the fact that many large urban centers lie on or in margin of this fault. Out of the five major source zones for earthquakes in Myanmar, three clusters lie around this large and active fault. Apparently, the Sagaing Fault has been segmented into three parts on mainland Myanmar based on the clusters of earthquake epicenters and region wise earthquake frequencies. Other seismo-tectonically important faults in Myanmar Kabaw Fault along the Kabaw Valley in Western Myanmar, and the Kyaukkyan Fault situated East of Naungcho and some unnamed thrust faults in North-Western Myanmar, (Thein & Swe, 2006).

The seismic activity which has resulted in the great earthquakes in Myanmar can be attributed to the two main causes,

- The continued subduction (with collision only in the North) of the northward moving Indian plate underneath the Burma Platelet at an average rate of 4.0 – 6.0 cm/yr.
- The northward movement of the Burma Platelet from a spreading centres in the Andaman Sea at an average rate of 2.5 – 3.0 cm/yr.

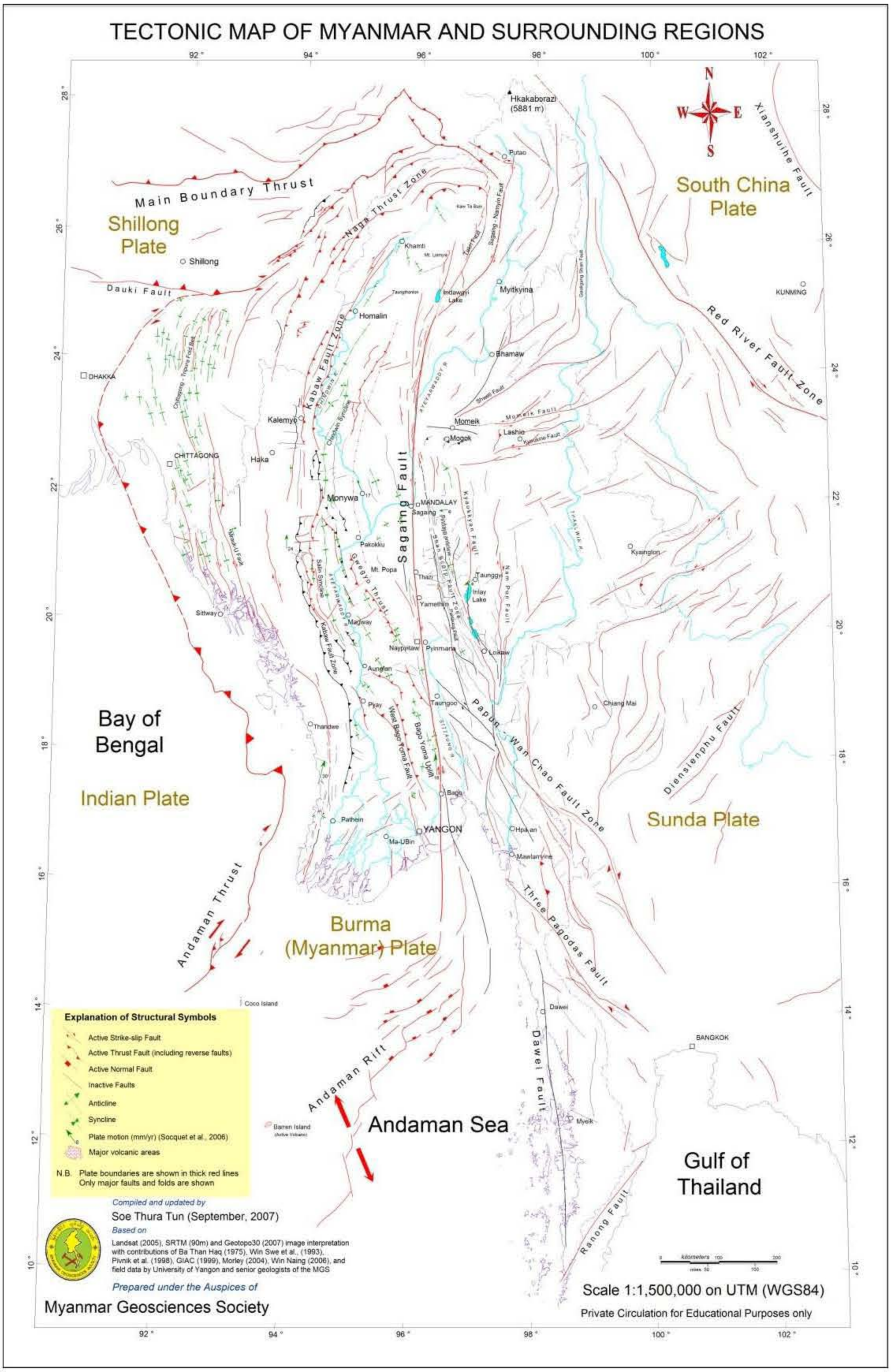
Historical Seismicity:

The seismic records of the region show that at least sixteen major earthquakes with magnitude ≥ 7.0 have occurred within the territory of Myanmar in the last 170 years. Among these, are the most destructive four and the 1975 Bagan earthquake which are shown in following table. Considering depths of occurrences, most of the earthquakes of greater depths occurred in Western part of the Myanmar may be due to subduction zone and those in the shallower depths were reported from the central and eastern part of the Myanmar. Compared to the earthquakes > 7 (Richter magnitude), the earthquakes < 6 magnitude have reported higher frequency in past 100 years. Table 2-1 shows the chronology of the most destructive earthquakes in the Myanmar.

Table 2-1: List of Most Destructive Earthquake Events

Earthquake	Date	Magnitude
Innwa (Ava) earthquake	23 March 1839	7.0
Maymyo earthquake	23 May 1912	8.0
Bago (Pegu) earthquake	5 May 1930	7.3
Sagaing earthquake	16 July 1956	7.0
Bagan earthquake	8 July 1975	6.8

Figure 2-2: Tectonic Map of Myanmar



2.1.4 Data & Uncertainty

In the present study four main data sets (refer Table 2-2) were used for deriving the possible PGA map for the study area.

Table 2-2: Earthquake Hazard Risk Modeling Data Overview

Data	Use	Source
Administrative and country boundary of Myanmar	To estimate the coverage area	MIMU
List of earthquake & fault map	Cataloguing the earthquakes for analyzing the PGA	Global Risk data platform (UNEP), NOAA, ANSS
Soil Map	To estimate the PGA with respect to the soil conditions	FAO

The seismic hazard risk of the three divisions of Myanmar in the delta region was determined based on region specific seismotectonic information, small scale geological & geomorphologic map, and information about the nature of active faults, seismic source, site amplification data. Following information are some major constrains which may contribute to the uncertainty.

1. Fault geometry, fault length-event magnitude relationships and seismic source details
2. The strong motion instrumental records were not available for the region
3. Attenuation models for the region

Further, the detail study for the collateral hazards like liquefaction potential of the region were not carried out as a part of this study due to the absence of detailed information (zoning) of the soils within the Ayeyarwady region.

2.1.5 Probabilistic Seismic Hazard Analysis (PSHA)

The analysis followed a simple but comprehensive process to produce a Level-1 PSHA. The steps involved are as follows:

1. Identification of main seismotectonic features
2. Identification of the main seismic sources
3. Collation a historical event catalogue
4. Selection of appropriate attenuation models
5. Simulation of base rock & surface motion analysis
6. Estimation of risks at defined Recurrence intervals
7. Creation of earthquake hazard risk maps

The following section provides an overview of the methodology used in this study. The earthquake hazard risk was derived through Level-1 analysis given the lack of scientific data at the level of resolution necessary.

a) Review of Literature

A wide range of national & international research articles, documents and books on seismology, earthquake engineering and earthquake risk assessment were reviewed in the context of the seismic hazard risk assessment. This included a review of past vulnerability and hazard risk assessments; earthquake scenario generation and Probabilistic Seismic Hazard analysis (PSHA) studies.

b) Construction of well structured GIS based database for the better analysis and map generation

A GIS based data was prepared from available GIS data of FAO, MIMU and UNEP. A detailed GIS database of the geomorphology of Myanmar was created at 1:1 million scale. This was reclassified into three major classes: rock, stiff and soft soil based on available soil and rock type classes.

c) Assumptions

Number of assumptions has been made in this PSHA to enable convergence between the assignment objectives and the available data sets. Following are the key assumptions which might improve such study if accommodated:

1. The earthquake catalogue extends from 1940 to 2009 period. The 100 year return period Earthquake was analyzed from this available data set.
2. Grid coverage of 0.1 x 0.1 degree (about 120sq km grid) has been deemed adequate for the purpose of hazard risk assessment.
3. The reclassification of geomorphologic data provides appropriate information on soil type in consonance with the attenuation model being utilized
4. Foreshock and aftershocks were excluded from the catalogue via recurrence analysis that uses a 0.2 x 0.2 degree grid band and two year time period filter
5. Future hazard risk has been simulated by historical events located at the particular event epicenters at which they occurred
6. Lateral in homogeneity of the geological formations and their transmission parameters are assumed not to significantly influence PGA estimates derived from the selected attenuation models
7. Krigging algorithm was adopted to derive appropriate zoning for the seismic hazard analysis
8. Collateral hazards (liquefaction and slope failure) have been excluded in the present analysis, as they take place at a much lower spatial scale. Such studies are typically undertaken during the seismic micro-zonation.

It is hoped that a listing of the assumptions and limitations of the models and data set used in this assignment will assist future assessments to improve upon these estimates. This method provides a analytical framework for improving the outputs as and when more data is available.

d) Model:

Based on the results of simulation and the limitations within some of the earthquake attenuation model to include the bed rock conditions the PGA as proposed by Si & Midorikawa (2000) was used for this study.

Si & Midorikawa (2000)

The Ground motion model for equivalent rupture distance:

$$\log A = aM_w + hD + \Sigma d_i s_i + e - \log (X + c_1 10^{c_2 M_w}) - kX$$

Where, A is Acceleration in cm/s^2, Mw is Magnitude

[a = 0.50, h = 0.0036, d_1 = 0, d_2 = 0.09, d_3 = 0.28, e = 0.60, k = 0.003 and σ = 0.27, c_1=0.005, c_2=0.5]

The Ground motion model for equivalent hypocentral distance (EHD):

$$\log A = aM_w + hD + \Sigma d_i s_i + e - \log X_{eq} - kX$$

Where, A is in cm/s^2

[a = 0.50, h = 0.0043, d_1 = 0, d_2 = 0.01, d_3 = 0.22, e = 0.61, k = 0.003 and σ = 0.28]

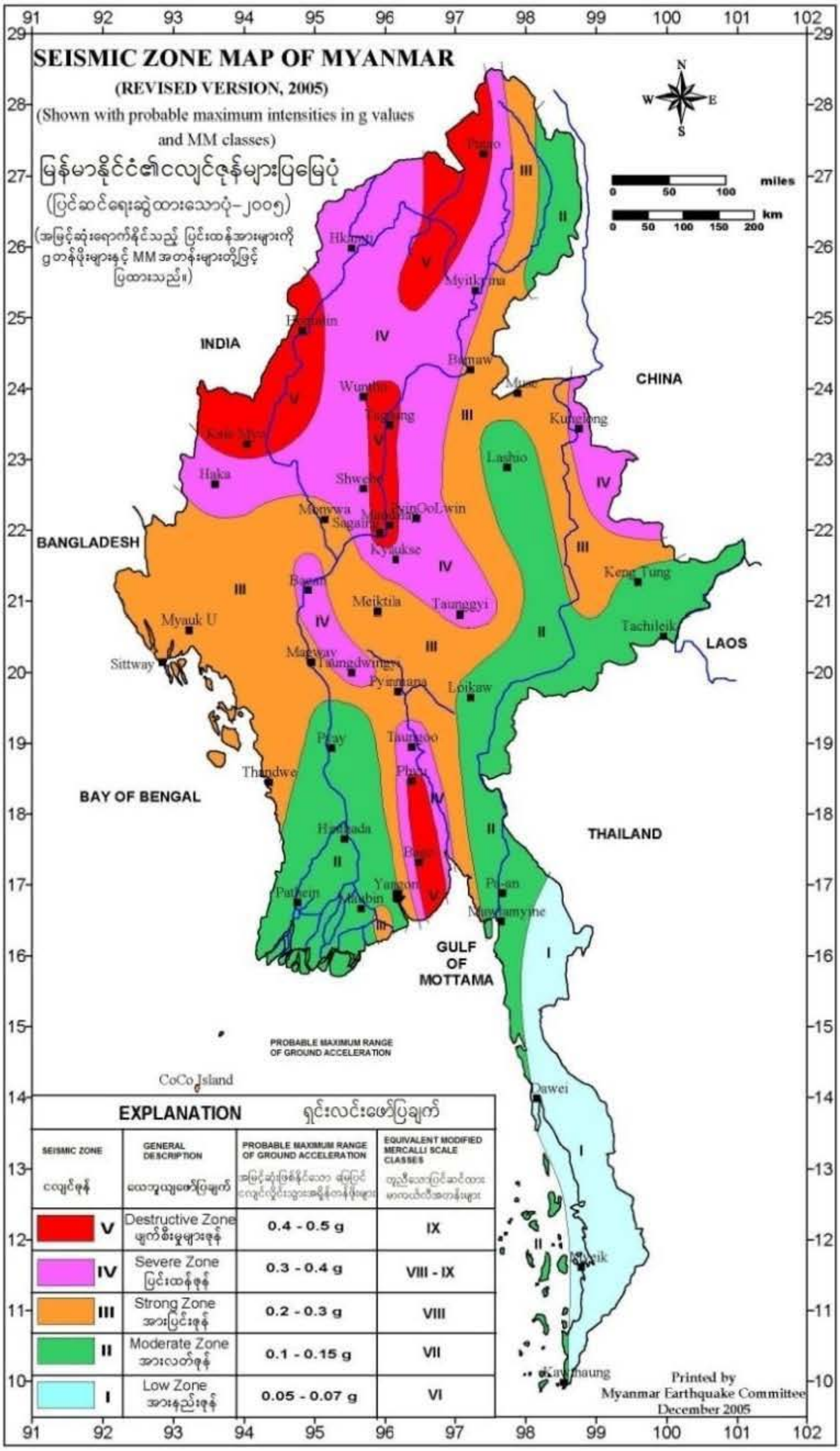
d_i is indicative of the type of fault. Where, i is taken 1 for crustal, 2 for interplate and 3 for intraplate.

This model uses two site categories (rock & soil) for most records following Joyner & Boore (1981). It multiplies rock PGAs by 1.4 to get soil PGA.

2.1.6 Results

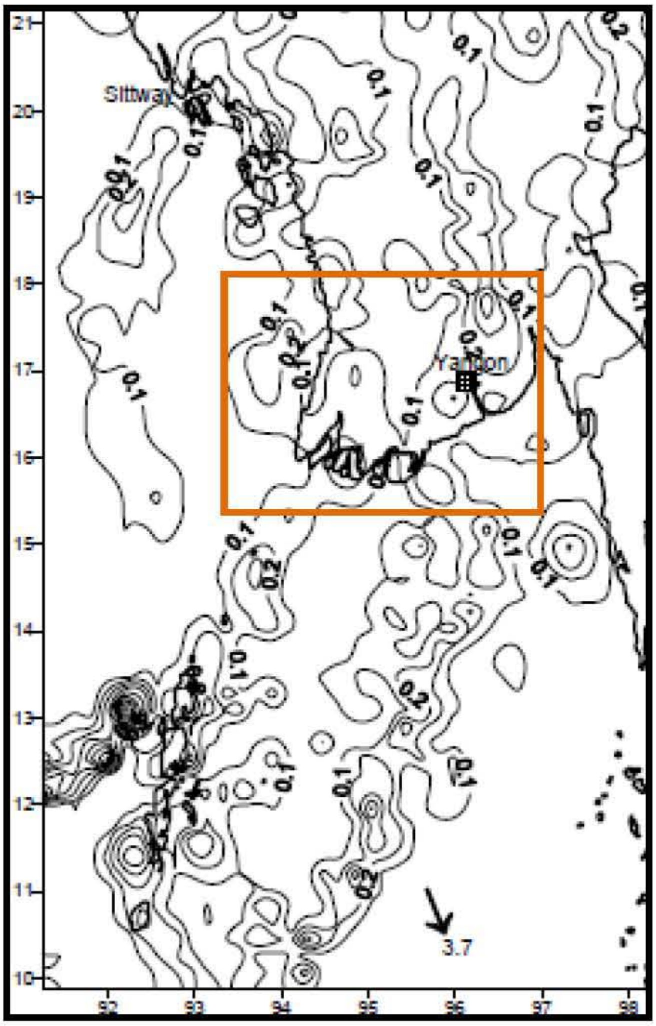
Figure 2-3is seismic zone map of the Myanmar given by Thein *et al.* (2005). The map has been prepared by making empirical & historical approach and is based on the European Macro-seismic Scale of 1992 and also follows Modified Mercalli (MM) intensity. Two figures have been refereed in present discussion from the Thein *et al.* (2005). Figure 2-3 provides the seismic zoning map and Figure 2-4 illustrates the possible horizontal ground acceleration map of Myanmar. As per Figure 2-4 the ground acceleration observed in the delta region (box) is between 0.1 and 0.4 which indicate moderate to destructive seismic zone for the region. The higher values i.e. 0.2 to 0.4 are in NE of Yangon which depicts strong to destructive zones and most of the delta region West of Yangon is showing ground acceleration 0.1 which is again a moderate zone.

Figure 2-3: Seismic Zone Map of Myanmar



Revised by Dr. Maung Thein, U Tint Lwin Swe and Dr. Sone Han (December 2005)

Figure 2-4: Partial representation of horizontal ground acceleration map of Myanmar



Source: Thein et al., 2005

Two methods of seismic zoning are used in present discussion here. The European Macro-seismic Scale EMS-98 (Table 2-3) is the basis for assigning seismic intensities in European countries. The scale is update of test version of 1992 and has also been used to prepare the seismic zone map of Myanmar (Thein *et al.*, 2005).

The European Macro-seismic Scale has been most recently updated in 1998 and is referred to as EMS-98[#]. As per the map the Southern Myanmar particularly delta region is distinctly divided in two broad domains, the zone East of Yangon is categorized in III, IV and V whereas; West of Yangon which also covers most of the delta region falls in the zone II.

Design Codes of India

Design codes of India [IS-1893 – part – 1: 2002] based on various scientific inputs from a number of agencies including earthquake data supplied by IMD, has grouped India into four seismic zones (Zone II, III, IV and V). Zone V is rated as the highest damage risk zone and is for most seismically active region, while zone II is low damage risk zone.

Table 2-3: EMS 98 Scale and the Scale of Design Codes of India

EMS 98[2] Scale	Observations	Possible Damage (Possible PGA as per seismic zoning in India)	Zone	
I. Not felt	Not felt even under the most favorable circumstances.	Very Low to Low Damage (0.1g)	2	**Low Damage**
II. Scarcely felt	Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.			
III. Weak	The vibration is weak and is felt indoors by a few people. People at rest feel a swaying or light trembling.			
IV. Largely observed	The earthquake is felt indoors by many people, outdoors by very few. The level of vibration is not frightening. Windows, doors and dishes rattle. Hanging objects swing.			
V. Strong	The earthquake is felt indoors by most, outdoors by few. Many sleeping people awake. A few run outdoors. Buildings tremble throughout. Hanging objects swing considerably. China and glasses clatter together. The vibration is strong. Top heavy objects topple over. Doors and windows swing open or shut.	Moderate Damage (0.16)	3	**Moderate Damage**
VI. Slightly damaging	Felt by most indoors and by many outdoors. Many people in buildings are frightened and run outdoors. Small objects fall. Slight damage to many ordinary buildings; for example, fine cracks in plaster and small pieces of plaster fall.			
VII. Damaging	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many ordinary buildings suffer moderate damage: small cracks in walls; partial collapse of chimneys.	Moderate to High Damage (0.24)	4	**High Damage**
VIII. Heavily damaging	Furniture may be overturned. Many ordinary buildings suffer damage: chimneys fall; large cracks appear in walls and a few buildings may partially collapse.			

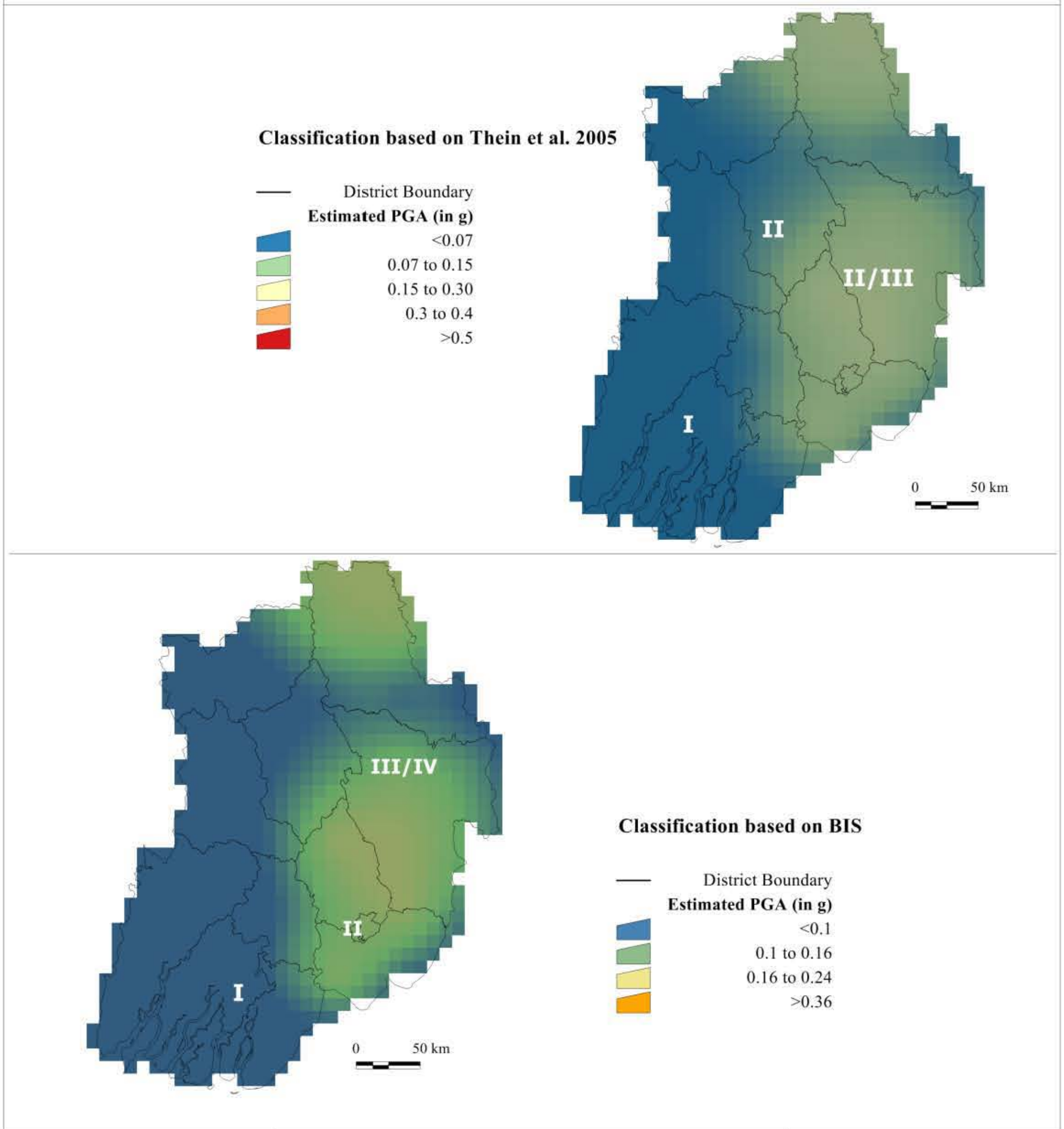
[2] http://www.gfz-potsdam.de/portal/gfz/Struktur/Departments/Department+2/sec26/projects/04_seismic_vulnerability_scalesrisk/EMS-98

<table>
<tr><th>EMS 98[2] Scale</th><th>Observations</th><th>Possible Damage (Possible PGA as per seismic zoning in India)</th><th colspan="2">Zone</th></tr>
<tr><td>IX. Destructive</td><td>Monuments and columns fall or are twisted. Many ordinary buildings partially collapse and a few collapse completely.</td><td rowspan="4">Very High Damage (0.36)</td><td rowspan="4">5</td><td rowspan="4">Highest Damage</td></tr>
<tr><td>X. Very Destructive</td><td>Many ordinary buildings collapse.</td></tr>
<tr><td>XI. Devastating</td><td>Most ordinary buildings collapse.</td></tr>
<tr><td>XII. Completely Devastating</td><td>Practically all structures above and below ground are heavily damaged or destroyed.</td></tr>
</table>

The Table 2-3 represents the combination of EMS' 98 and the scale of design codes of India. Figure 2-5 and Figure 2-6 compares two different earthquake hazard zonation standards for 100 and 200 year return periods respectively. Within this comparison, schema of Thein *et al.* (2005) (based on EMS 98 & MM scale) and design codes outlined by Bureau of Indian Standards were taken into consideration. This comparison was attempted to outline the uncertainty within the classification schemas.

Figure 2-5: Comparison of Two Zoning System (100 Year Return Period)

Comparision of Two Classification System for Seismic Zoning in Delta Region (PGA in g) - 100 Year Return Period



Notes:

In above maps the Seismic Zones are highlighted using Roman Numerals

There are two maps produced to demonstrate the difference between two classification schema (PGA values) namely Thein et al. 2005 and Design Code of India.

Sources:
TARU Analysis, 2010;
District Bounderies: MIMU;
PGA Values: Thein et al. (2005);
Design Codes of India,
[IS-1893 – Part – 1: 2002]

Projection: UTM 46 (N)
Datum : WGS 84

Date: 2/12/2010

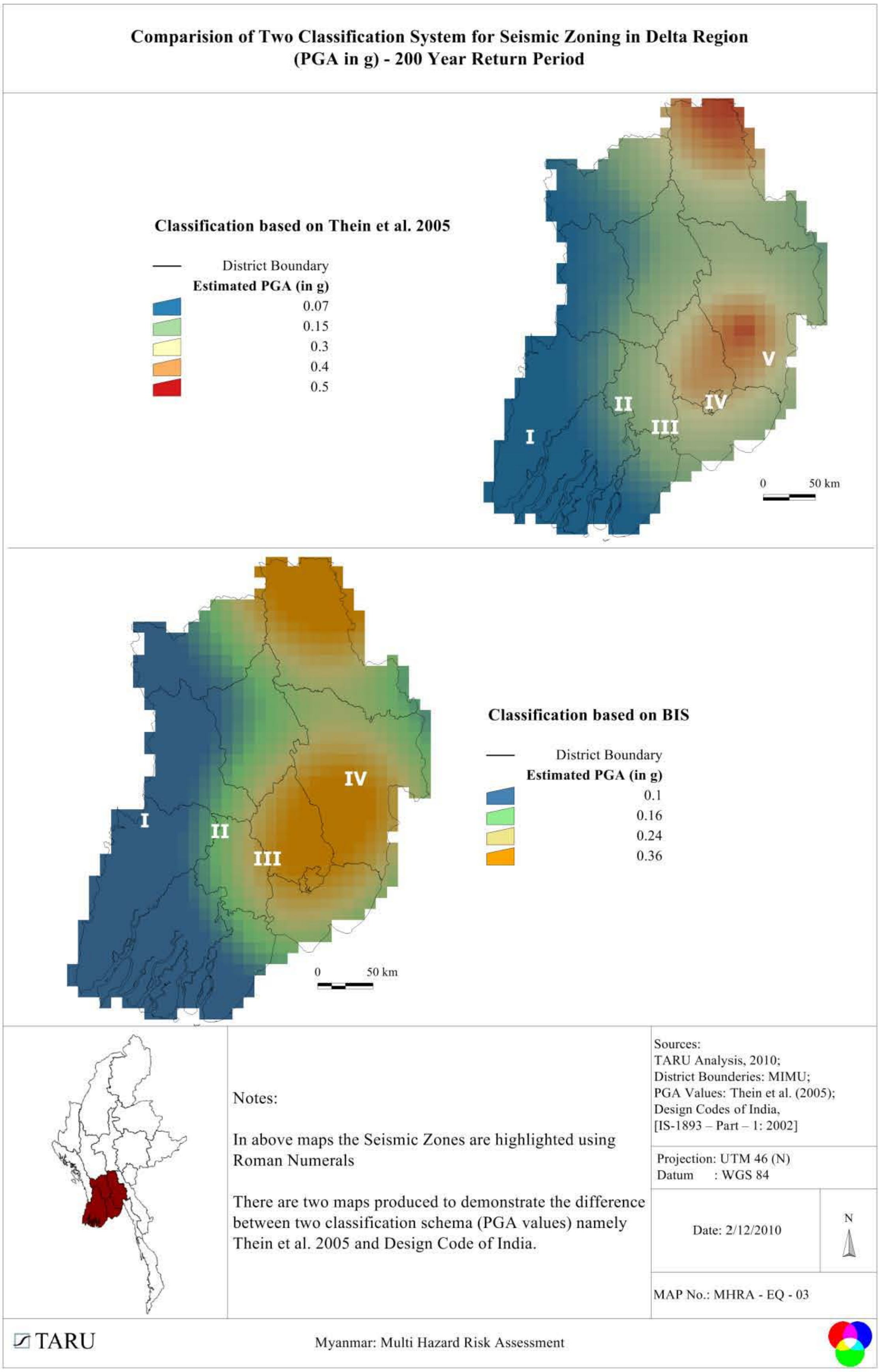
N

MAP No.: MHRA - EQ - 02

TARU

Myanmar: Multi Hazard Risk Assessment

Figure 2-6: Comparison of Two Zoning System (200 Year Return Period)



Estimation of PGA for Various Return Periods for the Present Study

Peak Ground Acceleration (PGA) for the seismic event for four return periods (25, 50, 100 & 200 years) was determined. These were based on the mean expected lifetime for temporary structure (25 years), typical non-engineering housing (50 years), engineering building and critical building (100 years) and critical lifeline infrastructure (200 years). PGA has been calculated based on the available limited information about the present study area.

The seismic zoning map produced by Thein *et al.* (2005) is shown in Figure 2-4. The PGAs for different recurrence intervals (25, 50,100 & 200 yrs) obtained in the present study are shown in Figure 2-7 & Figure 2-8. The PGA maps are shown as comparative maps for the 25 and 50 year return period with two different classification schemes. However, with the difference in the classification system for 25 & 50 year return period there is not any difference in the seismic zone of the region. This is making difference for the 100 and 200 year return period.

The results of the analysis indicate PGA values are < 0.07/0.1g for all the three districts i.e. Yangon, Bago (East and West) and Ayeyarwady for the 25 years return period taken in the present study. The PGA is almost similar for the 50 year return period as shown in the figures. The results for 100 year and 200 year return period are important and lie between 0.07g to > 0.36g. The PGA is between 0.15 to 0.30g in Yangon and Bago for the 100 year return period but for the 200 year return period it is >0.30g for most of the Yangon district and Southern Bago. The PGA distribution which was not experienced in Ayeyarwady district for the 100 year return period is apparently observed in the 200 year return period scenario especially in the eastern part.

Thus, the results indicate that higher values of PGA are distributed mainly in the Yangon and Bago divisions. This is significant as Yangon is densely populated division and one of the important places of the Myanmar. The PGA may vary (increase) with the soil cover in the region and might increase the extent of the damage as the soils in the districts of the present study area is alluvial with swampy type of conditions. This may increase the chances of liquefaction potential with high magnitude earthquake. The data pertaining to the past liquefaction activity, surface and sub-surface nature of the soil in the region and the groundwater conditions of the region can be of great value in determination of the seismic hazard more accurately along with the collateral damage occurring with the earthquake in the region.

Figure 2-7: Estimated Mean Division Peak Ground Acceleration (50 Years Return Period)

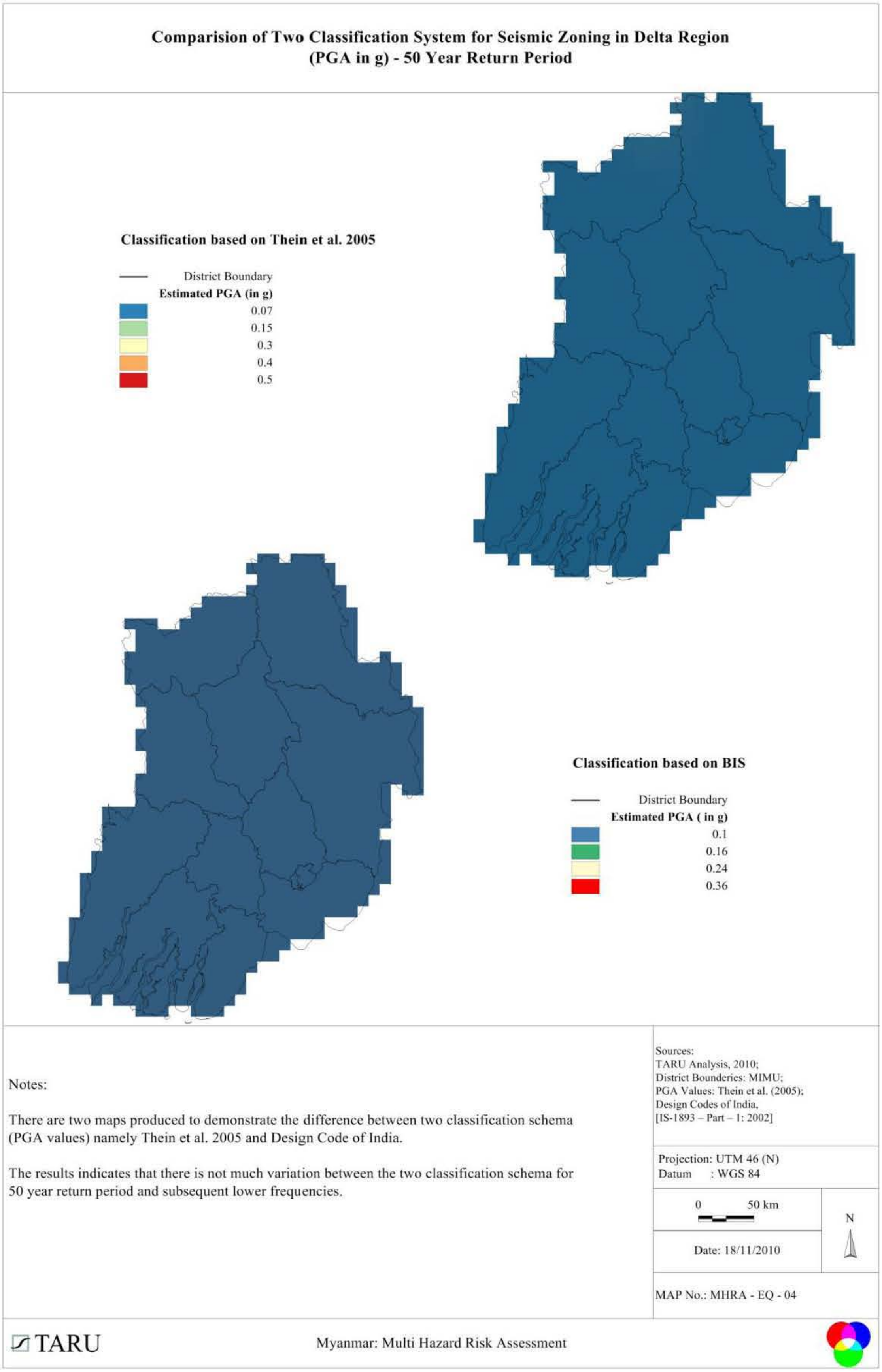
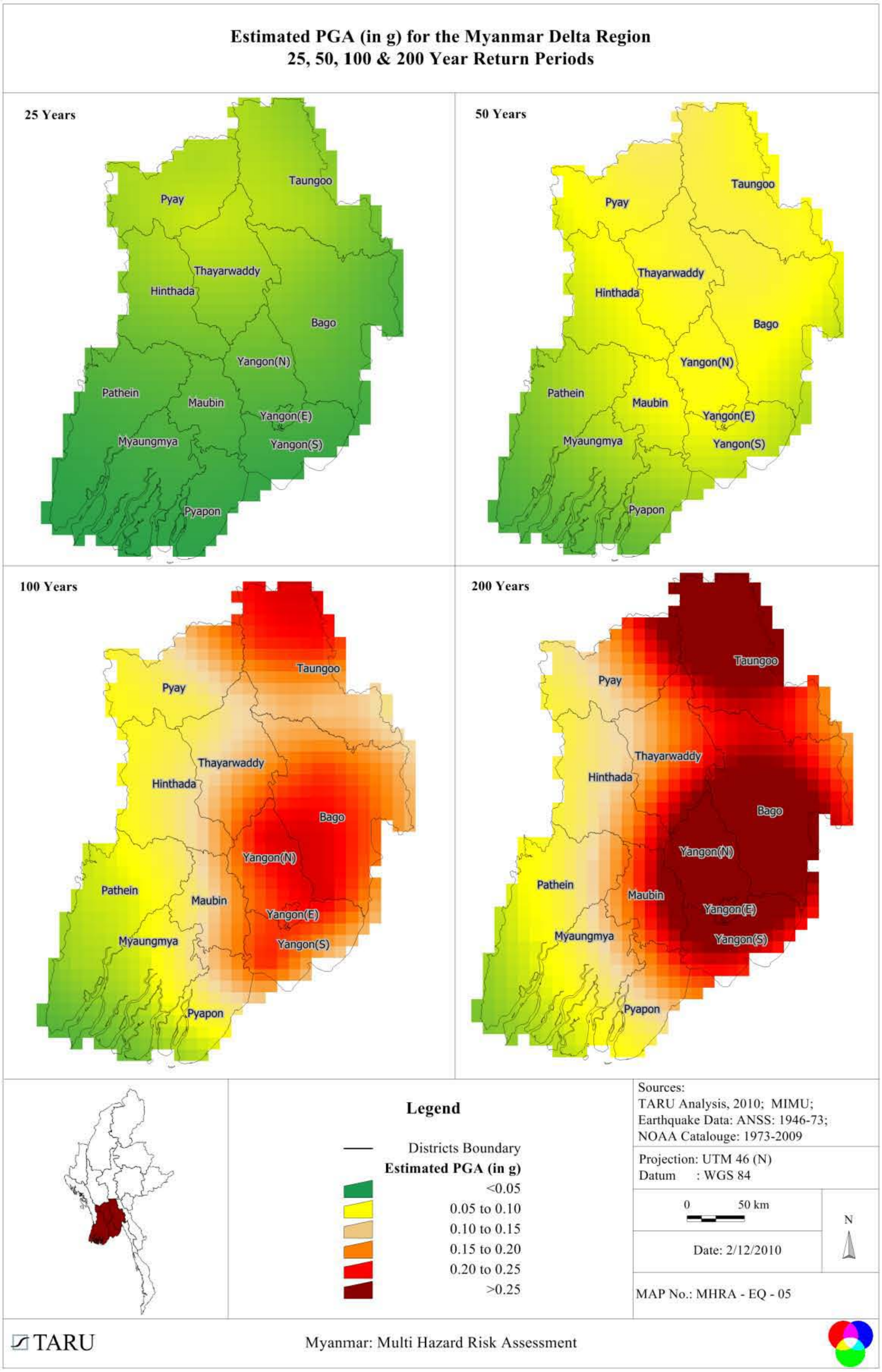


Figure 2-8: Estimated Mean Division Peak Ground Acceleration (PGA in g) (25, 50, 100 & 200 Years Return Period)



2.2 TSUNAMI

2.2.1 Objective

To prepare the possible Tsunami inundation/flooding scenario maps in the delta region of the Myanmar (Ayeyarwady, Yangon and Bago divisions)

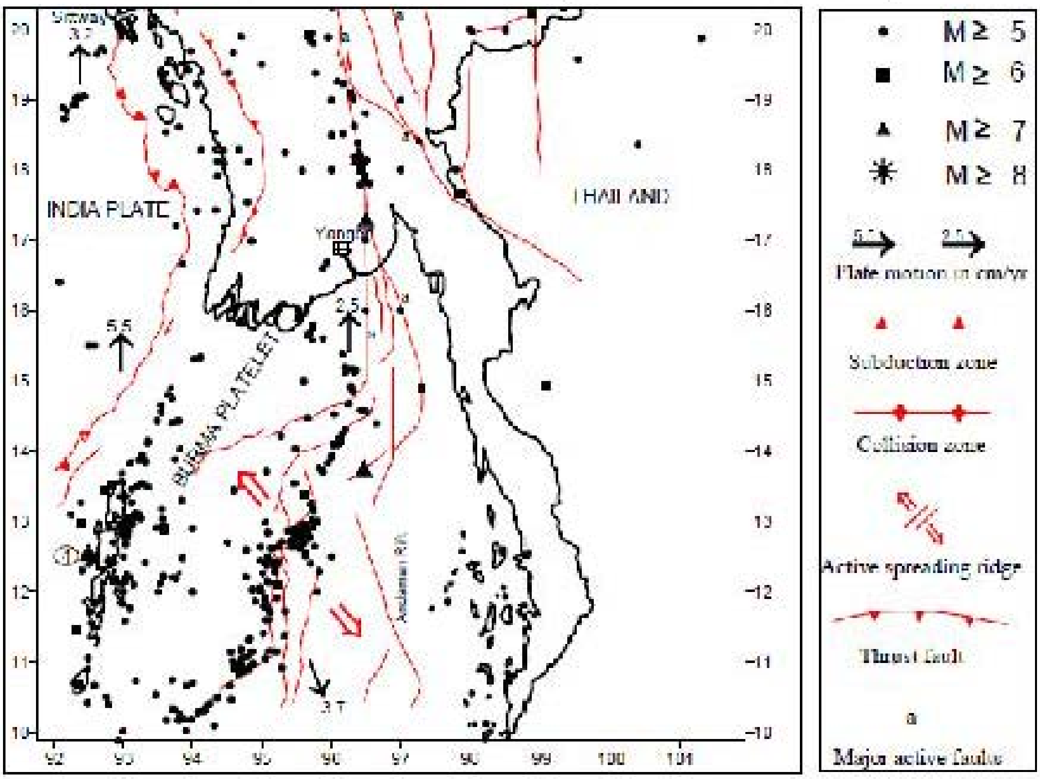
2.2.2 Introduction

The present study region lies in the proximity of subduction zone which is a dynamic tectonic domain. Moreover, 2004 Sumatra Tsunami also reached up to the coastal areas of the delta region in the Myanmar (Satake *et al.*, 2006), therefore it is essential to estimate the inundation pattern and horizontal reach of the Tsunami waves in the study area occurring along with the usual tides experienced in the study area. The seismotectonic surrounding the Myanmar region has been explained in the earthquake hazard analysis chapter. The Figure 2-9 represents the tectonic elements surrounding the offshore of delta region.

The principal cause of a Tsunami is the displacement of a substantial volume of water or perturbation of the sea usually attributed to a submarine earthquake, landslides, volcanic eruptions, or more rarely by meteorites and nuclear tests. The tides do not play any part in the generation of Tsunamis, but the tidal levels at the time of reaching the coast determines the horizontal spread of the Tsunami waves (especially in coasts with high tidal ranges). Tsunamis have a small amplitude (wave height) offshore, and a very long wavelength (often hundreds of kilometers long), which is why they generally pass unnoticed at sea but they grow in height when they reach shallower water.

Figure 2-9: Seismotectonic Set-up Surrounding Myanmar Delta Region

Red lines indicate active faults (after Thein & Swe, 2006).



2.2.3 Data

Data sources used to analyze the risk is presented in Table 2-4.

Table 2-4: Data Source Used to Model Tsunami Risk

Data	Use	Source
Elevation	Elevation and bathymetry dictate the flow of tsunami	SRTM, Etopo01
Tidal Heights	To understand the effect of tides on tsunami inundation.	Total Tide Software 2004
Tsunami Heights	To analyze the spread and depth of inundation based on probable tsunami heights	EWC[3] Tsunami simulation of various scenarios & Satake *et al.* 2006 and Fritz *et al.*, 2007
Division and district boundaries	To analyze the population at risk	MIMU

2.2.4 Methodology

Tsunamigenic earthquake scenarios were simulated by DMH/EWC. These simulation results were used for modeling the inundation scenarios over the land. Time-Stage relationships were established considering the worst case scenario where the event could last for more than three hours. Based on probable tsunami heights at the coast two scenarios were analyzed in this study

a) Tsunami heights with maximum tidal heights in study area

b) Tsunami height with average tidal conditions in study area

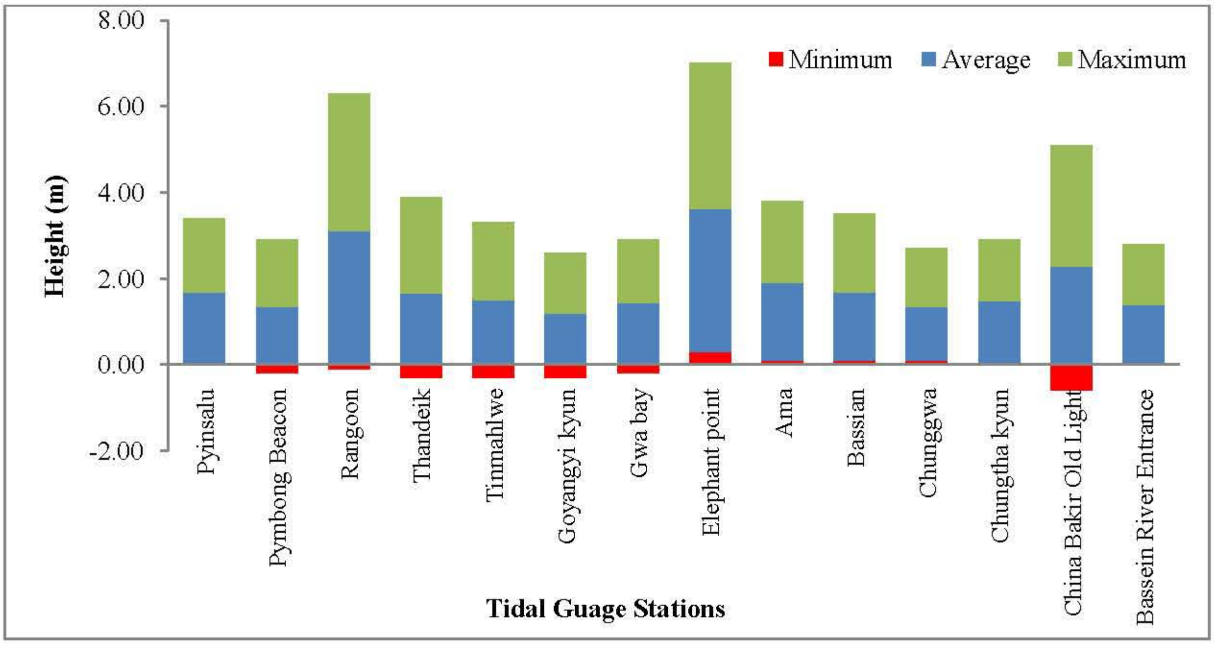
The inundation simulation within this study was carried out using Flo2D software. Flo2D is a two dimensional dynamic routing model that simulates channel flow, unconfined overland flow and street flow. It can simulate inundation over complex topography and roughness while reporting on volume conservation; the key to accurate spread and inundation. The model uses the full dynamic wave momentum equation and a central finite difference routing scheme with eight potential flow directions to predict the progression of a flood hydrograph over a system of square grid elements

The Tidal Conditions

The study area experiences diurnal tides in six hour time period. Tidal heights of 15 tidal gauge stations falling in the present study area have been used in the analysis. Figure 2-10 represents tidal heights observed in the delta region from West to East. The tidal heights observed in the eastern side of the study area (Yangon) are around twice that of Western side (Ayeyarwady delta region). This is mainly attributed to the coastal configuration in the eastern region, which appears to be funnel shaped.

[3] DMH/EWC-Early Warning Center, Nay Pyi Taw)

Figure 2-10: Tidal Heights from Tidal Gauge Stations in the Study Area



Source: Total Tide software 2004

Tsunami Heights

EWC presented six scenarios illustrating the Tsunami heights along the Myanmar coast which may be experienced due to earthquake of magnitude 8.5 (Mw) at different hypocenters. The Tsunami heights along with the height of tides observed in the study area were used to prepare the possible inundation map. The Tsunami maps obtained by DMH/EWC are presented in the Figure 2-11 to Figure 2-16.

Figure 2-11: Tsunami: Scenario 1

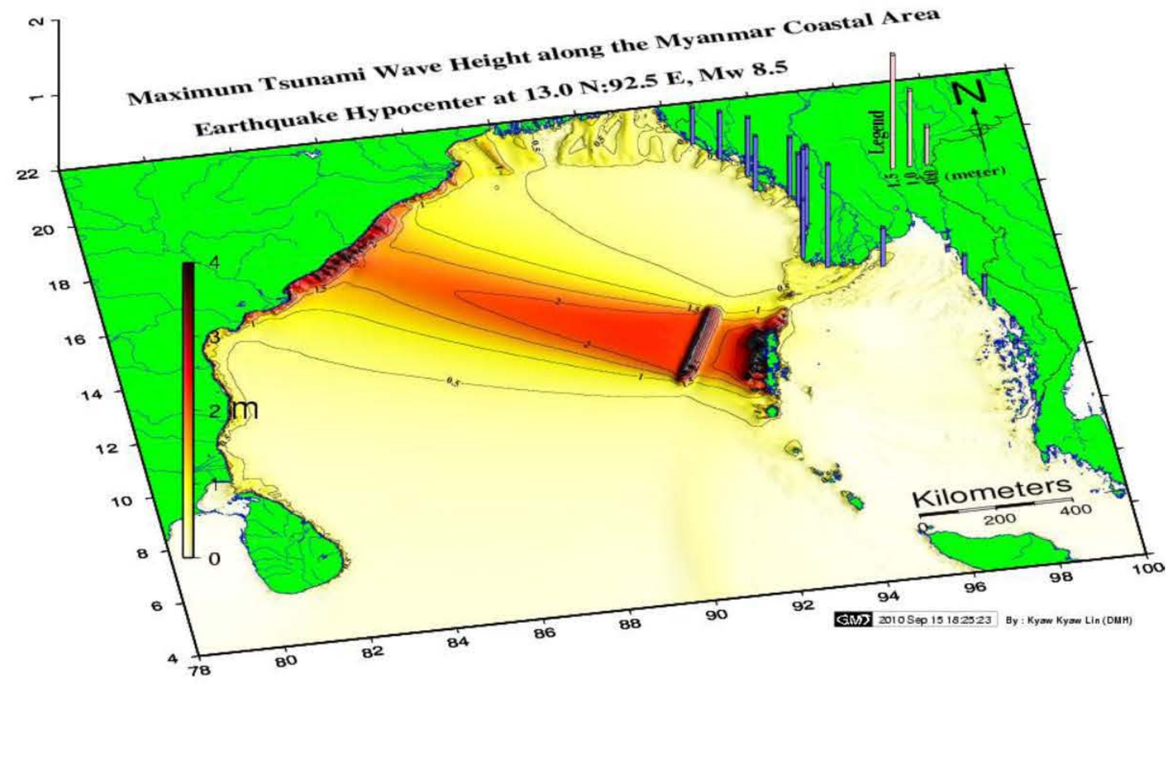


Figure 2-12: Tsunami: Scenario 2

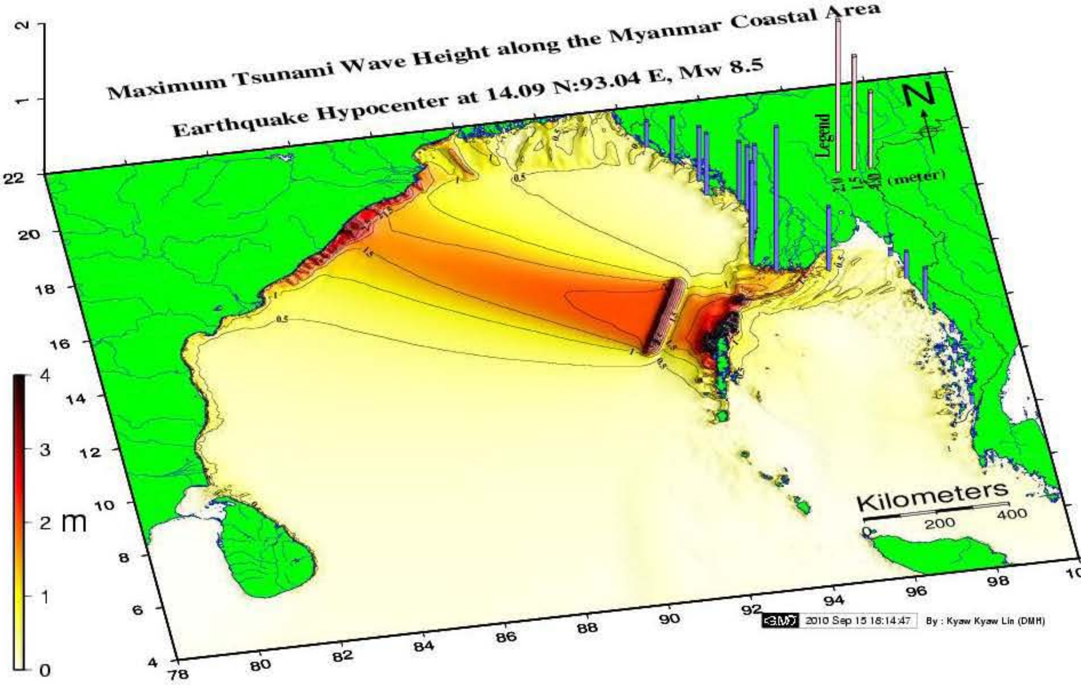


Figure 2-13: Tsunami: Scenario 3

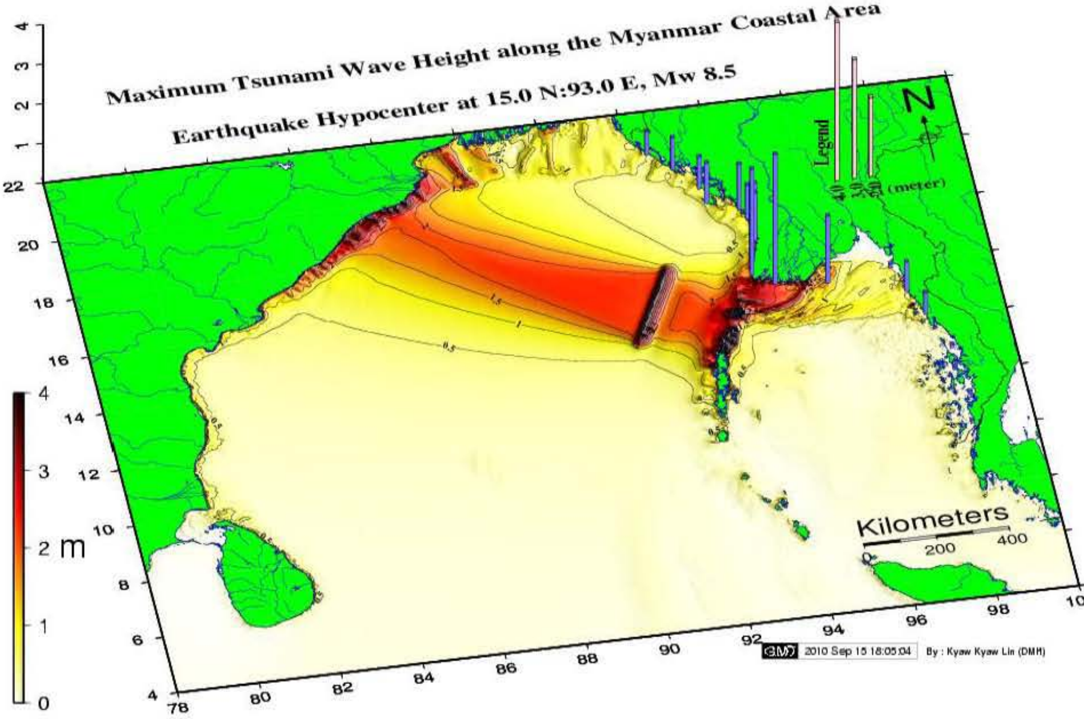


Figure 2-14: Tsunami: Scenario 4

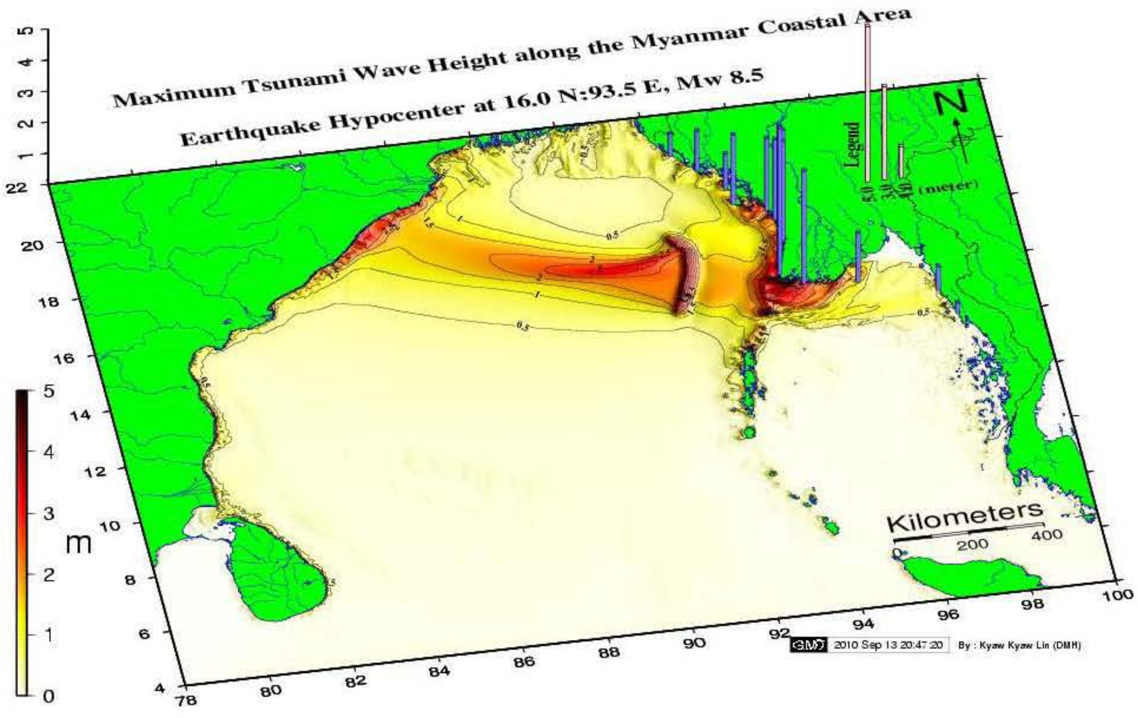


Figure 2-15: Tsunami: Scenario 5

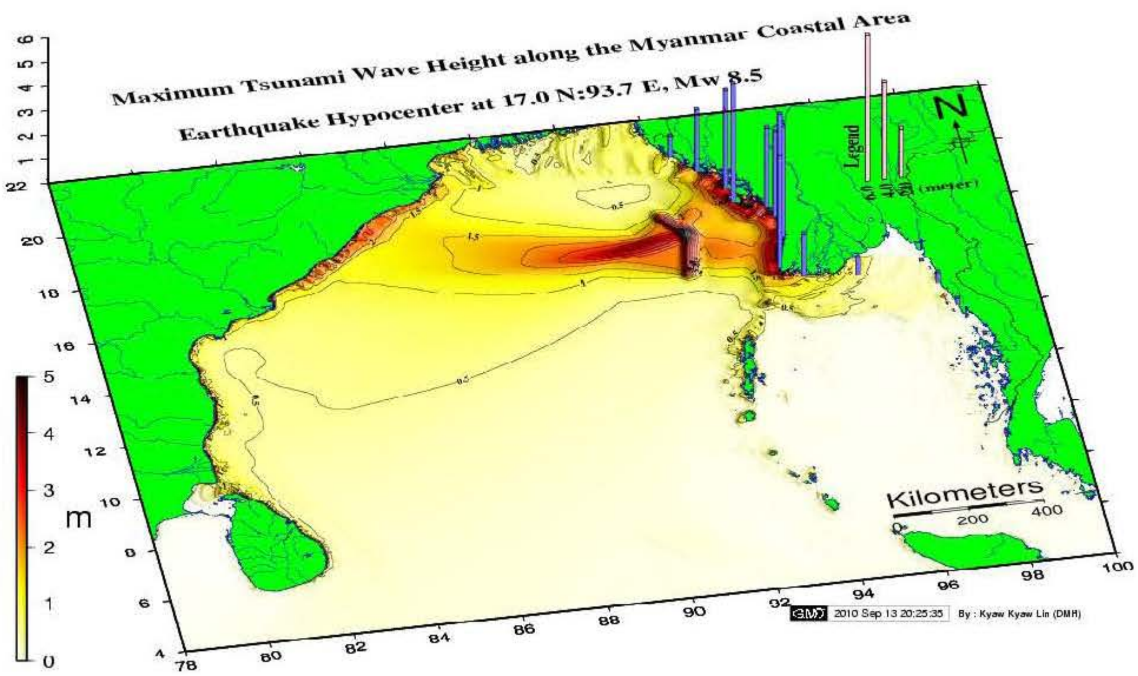
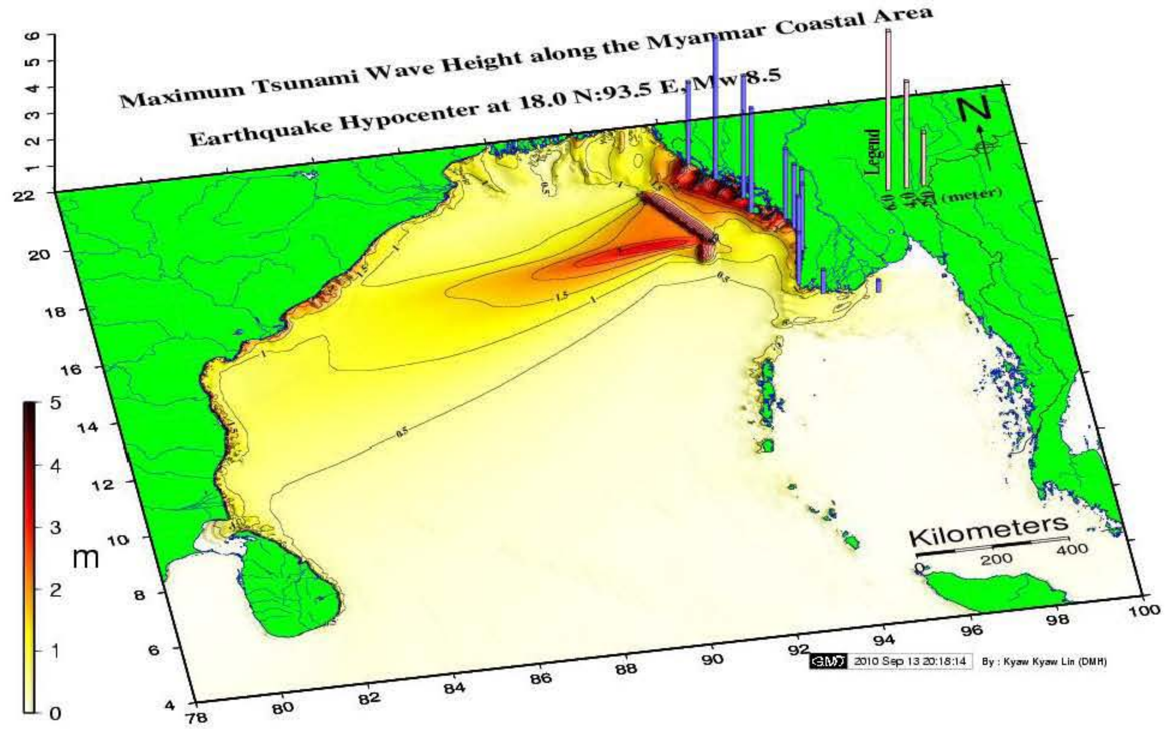


Figure 2-16: Tsunami: Scenario 6



Results from various scenarios illustrated in the Figure 2-11 to Figure 2-16 indicate that scenario number 3 and 4 are most important for the delta region and eastern part of the study region (Yangon). Scenario 5 shown in Figure 2-15 has a significant effect on the Western part of the Ayeyarwady division.

2.2.5 Results

The results of the Tsunami hazard risk are illustrated in Figure 2-17 & Figure 2-18. From the inundation maps it is evident that even though possibility of Tsunami is high for the delta region as it lies in the proximity to the active tectonic domains in the offshore in the South. But, the hazard risks due to Tsunami observed from the model results are relatively low during the average tidal conditions. The results obtained from the analysis indicate that around 333 villages in the Ayeyarwady division and 2 villages in the Yangon division may be affected.

The maximum tide for the study area is usually around the months of July to August. Occurrence of Tsunamigenic earthquakes during this time period will increase the risk of the delta region with such event. Around 586 villages within Ayeyarwady division and 48 in Yangon division may be affected due to tsunami occurring during high tide. Table 2-5 shows the numbers of villages (and their respective townships) that are at risk due to Tsunamigenic conditions in the delta region.

Figure 2-17: Probable Inundation Due to Tsunami Hazard (Average Tidal Height)

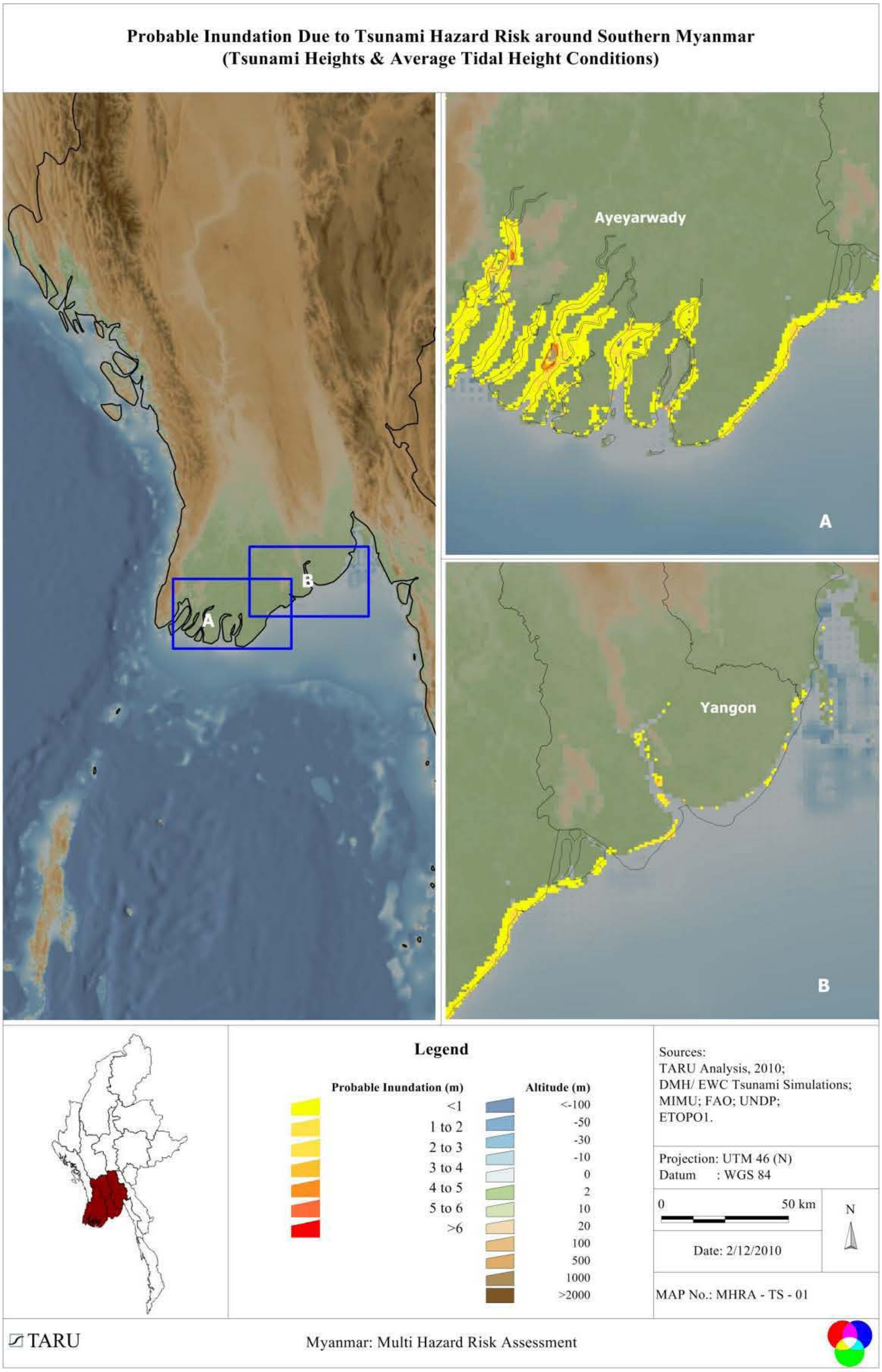


Figure 2-18: Probable Inundation Due to Tsunami Hazard (Maximum Tidal Height)

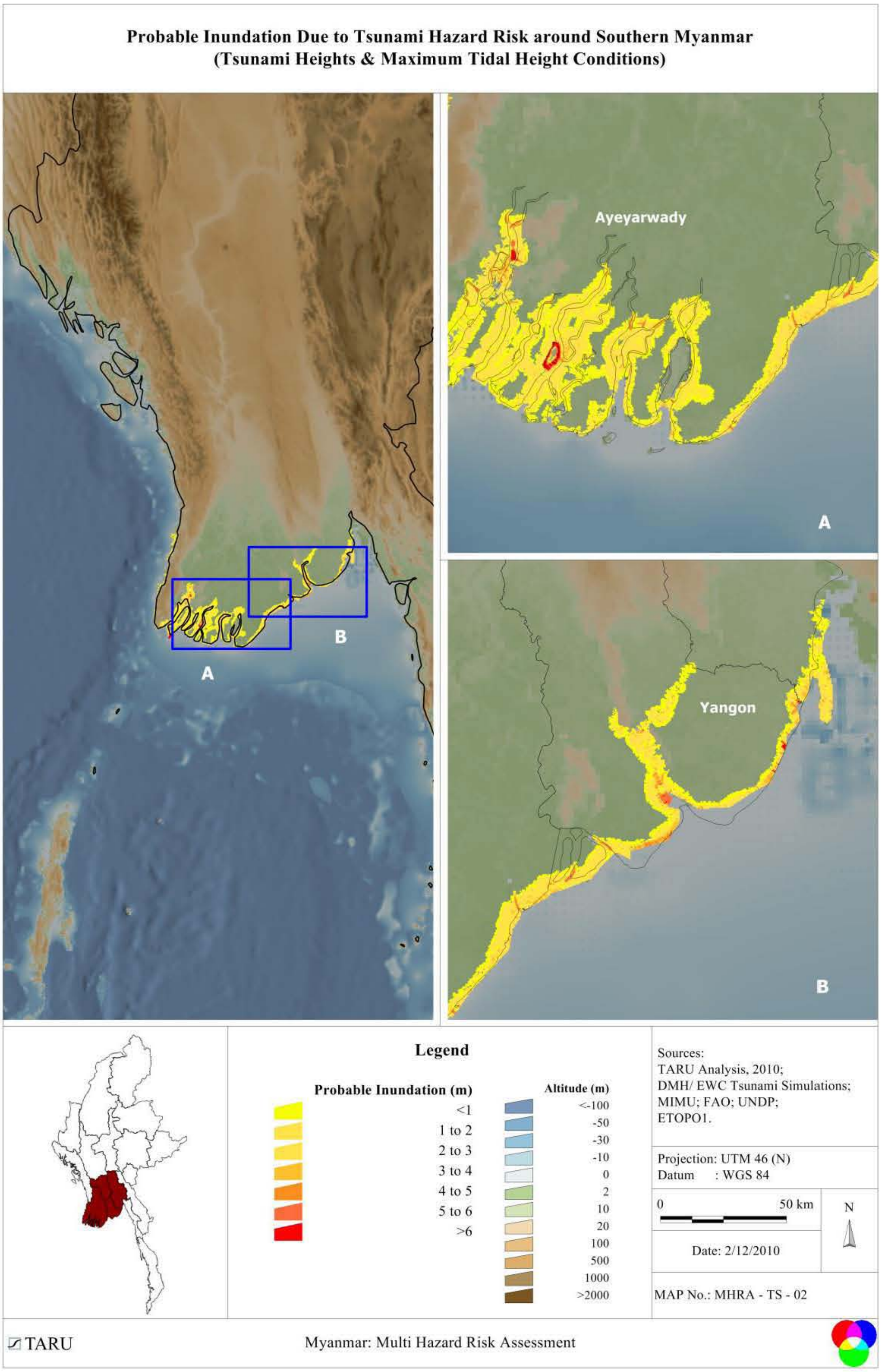


Table 2-5: Summary of the Numbers of Village and Population at Risk Due to Tsunamigenic Conditions in Delta Region

Division/*District*/Township	Average Tide		Maximum Tide	
	No. of villages at risk	Population at risk	No. of villages at risk	Population at risk
Ayeyarwady	333	273,366	586	486,320
Labutta	197	148,878	323	262,209
Labutta	187	140,647	305	247,641
Mawlamyinegyun	10	8,231	18	14,568
Myaungmya	7	6,650	9	8,429
Myaungmya	7	6,650	8	7,600
Wakema	-	-	1	829
Pathein	25	29,864	45	54,564
Ngapudaw	22	26,000	42	50,700
Pathein	3	3,864	3	3,864
Pyapon	104	87,974	209	161,118
Bogale	72	49,714	112	85,358
Dedaye	12	9,336	65	32,676
Pyapon	20	28,924	32	43,084
Yangon	2	5,471	48	132,237
Yangon (East)	-	-	2	4,234
Dagon Myothit (East)	-	-	1	2,117
Dagon Myothit (Seikkan)	-	-	1	2,117
Yangon (South)	2	5,471	45	128,003
Dala	-	-	7	28,101
Kawhmu	-	-	5	5,760
Kayan	1	3,292	3	9,876
Kungyangon	-	-	10	13,300
Kyauktan	-	-	12	25,404
Thanlyin	-	-	5	39,025
Thongwa	1	2,179	3	6,537
Yangon (West)	-	-	1	0
Kyeemyindaing	-	-	1	0
Grand Total	**335**	**278,837**	**634**	**618,557**

2.3 CYCLONE

> ***"Then fiery clouds collect in thick masses; the thunder sounds deep and heavy. Rainbows appear, now forming an unbroken curve and again separating, and the ends of the bow dip into the sea. The sea sends back a bellowing sound, and boils with angry surges; the loose rock dash against each other, and detached sea-weed covers the water; there is a thick, murky atmosphere; the water fowl fly about affrighted; the trees and leaves bend to the south - the typhoon has commenced."***
>
> **S. Wells Williams (1883)**

2.3.1 Objectives

To derive the nature, geographical distribution, severity and frequency of cyclonic storms in delta region. To generate possible inundation maps due to cyclonic storm surges leading to disastrous conditions in the study area based on historical records.

2.3.2 Cyclone & Wind Hazard Analysis

Cyclone and wind hazard risk analysis use parametric models and probabilistic assessment methods since the 1980s to determine basic/peak design wind speeds at specified sampling and recurrence intervals (Holland, 1980, Jelesniaski, 1992; Georgiou et.al, 1983; 1984; Simiu & Scanlan, 1996; WMO, 2002).

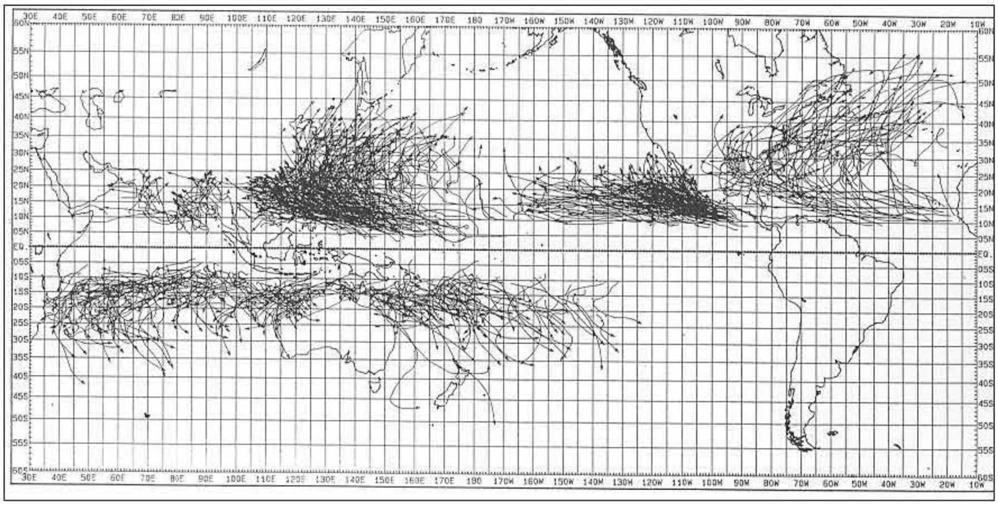
With the developments in tropical meteorology studies, remote sensing technology, the direction of movement and wind intensities of tropical cyclones can accurately predicted from a limited number of storm parameters (WMO, 2002). These parameters include the central pressure difference, the radial distance to the region of maximum wind, the storm translation speeds and spatial-temporal distribution (Houston et.al, 1994, 1999; Kaplan & DeMaria, 1995, 2001; Holland, 2000). Even though large variations exist in the meteorological parameters of individual tropical cyclones and storms, their general structure is typically consistent for all storms, enabling the use of a mix of theoretical and empirically tested models to assist hazard risk analysis.

The primary challenge therefore in cyclone related risk studies is to assemble a reliable catalogue of cyclones and historical records of the storm parameter, to apply appropriate statistical technique to obtain a representation of these parameters in the region of interest and thus simulate wind fields for a particular region with appropriate corrections for surface winds and post landfall filling. The extreme value distribution of the regional wind climate is then analyzed to determine wind speed probability estimates over defined recurrence periods using standard maximum-likelihood techniques (Simiu & Scalan, 1996; Watson, 1997; Sinha & Mandal, 1999). Return period of the cyclone were calculated for 25, 50, 100 and 200 years. The relationship between the return periods and the exceedance probability remain same as that elaborated within the section Earthquake Hazard Risk.

Tropical Cyclone Hazard Risk: The Global Context

Global cyclone tracks over relatively short period (1979-1988) in Figure 2-19, presents a graphical form of the relative frequency of cyclone events (Neumann, 2000). The eastern and Western north Pacific and the Southern Indian Ocean are clearly more intense basins of activity. Bay of Bengal is part of Indian Ocean basin and also under present study.

Figure 2-19: Global Tropical Cyclone Tracks (1979-1988)



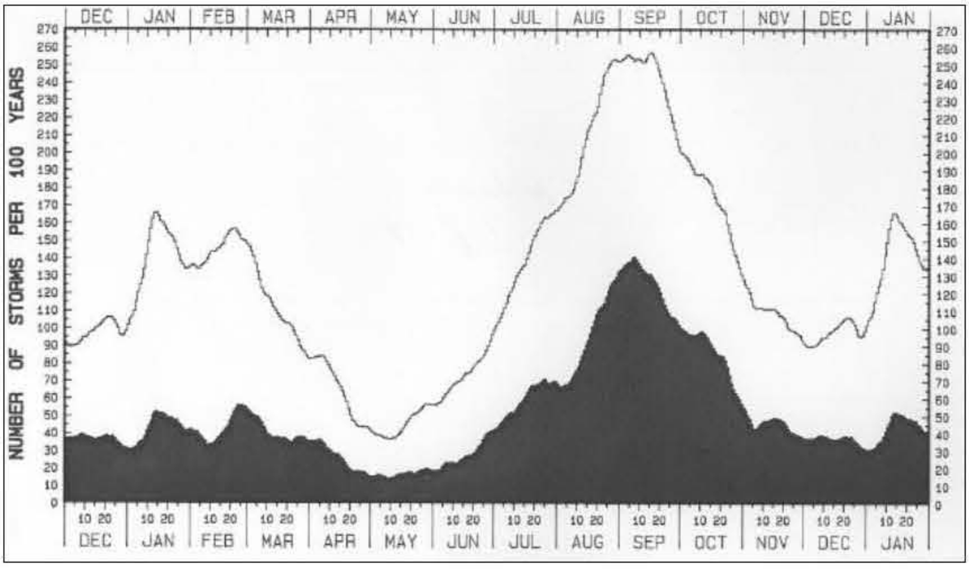
Source: Holland, *et al.* 2000

Nevertheless, the highest loss of life (Bay of Bengal) and loss of property (North Atlantic) clearly indicates the importance of vulnerability in the overall risk profile.

a) Seasonal Profile of Tropical Cyclone Occurrence

The global seasonal profile of cyclonic and other storms over a 30 to 103 year period (depending on basin data sets) is presented in Figure 2-20. The data is presented over a 15 day linear moving average and shows, three major peak seasons. The data shows that majority of the cyclones which have landfall over Myanmar delta are during pre monsoon or post monsoon months.

Figure 2-20: Global Seasonal Tropical Cyclone Frequency (1891-1989)

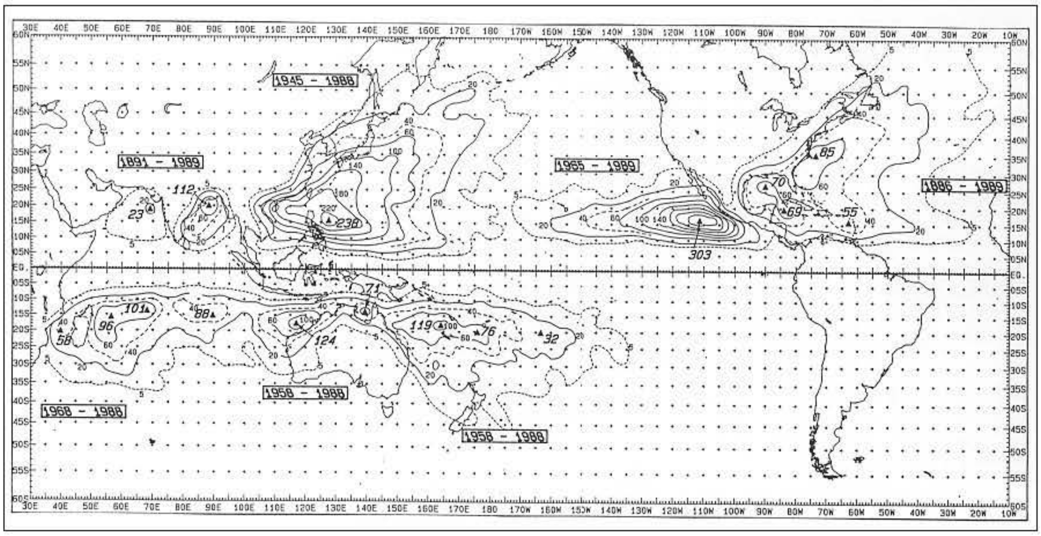


Source: Holland, *et al.* 2000

b) Tropical Cyclone Density

The frequency of tropical cyclones over a 100 year period within 140 km of any point is presented in Figure 2-21. The maximum densities occur in the eastern north Pacific (303 / 100 years), just off the Philippine coast (238 / 100 years). The frequency in the Bay of Bengal is coming to 20/100 years (Neumann, 2000).

Figure 2-21: Global Tropical Cyclone Frequency Density (1891-1988)

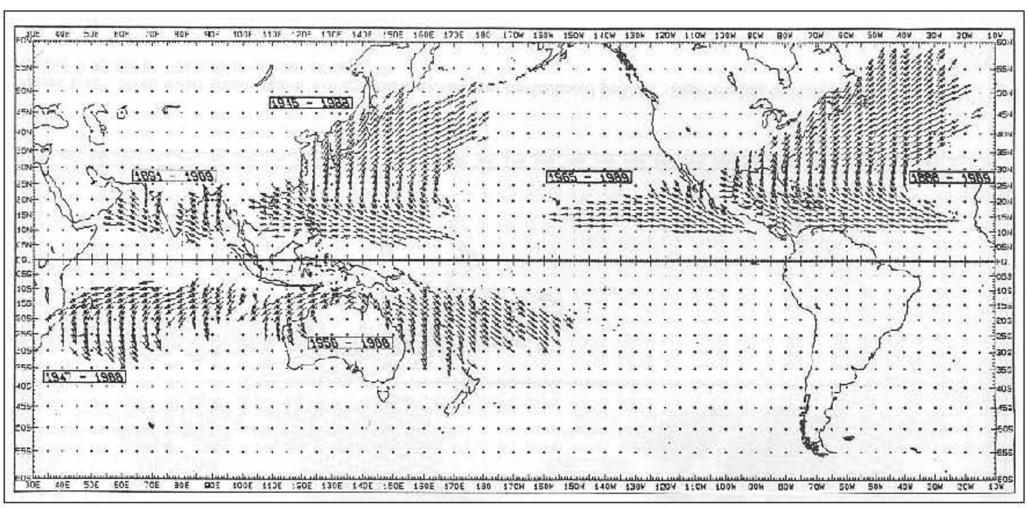


Source: Holland, *et al.* 2000 (*Note: Period of coverage varies between basins*)

c) Tropical Cyclone Direction of Motion

The directions of motion of tropical cyclones are presented in Figure 2-22. Classic re-curvature patterns are observed in the eastern north Pacific and north Atlantic basins and to a lesser extent in the Southern Indian Ocean basin. In the Bay of Bengal, the typical trend is towards the north and North-West, with some cyclones originating from the East.

Figure 2-22: Mean Tropical Cyclone Direction (1891-1989)

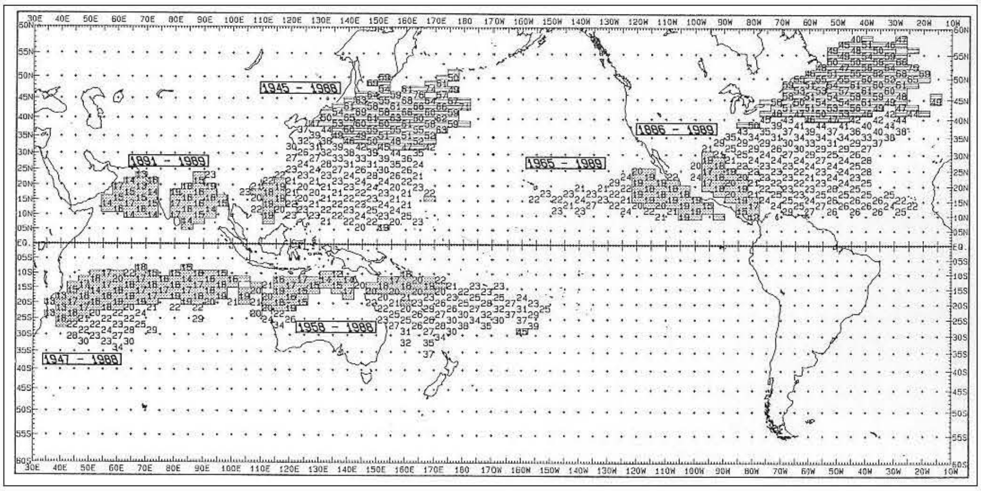


Source: Holland, *et al.* 2000 (*Note: Period of coverage varies between basins*)

d) Mean Tropical Cyclone Scalar Speeds

The speed of translation of cyclonic storms varies considerably for individual basin and within basin, as presented in Figure 2-23. The fastest are in the higher latitudes of the North Atlantic and Western North Pacific basins where mean speeds can exceed 75 kmph. Cyclonic storms in and around Myanmar are have much lower translational speed ranging from 14 to 16 kmph (Neumann, 2000).

Figure 2-23: Mean Tropical Cyclone Scalar Speed (kmph) for 1891-1989 period



Source: Holland, *et al.* 2000 (*Note: Period of coverage varies between basins*)

2.3.3 Uncertainty

The unavailability of hazard data at the regional level does contribute to the uncertainty within the analysis. The limitations included:

1. Accurate bathymetric and topographical data of the study area for GIS based modeling in coastal areas is still a considerable constraint to determine the hazard related to cyclones.
2. Lack of appropriate damage and vulnerability datasets for buildings that could have been utilized to develop a tentative cyclone and storm surge damage
3. Wind and storm surge are crucial factors in the determination of damage occurring in the coastal regions associated with cyclones. Since very few tropical storms actually strike at a predicted site (presumed site) and historical records only exist for less than hundred years or so, there is always a limited scope for better hazard estimations for cyclones.
4. The impacts of climate change on cyclone frequency and intensities are still unknown.

2.3.4 Study Area (Ayeyarwady, Bago & Yangon Delta Region)

Although the devastation caused by Cyclone Nargis in the Ayeyarwady delta region has caught international attention, the fact remains there that the region has a history of severe tropical storms. However, Figure 2-21 to Figure 2-23 indicates that frequency of high intensity cyclones making landfall in Delta region (e.g. Cyclone Nargis) are rare. Over the last sixty years, eleven tropical cyclones had hit the Myanmar, out of which only two made landfall in the delta region. The Cyclone hazard risk of the delta region was analyzed and is shown in Figure 2-24 & Figure 2-25. Cyclone Nargis hit the coast of Myanmar on 2nd May 2008 and was rated as the eighth deadliest cyclone of all time to hit the region. It was the first tropical cyclone to strike the country since Cyclone Mala made landfall in 2006. There are two prominent Cyclone seasons for the country i.e. between April to May and October to December. Historical data indicate that on an average, every ten years a cyclone had landfall in Myanmar. Hence an appropriate plan should be in place to deal with frequent and potentially damaging events for Myanmar, especially for Rakine and Western coastal regions.

Figure 2-24: Cyclone & Storm Tracks

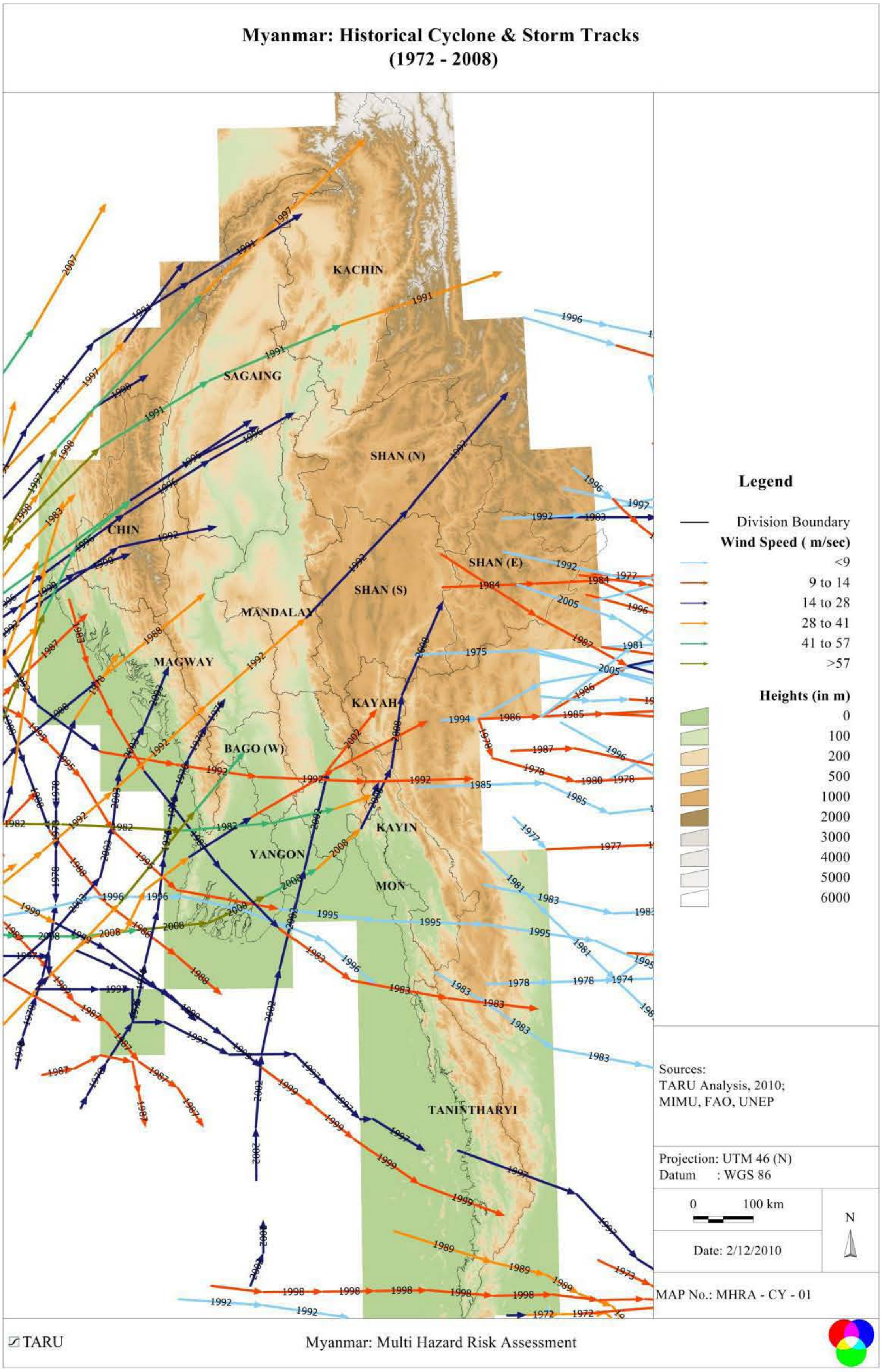
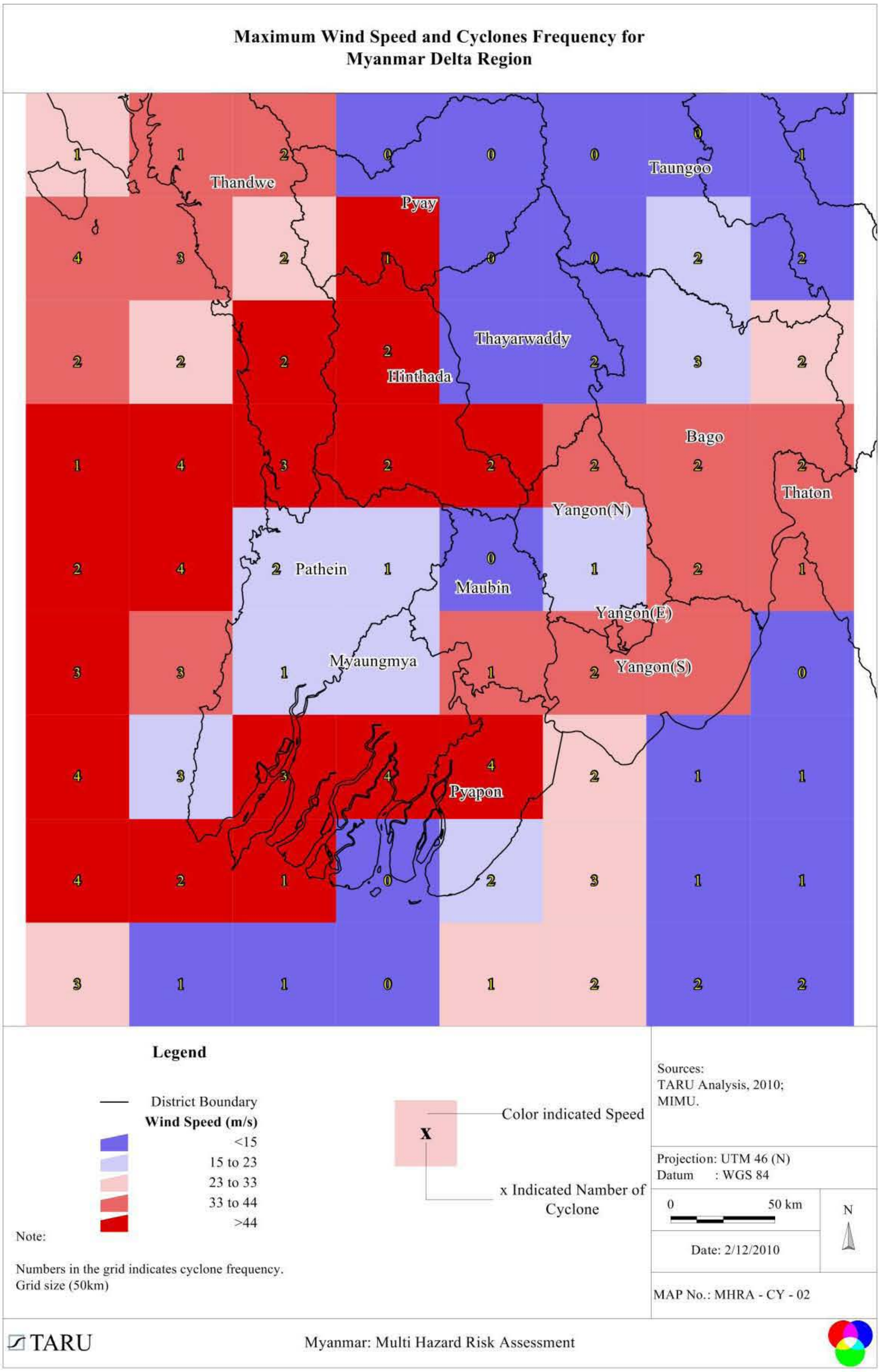
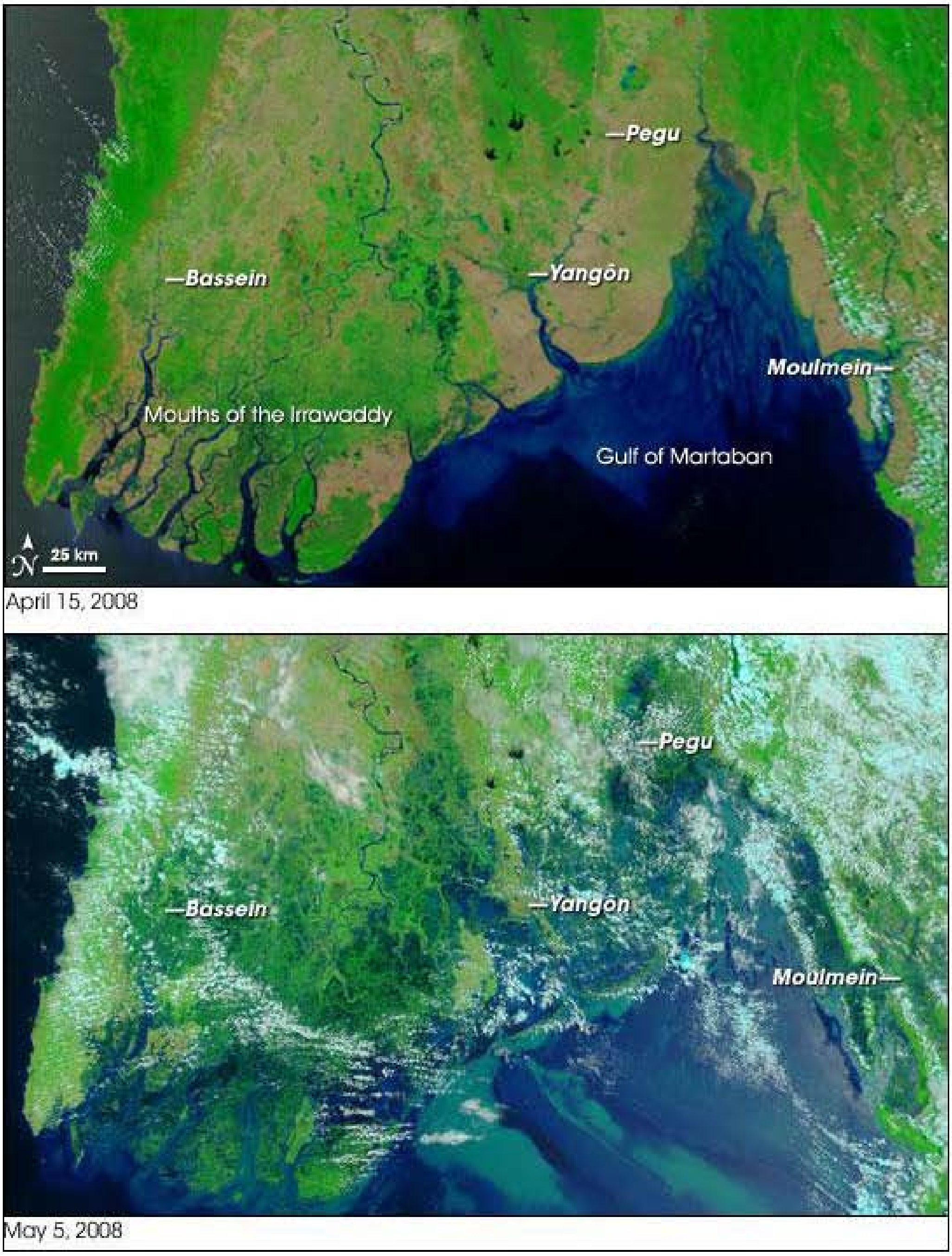


Figure 2-25: Cyclone Distribution in Delta Region



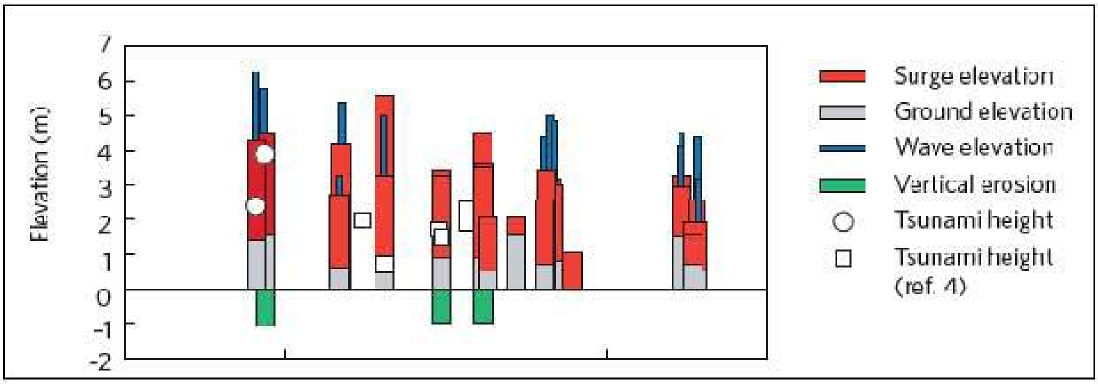
During Nargis storm, most areas around the delta experienced high storm surge levels. Based on reported evidence roughly 2m high storm waves were superimposed on surge levels. The inundation distances reached 50 km inland from the nearest coastline (Fritz *et al.* 2009). Figure 2-26 shows image taken by NASA which clearly shows the extent of inundation occurred in the delta region due to the Nargis cyclone.

Figure 2-26: Deltas in Crisis: Ayeyarwady Delta



Source: http://deltas.usgs.gov/imagery.aspx

Figure 2-27: Comparison of Measured Storm Surge and Storm Wave



Source: Fritz, *et al.* 2009

Historical Cyclone Tracks in the Study Area

Previous records in the study area reveal that the cyclones move from West to east, South-West to northeast and also from South to North. The cyclones which were from West to East were reported during years 1982, 1992, 1995 & 1996, from North-West to South East in year 1983, from South to north in year 2002 and from South-West to northeast in year 2008. Apart from the cyclones mentioned in the preceding text which passed through the delta region, several other cyclones have also passed through nearby regions of Southern Myanmar e.g. years 1976, 1978, 1997, 1999, 2003, 2006 etc.

Based on the historic cyclonic wind speed data, it appears that the study area has experienced the cyclonic conditions with the maximum wind speed of over 53m/sec. It is also understood from the record that Ayeyarwady division of the study area has experienced almost all the seven cyclones which had hit the Southern Myanmar region along with Yangon and Bago divisions. Since the delta region has very high population density, more attention is necessary as far the region's vulnerability from cyclone risk is concerned.

2.3.5 Probabilistic Cyclone and Wind Hazard Assessment

The method followed for probabilistic cyclone and wind hazard assessment for Myanmar delta is as follows.

1. Collation of cyclone, storm and depression track catalogue (1972-2008)
2. Temporal and spatial interpolation of storm tracks at 0.1 degree traverse intervals, determination of velocity of translation, bearing at each track point and the time period of filling of land falling of storms
3. Estimation of critical storm parameters: velocity of translation, bearing at each track point, radius of maximum winds, and peak velocity at the radius of maximum winds
4. Wind field simulation for selected grid points (0.1 x 0.1 degree coverage)
5. Estimation of exceedance peak gust wind speed probabilities for 25, 50, 100 and 200 year recurrence intervals
6. Preparing wind hazard risk maps

A detailed description of each step and the intermediate outputs are presented in the following section.

- **Collation of Cyclone and Storm Track Catalogue**

The collation of a comprehensive cyclone and storm track catalogue, exclusion of repetitions, correction of errors, and normalization to common wind speed/pressure units and estimation of critical storm parameters were undertaken from:

  - The US Navy, Global Cyclone Climatic Atlas
  - Cyclone tracks from UNEP – Global Risk Data Platform
  - Satellite based cyclonic storm data from JTWC
  - Storm windfall data from UNEP-GRID

- **Storm Track Temporal and Velocity Interpolation**

Following the compilation of the cyclone and storm track catalogue; temporal and spatial velocity interpolations were undertaken using spline-fit algorithms on the GIS at 0.1 degree intervals along the storm track. This was undertaken to enable a rigorous determination of vector wind field as development, intensification and filling takes place over the storm life cycle. Linear temporal interpolation was undertaken assuming that significant non-linear changes do not take place over the short distances (~ 11 km) at which the track data points interpolated. The velocity of storm translation and bearing at each track point was determined to estimate the influence of storm translation and Coriolis forces on the overall wind field.

- **Simulation of Storm Wind Fields**

Each storm wind field was simulated at a 0.1 degree linear track interval with appropriate corrections for post landfall filling and intensity decay, terrain roughness and topography. Key observed/estimated parameters include: track velocity, track bearing, mean central pressure, radius of maximum winds, maximum sustained gradient and sea-surface wind velocity, 10 ' and 3" peak gust wind velocity.

- **Wind Field Modeling**

Following the construction of the interpolated track database, storm wind fields were simulated across a point grid (0.1 x 0.1 degree interval) using a modified Holland (1997) and Jelesniaski SLOSH (1992), idealized Holland (1980) wind field equation with corrections for gradient wind at 10 m elevation and 3 second peak gust wind speeds (Holland et al, 2000, Sinha & Mandal, 1999, Simiu & Scanlan, 1996). Key parameters included: velocity of translation, Central pressure and peak gust wind speeds (3-second averaging at 10 m).

- **Extreme Value Distribution Estimation**

Extreme wind speed exceedance probability for four return periods namely 25 (96 percentile), 50 (98 percentile), 100 (99 percentile) and 200 (99.5 percentile) years was estimated from the extreme value distribution defined for each of the grid points (Johnson & Watson, 1977; Watson, 1997; Casson & Coles, 2000; Cossette *et al.*, 2002).

2.3.6 Cyclone & Wind Hazard Risk Assessment

The following section presents an overview of the methodology used in the assessment of cyclone and wind hazard risk.

a) Definition of Assessment Grid Density

Definition of the assessment grid density was undertaken. The grid density was selected as 0.1 x 0.1 degrees.

b) Selection of Appropriate Wind-Field Model

The selection of an appropriate wind field model to simulate the estimated wind fields of historical storms was undertaken, by reviewing available literature and models (Jelesniaski, 1974, 2000; Jeary, 1999; Basu *et al.*, 1987; Mandal & Gupta, 1993; Kaplan & DeMaria, 1995, 2001; Watson, 1997; Houston et. al., 1999; Sinha & Mandal, 1999; Holland, 2000; Cossette et. al., 2002; WMO, 2002). A combination of the widely referred Holland / Jelesniaski wind field model was finally chosen, based on its robustness in various goodness of fit test.

c) Assumptions

Few assumptions have been made to enable the convergence between the assignment objectives and the available data sets. Key assumptions are listed below:

1. The parameterization of the Holland cyclostrophic balance and DeMaria filling equations for the Arabian Sea, Bay of Bengal and the north India landmass with a limited set of values (R_{max}, a & b) can appropriately represent the wind field distribution for the region.
2. The DeMaria filling equation can appropriately estimate the decay in maximum winds due to the overland movement of land falling cyclones and storms in the region.
3. A linear temporal interpolation of spatially interpolated data points (using a best fit spline - function in GIS) at a 0.1 degree interval is an appropriate approximation of cyclone and storm tracks
4. Grid coverage of 0.1 x 0.1 degree is deemed adequate for the delta.
5. Krigging algorithm was used to derive appropriate contours and zoning for the hazard analysis.

d) Limitations

Cyclone and wind hazard risk assessment has a number of limitations, due to the lack of data availability and the limited validation of the Holland and DeMaria parametric models. Key limitations are presented below:

1. The collated cyclone, storm track and depression catalogue has limited temporal and spatial accuracy, especially in the pre-satellite based imaging era, when 3 to 4 data points were recorded per track per day.
2. A rigorous parameterization of cyclonic storms especially for the Arabian Sea has not been undertaken. Hence, critical parameters such as the radius of maximum winds (R_{max}) and Holland's 'b' parameter are assumed at a limited number values that have been derived from various literature.
3. DeMaria's land falling cyclone filling model has been well tested for the United States (Houston, 1994, 1999). The applicability of this model to north Indian Ocean basin cyclone has yet to be rigorously understood and proved (Adityam & Sarkar, 1998; Sinha & Mandal, 1999).

It is hoped that with the assumptions, limitations, appropriate model and data set used with this document provides scope for further improvements upon these estimates.

2.3.7 Results

To classify the cyclone categories mainly two standard classifications i.e. Saffir-Simpson and Beaufort classifications are referred. However, after referring them, a need was felt to understand these classifications with respect to their application in the Myanmar delta study region which is a part of the Indian Ocean basin.

As per India Meteorological Department (IMD), which observes the cyclone over the north Indian Ocean, when the maximum sustained 3 minutes surface winds are more than 61 m/s, the low pressure system is called as "super cyclone" over north Indian Ocean and this also includes the present study area of Myanmar. The maximum wind speed of the cyclone, as reported by the IMD, was about 61 m/s in the year 1977 and it was accompanied by storm surges attaining 5 meters height. Typical failures observed included complete collapse of roofing system in most of the dwellings and semi-engineered buildings with thatch, tiles and AC sheets, failure of connections, failure of gable walls, and progressive collapse of roof steel trusses (Shanmugasundaram *et al.*, 2000). The U.S. joint typhoon warning center assigns "super typhoons" for those which has maximum sustained 1 minute surface winds of at least 65m/s.

The Table 2-6 and Table 2-7 provide the present approach to derive appropriate scale for the probable cyclone hazard zone for the Myanmar delta region. It was understood that the classification provided in the Saffir-Simpson scale for the cyclone categorization was showing the categories which may not be experienced in the study area as observed with the history of cyclones in the Myanmar delta region (refer Historical cyclone track) and hence underestimation of the hazard zonation may occur with the results obtained in present study. By referring, the BIS Code: 875 (Part III) 1987, it was felt that the same might be more appropriate to use in combination with Saffir-Simpson scale in the present study area to prepare the cyclone related hazard risk zoning.

Table 2-6: BIS Code: 875 (Part III) 1987

Wind Speed (m/s)	Category
<8.75	Low
8.75-13.9	Depression
14.4-17	Deep Depression
17.5-24.2	Cyclonic Storm
24.7-32.4	Sever cyclonic storm
>33	Severe cyclonic storm with core of hurricane wind

Table 2-7: Saffir - Simpson Scale (1971)

Category	Winds km/hr	Winds m/s	Extent of Damage	Effects
Five	≥250	>69	Catastrophic damage	People, livestock, and pets are at very high risk of injury or death from flying or falling debris, even if indoors in mobile homes or framed homes. A high percentage of industrial buildings and low-rise apartment buildings will be destroyed; Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months
Four	210–249	58-69	Catastrophic damage	Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months
Three	178–209	49-57	Devastating damage	There will be a high percentage of roof covering and siding damage to apartment buildings and industrial buildings, Electricity and water will be unavailable for several days to a few weeks after the storm passes
Two	154–177	43-48	Extremely dangerous winds will cause extensive damage	Substantial risk of injury or death to people, livestock, and pets due to flying and falling debris, Poorly constructed frame homes have a high chance of having their roof structures removed especially if they are not anchored properly, Many shallowly rooted trees will be snapped or uprooted and block numerous roads, Near-total power loss is expected with outages that could last from several days to weeks
One	119–153	33-42	Very dangerous wind will produce some damage	Mainly roofs are affected, flying objects may kill people. Some poorly constructed frame homes can experience major damage, involving loss of the roof covering and damage to gable ends as well as the removal of porch coverings and awnings

Table 2-8: Mixture classification from Saffir – Simpson, 1971 & BIS Code: 875 (Part III), 1987

Speed (m/s)	Damage	Category
17.5-32 (BIS)	Very low wind speed will produce low damage	Low
33-42 (SS)	Very dangerous wind will produce some damage	Medium to High
43-48 (SS)	Extremely dangerous winds will cause extensive damage	High
49-57 (SS)	Devastating Damage	High to Very High
>57 (SS)	Catastrophic Damage	Severe

Probabilities for four return periods (25, 50, 100 & 200 years) were determined for the study area from the cyclone hazard zoning perspective. These are based on the mean expected lifetime for temporary structure (25 years), typical non-engineering housing (50 years), engineering building and critical building (100 years) and critical lifeline infrastructure (200 years). The results obtained are presented in Figure 2-28 & Figure 2-29.

Figure 2-28: Comparison for Various Cyclone Classification Schemes (50 Year Return Period)

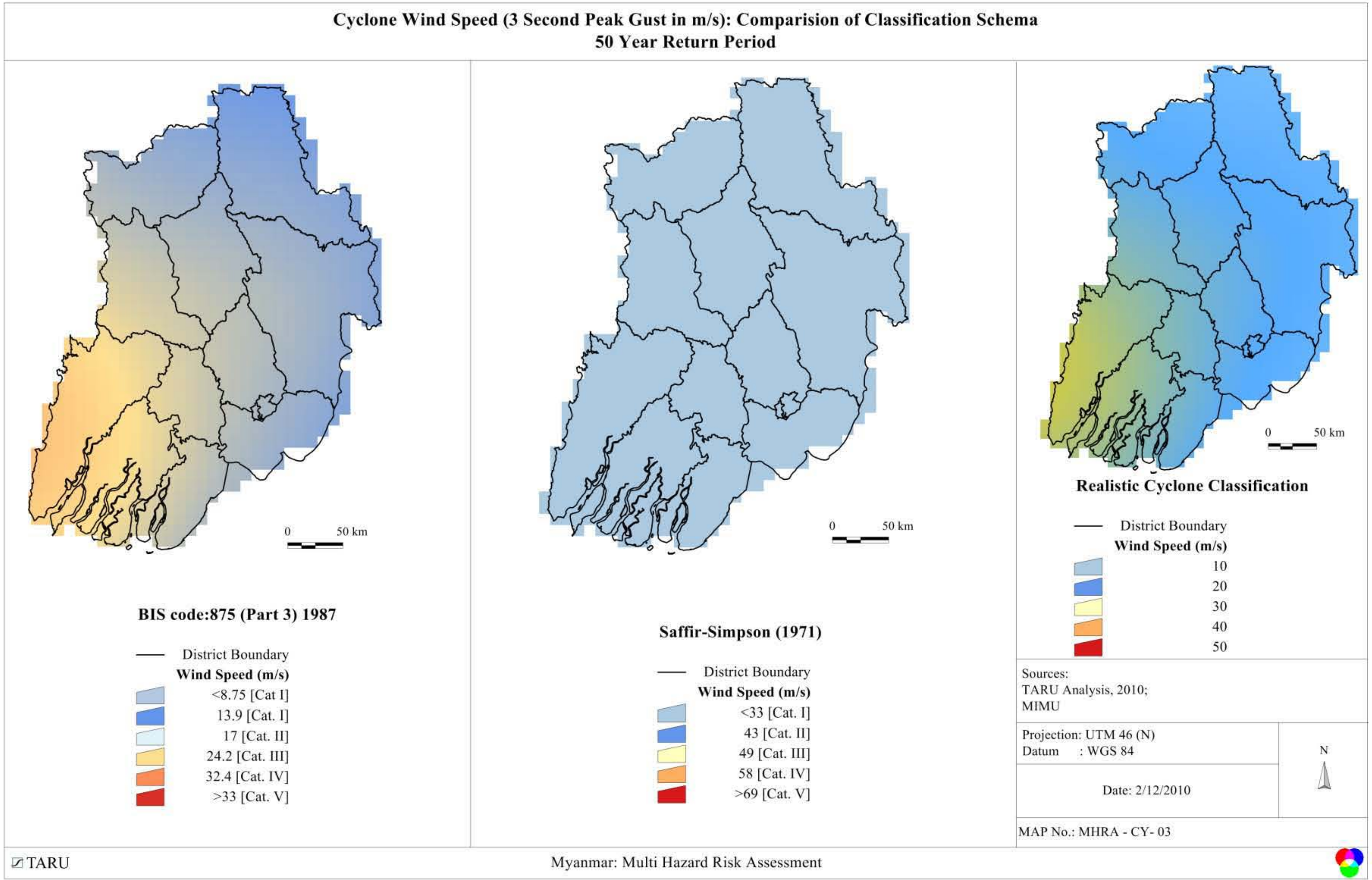
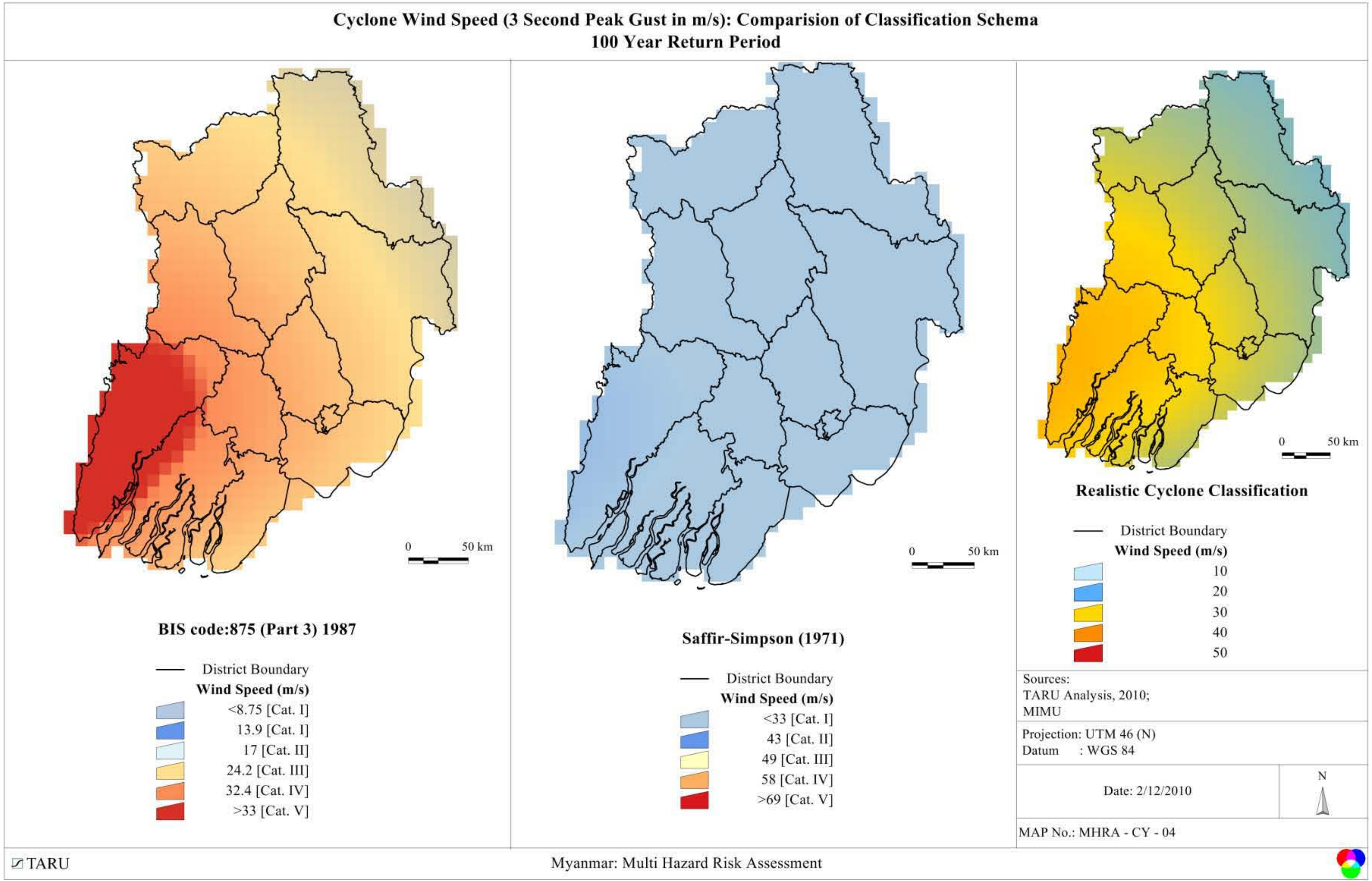


Figure 2-29: Comparison for Various Cyclone Classification Schemes (100 Year Return Period)



In each model run, it is observed that the wind speeds in four scenarios are mostly higher in the Western delta provinces and it progressively diminishes across the eastern parts. The result indicates higher wind speed for Ayeyarwady division compared to Yangon and Bago divisions. Most of the cyclones tracks in this division are from West to east. From the historical records, it is observed that the highest wind speed was experienced during the Nargis cyclone that was >53 m/sec.

The maximum probable wind speeds for different return periods are outlined in Table 2-9. With the 25 year return period scenario the wind speed observed is between 16 to 18 m/s. The 50 years return period shows the wind speed in the range of 20 to 30 m/sec. Under this probability scenario, the spatial coverage is also extending further in the eastern parts of the division. The 100 year return period shows slight variation with respect to the 50 year return period scenario.

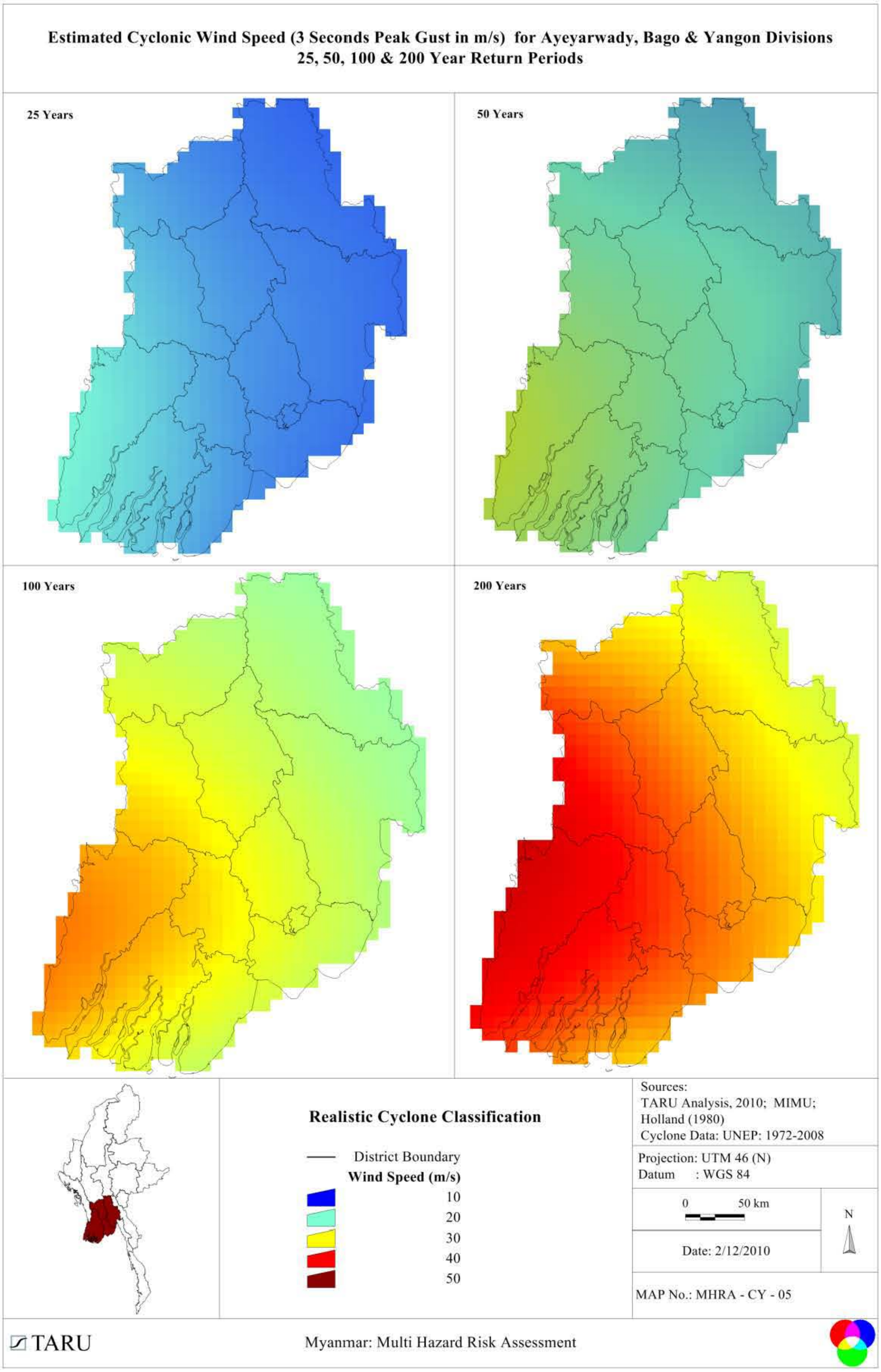
Within the 200 year return period scenario the Ayeyarwady division shows two main classes of the higher wind speeds. The entire Western and central Ayeyarwady division is in the range of 35 to 43m/s range. The Southern Ayeyarwady division remains in the range of 30m/s. The extreme eastern part of the study area including Bago exhibits an average wind speed of around 30m/s. Thus, with the 200 year return period scenario, high wind speeds are possible in entire Western part of the delta along with few regions of East and north.

Thus, based on the present analysis, it is evident that the Southern and Southeastern delta region of Ayeyarwady division remains the most risk prone, followed by South Western Yangon division in the study area. The Bago East seems to be the least risk prone region due to possible cyclonic winds.

Table 2-9: Return Periods and Modeled Wind Speed

Return Period (Years)	Modeled Highest wind speed range (m/s)
25	16 to 18
50	20 to 30
100	25 to 35
200	>35

Figure 2-30: Estimated Cyclone Wind Speed (3 Second Peak Gust in m/s) for Ayeyarwady, Bago & Yangon Division



2.4 STORM SURGE

2.4.1 Objective & Methodology

The objective was to prepare possible storm surge inundation map of the study area considering the prevailing coastal configuration and tidal level in the delta region.

Inundation/flooding in the coastal area can occur due to cyclonic condition which may result in storm surges. In order to prepare the map showing possible inundation scenario in the study area, Flo-2D V. 2009.6 software was used. For the present study area, time-stage relationship was derived considering the tides experienced in the delta region. Tide cycles were analyzed and six to eight hours of the storm surge conditions in case of cyclonic events was considered for risk estimation (spread and inundation). The coastal configuration (topography/bathymetry) and the water bodies near the coast were taken into consideration while modeling. Since, these features greatly influence the extent of spread and height of inundation.

In order to analyze the worst case scenario the maximum storm tide which was experienced during Nargis (Fritz et al., 2009) was considered for estimation of spread and inundation. Since we were not able to procure historical storm surge data along the east coast region of the delta (including Yangon) similar (Nargis) surge conditions were assumed for simulation.

2.4.2 Data & Uncertainty

Table 2-10 provides an outline of data, their source and use within storm surge modeling.

Table 2-10: Data Used for Storm Surge Modeling

Data	Use	Source
Elevation/Bathymetry	To incorporate the effect of coastal configuration and bathymetry in the inundation modeling	SRTM/ETOPO-01
Tidal Heights	To simulate the effect of tides on storm surge.	Total Tide, 2004
Storm Surge Heights	To analyze the historical events to gain insights for storm surge simulation	Fritz *et al.* 2009
Division and district boundaries	To quantify the extent of impact	MIMU

About 15 tidal gauge stations in the present study area were considered for modeling and their locations are shown in Figure 2-31. Tidal records suggest that the tidal conditions vary in the delta region of Ayeyarwady division (Western study area) and Yangon divisions (eastern study area). The tidal heights observed in the eastern side of the study area are higher than the Western side of the study area i.e. Ayeyarwady delta region.

Storm surge heights observations related to the Nargis cyclone were collated from Fritz *et al.* (2009). About 25 locations neighboring Labutta, Bogale and Pyapon of the Southern delta region reveal the average storm surge height to be 3.17m observed after the Nargis cyclone. Maximum storm surge height was observed at Pyinsalu (5.6 m). These observations have been taken into an account to estimate the storm surge inundation in the study area along with tides occurring in the present study area.

Figure 2-31: Tidal Gauge Stations and Storm Surge Records

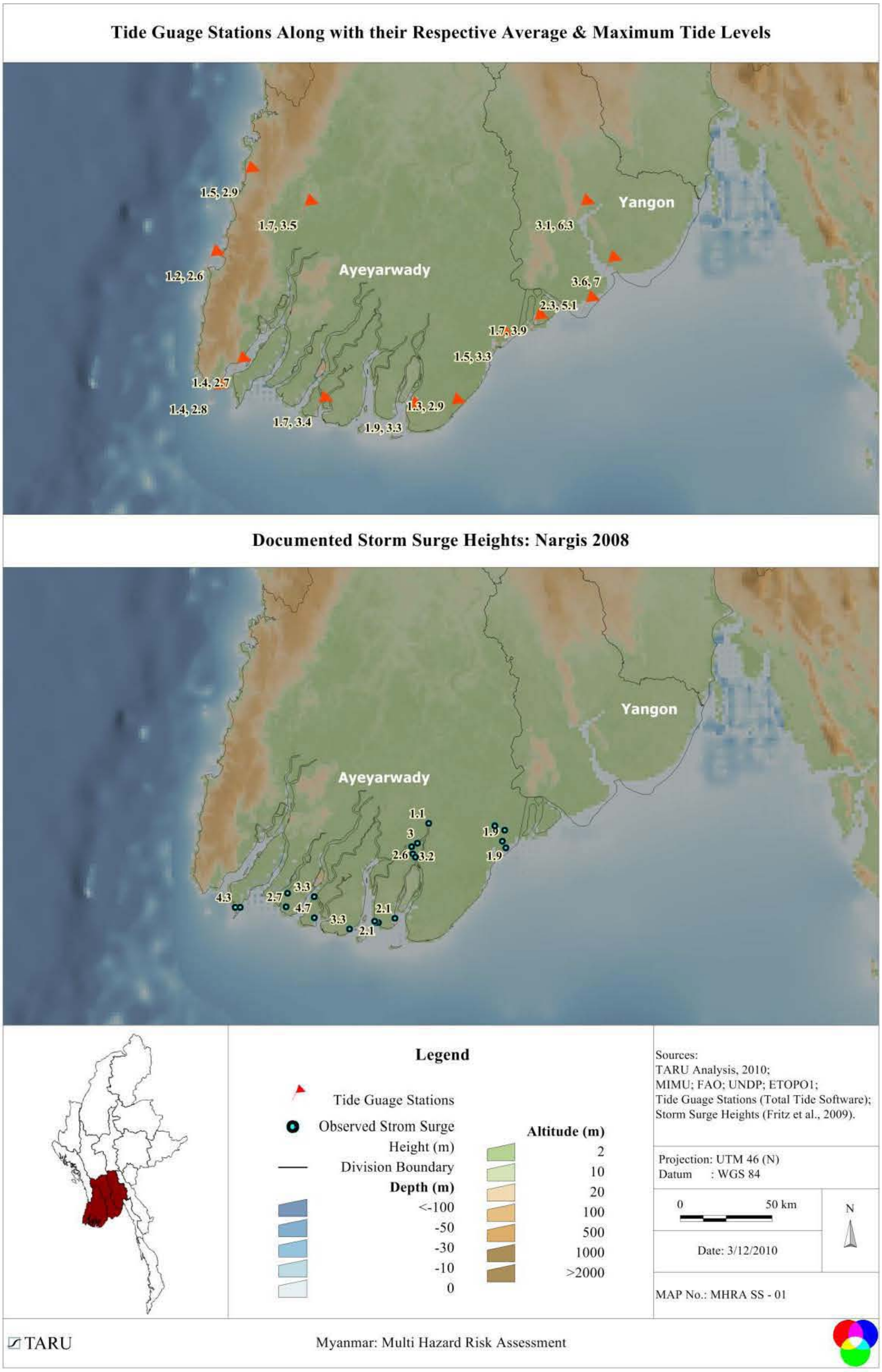


Figure 2-32: Tidal Heights Indicating High Amplitude in Study Area

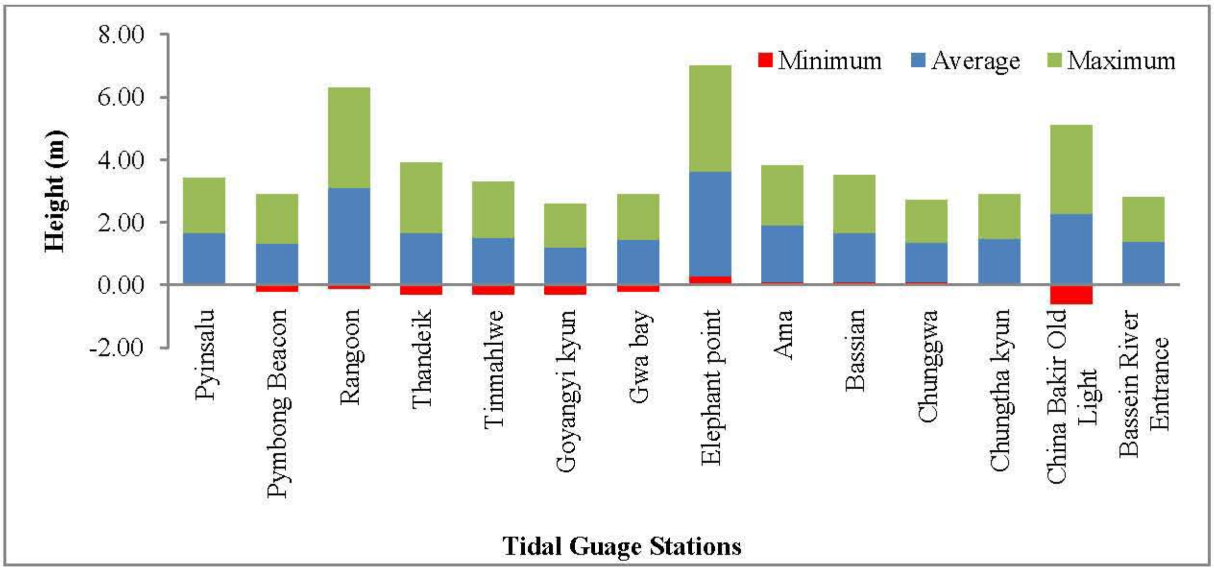


Table 2-11: Locations of Storm Surge Heights (after Fritz *et al.* 2009)

Location	Longitude	Latitude	Surge Height [m]
Thaukkya	95.77	16.20	1.9
Gway Gone	95.79	16.16	1.9
Lae Bin Dan	95.78	16.25	2.6
Nauk Pyan loe	95.73	16.27	3.3
Bogale	95.39	16.29	1.1
KyarChaung	95.33	16.19	3
Tae Tae Ku	95.31	16.17	2.6
Along Kyondon River	95.31	16.14	3.4
Hteik Chaung	95.32	16.12	3.2
Kadon Kani	95.22	15.82	2.1
Ohn Pin Su	95.13	15.80	2.1
Ayeyarwady	95.12	15.80	3.6
Aung Hlaing	94.98	15.77	3.3
Pyinsalu	94.81	15.83	5.6
Ye Gyaw Wa	94.81	15.93	3.3
Mi Chaung Ai	94.67	15.88	2.7
Dae Yae Phyu	94.67	15.95	4.2
Ze Thaung	94.41	15.88	4.3
Kyauk Ka Latt	94.43	15.88	4.5

2.4.3 Results

Figure 2-33 shows the possible inundation/flooding map for the delta region of the Southern Myanmar. Division wise observations have been given in Table 2-12 & Figure 2-33 represents the plot of inundation extent in each district of the study area and has been correlated with the population. This gives estimation about the population vulnerable to the flooding due to storm surge inundation in the study area.

Table 2-12: Summary of the Observation for the Divisions Affected

Division	District	Observations
Ayeyarwady	Pathein Myaungmya Pyapon	The results indicate that an average inundation height in the division remains between 1.34m to 3.35m. The maximum inundation height is observed at Labutta town (around 7.69 m).
Yangon	Yangon (N) Yangon (S) Yangon (E)	The results indicate that an average inundation height in the division remains between 0.27m to 4.79m. The maximum inundation height is observed at Tanyin town (around 9.13m).
Bago	Bago (E)	The results indicate that an average inundation height in the division remains between 1.27m to 1.93m. The maximum inundation height is observed at Kawa town (around 7.79 m).

Figure 2-33: Possible Inundation/Flooding Map

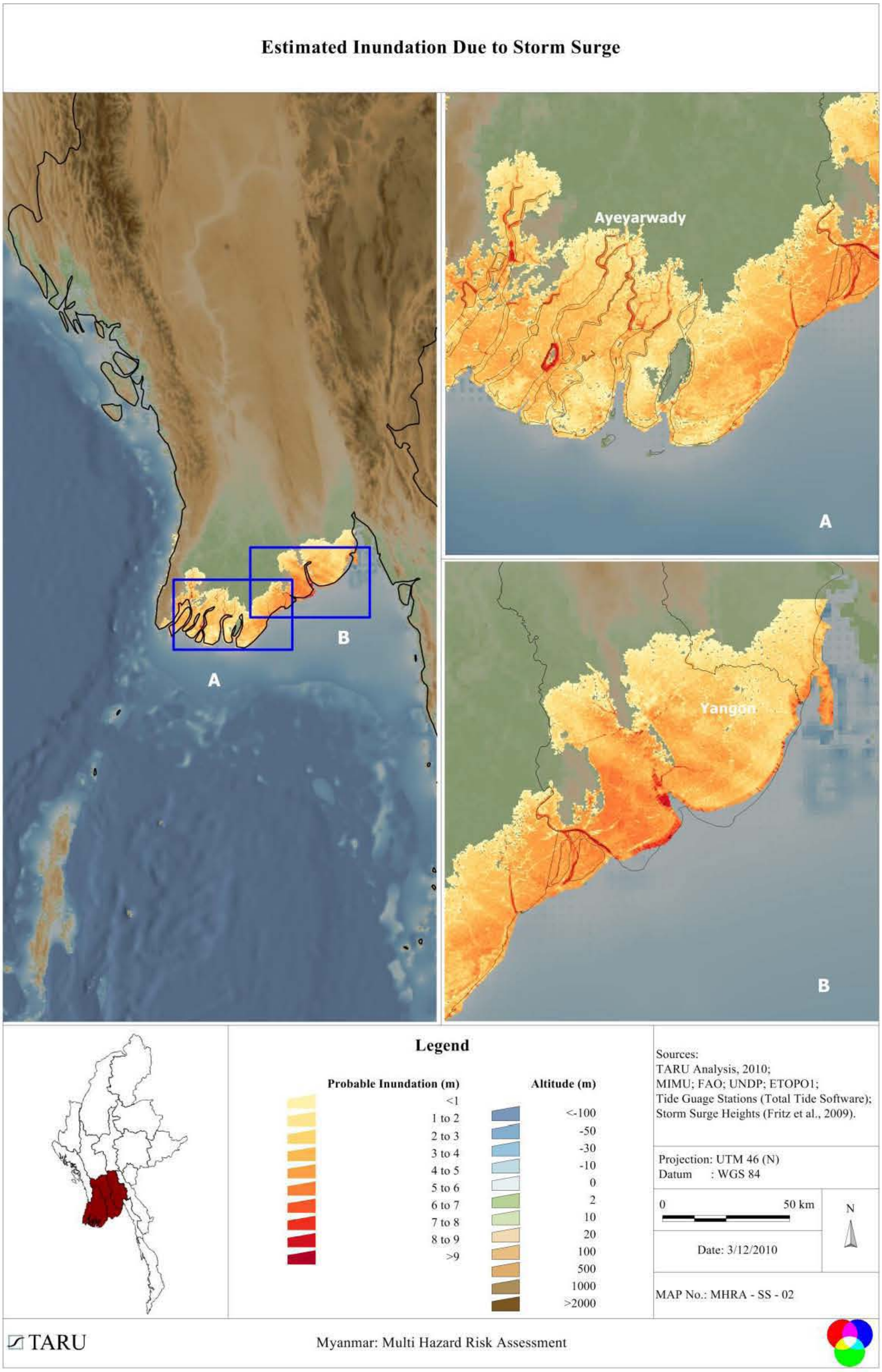


Figure 2-34: District Wise Vulnerable Population Affected due to Storm Surge Flooding in the Study Area

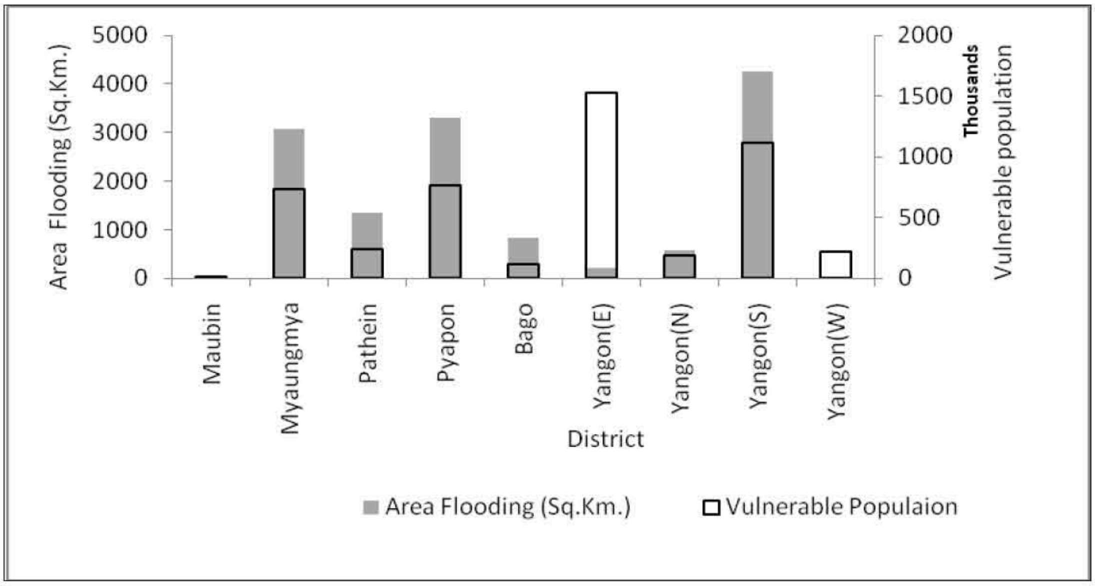


Table 2-13: Township Level Number of Villages and Population at Risk due to Possible Maximum Storm Surge

Location	No. of Village at Risk	Population at Risk
Ayeyarwady	**1,594**	**1,484,458**
Labutta	**615**	**509,711**
Labutta	453	382,421
Mawlamyinegyun	162	127,290
Maubin	**5**	**5,215**
Maubin	5	5,215
Myaungmya	**147**	**126,071**
Myaungmya	76	70,179
Wakema	71	55,892
Pathein	**114**	**163,612**
Kangyidaunt	5	15,176
Ngapudaw	85	104,000
Pathein	24	44,436
Pyapon	**713**	**679,849**
Bogale	232	194,600
Dedaye	285	222,323
Kyaiklat	38	26,876
Pyapon	158	236,050

Location	No. of Village at Risk	Population at Risk
Ayeyarwady	**1,594**	**1,484,458**
Yangon	**536**	**1,725,004**
Yangon (East)	**8**	**14,819**
Dagon Myothit (East)	5	8,468
Dagon Myothit (Seikkan)	3	6,351
Yangon (North)	**32**	**455,978**
Hlaingtharya	12	423,267
Hlegu	12	23,287
Htantabin	8	9,424
Yangon (South)	**495**	**1,254,207**
Dala	36	122,404
Kawhmu	70	81,326
Kayan	47	318,728
Kungyangon	87	115,710
Kyauktan	79	167,615
Taik Kyi	1	9,096
Thanlyin	17	128,172
Thongwa	78	173,301
Twantay	80	137,855
Yangon (West)	**1**	**0**
Kyeemyindaing	1	0
Grand Total	**2,130**	**3,209,462**

The results represent the worst case scenario i.e. scenario if a cyclonic storm similar to Nargis Cyclone passing through the corresponding coastal area. Therefore, there are instances of possible overestimation of the flooding by the model especially along the eastern coastal regions of Myanmar, particularly the Yangon Division. This overestimate may be due to the uniform consideration of the maximum storm surge heights based on observed levels along the delta (Frizt *et al.*, 2009). The cyclones that may have a landfall over the delta region do originate from the Northern Indian Ocean Basin (Bay of Bengal). These cyclones are likely to have landfall from Western side or SouthWestern side due to the nature of the storm. Therefore, the possibility of an event entering the land via the eastern coastal areas of Myanmar is minimal. However, the historical data indicates that the track of the cyclone in the year 2002 was from South to north. Taking this into consideration, the eastern side of the study area has been analyzed by using the uniform storm surge height and including the possible average maximum tide.

2.5 FLOODS

2.5.1 Objectives

Modelling the impacts of fluvial flooding from Irrawaddy and other rivers flowing in the study area (Bago and Sittaung) and pluvial flooding due to extreme weather events in combination with storm surge inundation.

2.5.2 Flood Model

Numbers of parameters are required to capture various aspects that lead to flooding in the given area. In the present study a one dimensional ***hydrological model*** has been used to generate the flow series for the entire catchment of Ayeyarwady, Bago and Sittaung, while a two dimensional ***hydraulic model*** was used to analyze the implication of a flood passing through the river stretches. Finally, the urban storm model was used to analyze the effect of local rain under flood situation.

a) The Soil and Water Assessment Tool (SWAT)

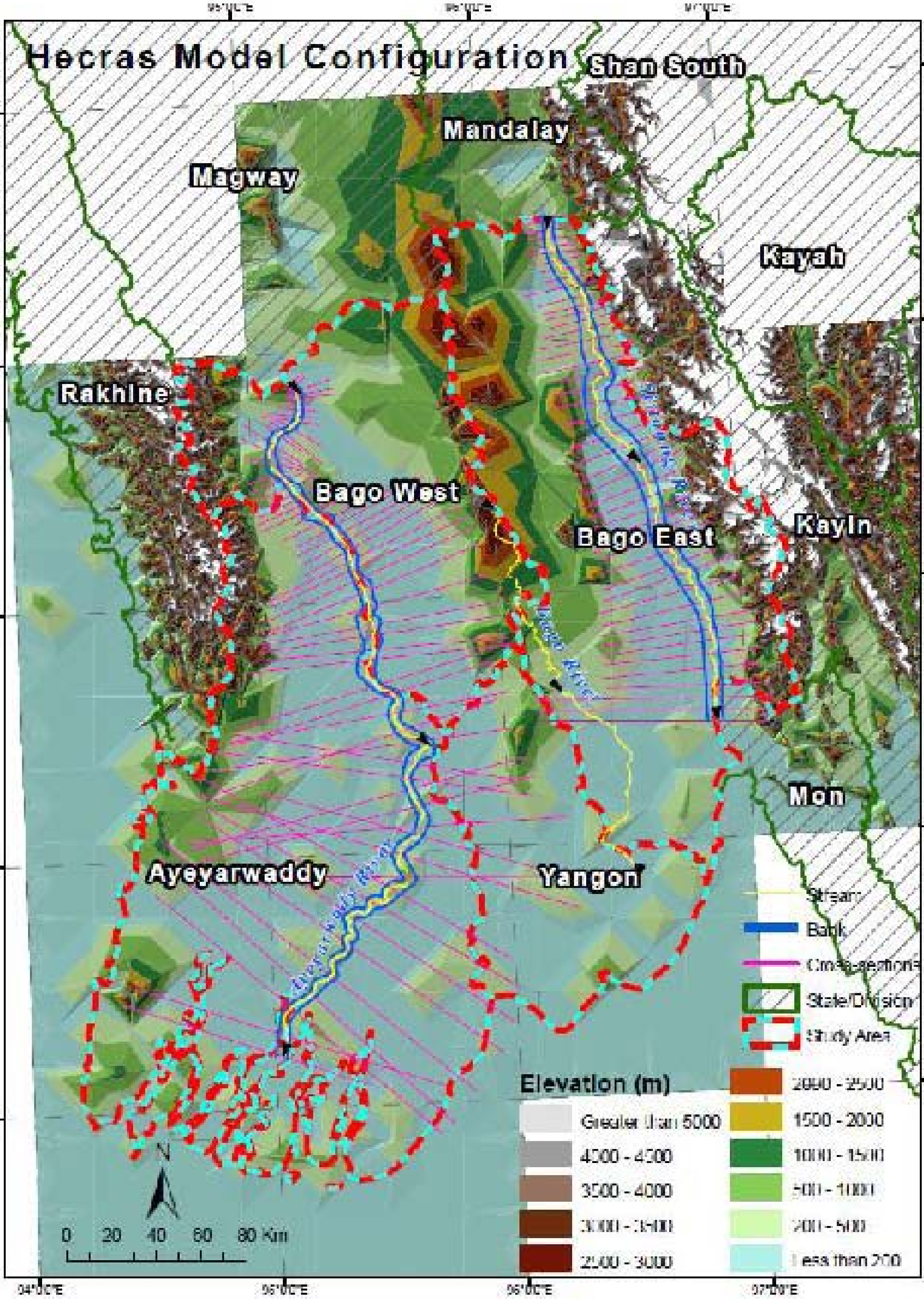
A hydrological model (SWAT) was used to analyze flooding in the Irrawaddy, Bago and Sittaung river systems. In the absence of the observed river flow data made available, indirect assessment has been made by using the SWAT hydrological model with the daily gridded rainfall and other weather parameters of PRECIS baseline data obtained from IITM, Pune. The daily flow series were generated at various locations along the two rivers.

b) Hydrologic Engineering Centre – River Analysis System (HEC-RAS)

HEC-RAS is a one dimensional steady and unsteady flow hydraulic model developed by the U.S. Army Corps of Engineers (HEC, 2002). The HEC-RAS hydraulic model takes the analysis further by translating the flood events into flood waves moving through the river channel. These flood waves may cause inundation when the carrying capacity of the channel is exceeded by the volume of the wave. The output of the model provides the water surface profiles all along the river along with its temporal variation (change in flow depth during the flood period). Effect of storm surge has also been modelled using HEC-RAS. The model requires high quality of data corresponding to channel geometry and terrain to simulate the water surface profiles and the inundation.

The model inputs also include data related to engineering structures such as bridges, embankments, etc., so that their effect on the flow can be considered within the analysis. In the current study, due to lack of information, data related to the engineering structures were not considered for the analysis. Such data when accommodated will improve the quality of the output. Figure 2-35 shows the setup of HEC-RAS model for the study area.

Figure 2-35: Hydraulic Modeling Setup for the Study Area



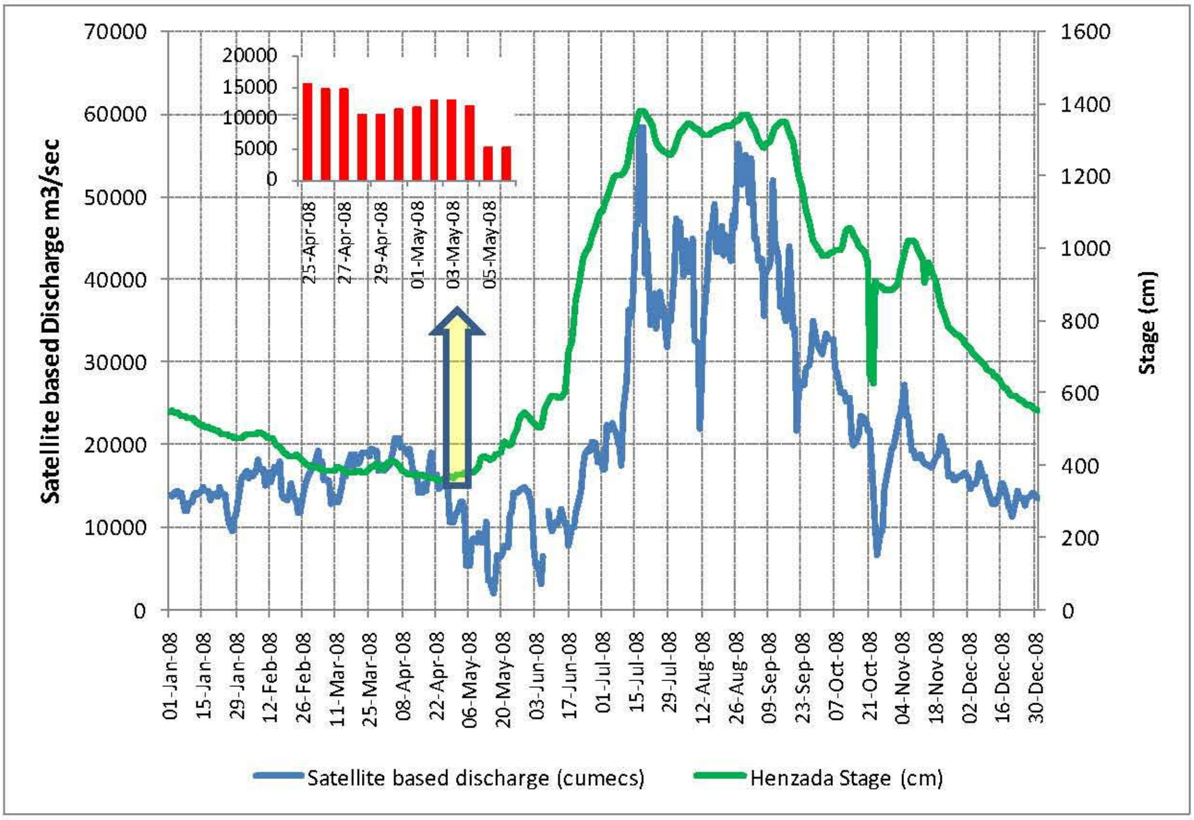
c) Storm Water Management Model (SWMM)

One of the major causes of flooding in urban areas is intense local rainfall. The flooding is usually aggravated because of the poor natural drainage conditions prevailing during the flooding period. The SWMM has been used to simulate the pluvial flooding. SWMM is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas and is used for simulation of hydrologic and hydraulic conditions.

d) Space-based measurement of river runoff

Due to the non-availability of dependable precipitation input for the present SWAT hydrological modeling, an Advanced Scanning Microradiometer (AMSR-E)[4] river discharge data provided by Dartmouth Flood Observatory was used as alternative to the simulate discharges for SWAT. Figure 2-36 provides the plot of the discharge at Yenangyaung and the observed stage provided by the client at Henzada

Figure 2-36: Henzada observed Stage and Satellite based river discharge at Yenangyaung (upstream of Henzada) - 2008



[4] http://www.dartmouth.edu/~floods/AMSR-E%20Gaging%20Reaches/technical.html

Table: 2-10. Satellite Based Station Information

Particular	Details
Site ID:	36
River:	Irrawaddy
Site Names:	Yenangyaung, Magwe, Burma
Latest Measurement:	03-Sep-10
Latest M/C Ratio:	1.66
Estimated Current Discharge: m3/sec	26460
Latitude	20.5288
Longitude	94.8004
Contributing Area: km2	310198
Ratio to Comparison Station:	2.64
Mean Annual Runoff (mm): (2003-2009)	1487
Total Runoff of 2010 (mm):	1244.7
Seven Day Total (mm):	50
Percent of mean 7-day total %: (today's value compared to mean for same period, 2003-2009)	69.1
5 yr recurrence flood m3/sec: (from Log Pearson III analysis)	56601
(from Gumbel Extreme Value analysis)	54242
Comparison Station Information:	Sagaing (2260500)
Contributing Area (sq. km):	117452
(Data from this gauging station are used for the calibration to discharge, with an adjustment for different contributing areas)	
Notes: Calibration to nearby ground station has been accomplished. Accuracy Estimate: Good, Discharge and runoff, based on satellite remote sensing (NASA AMSR-E Data)	

2.5.3 Model Assumptions

The modeling exercise was greatly hampered by the following data insufficiency

- Terrain data – high resolution ASTER had height inconsistency, therefore SRTM data was used
- Elevation on the delta portion was erroneous which was difficult to rectify
- River cross sections were not provided
- Climate data was restricted to gridded satellite derived rainfall which did not show the amount of rainfall reported during the Nargis event

2.5.4 Data & Uncertainty

Temporal and Spatial data from a number of sources were used including:

- Digital Elevation Model: SRTM of 90 m resolution[5]; ETOPO5[6]
- Drainage Network[7];
- Soil maps and associated soil characteristics[8];
- Land use[9]; and
- Daily TRMM rainfall and temperature (1998-2008)

2.5.5 Method

The discharge at Yenangyaung, was routed through the river using hydraulic model for the period around the Nargis cyclone event. HECRAS was setup for two main river systems of the study area, Irrawaddy River and Sittaung River flowing across both the divisions of Bago.

In the absence of actual surveyed river cross-sections, for the present study SRTM merged with ETOPO-01 altitude and bathymetry was used to extract the cross sections across both the rivers. Boundary conditions on both upstream (discharge at Yenangyaung) and downstream (storm surge) end of the river system were applied. A surge of 3.6m height above the normal water level was used. This approximate surge height is based on the observations[10] carried out after the Nargis cyclone. With the availability of further information including time series tidal and surge information the model and their results could be improved. The third component in modeling involves the effect of local rain on flooding. This was taken up using urban storm water model SWMM.

This model simulates the hydrological behavior of an urban area by incorporating the urban infrastructure in place. In the absence of urban infrastructure network (sewerage and drainage network) of the study area, the model was setup using natural drainage inside the study area as the drainage network. All river networks were taken as open rectangular drains and confluence of small streams with main Irrawaddy River was treated as junction. The non-availability of the local precipitation data was a limitation in present configuration. Since the TRMM precipitation data also did not provide the realistic information, the SWMM modeling effort was resorted to the "sensitivity analysis" for the area which was carried out by increasing the rainfall by 50% and 100% on the rainfall pattern extracted from TRMM gridded rainfall for the Nargis cyclone period. The idea was to ascertain as to what will the flooding pattern on account of local heavy precipitation.

Rainfall event as stated above was used for simulation. The additional assumptions made include, considering 40% of the total study area as urban land (estimated using Google Earth), and clayey loam soil for the area.

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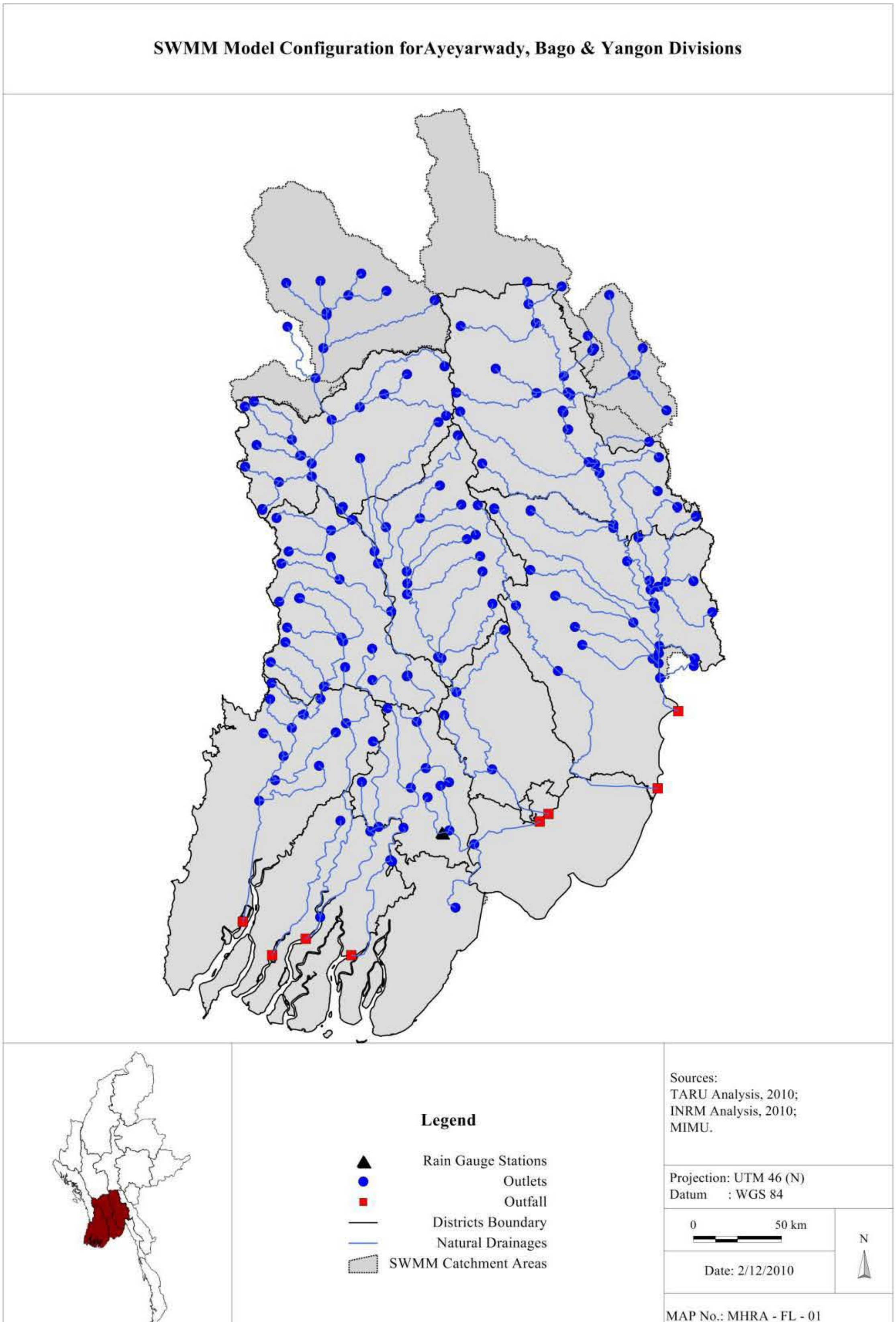
[5] http://srtm.csi.cgiar.org/
[6] http://www.ngdc.noaa.gov/mgg/global/global.html
[7] HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) http://gisdata.usgs.net/website/HydroSHEDS/
[8] FAO Global soil, 1995, http://www.lib.berkeley.edu/EART/fao.html
[9] Global landuse, Hansen et al., 1999http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp
[10] http://mceer.buffalo.edu/infoservice/disasters/burma_cyclone.asp#1

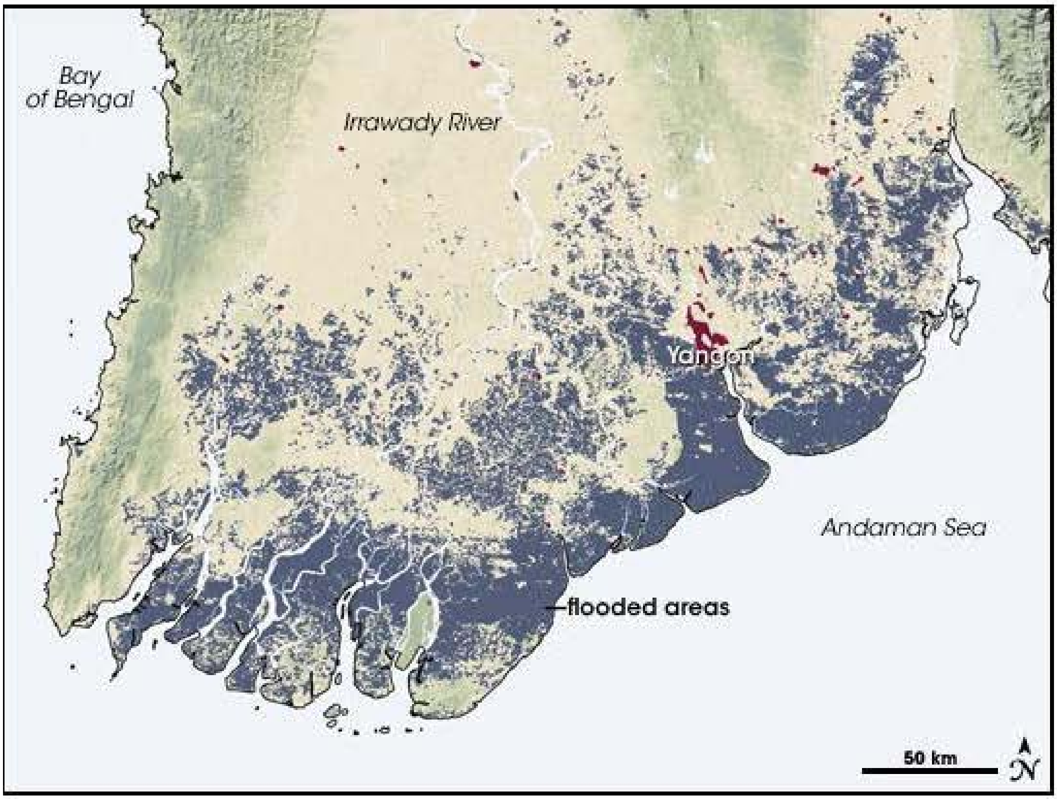
Figure 2-37: Urban Storm Water Modeling Setup for the Study Area



2.5.6 Results

Figure 2-38 illustrates the Nargis Cyclone Flooding.

Figure 2-38: Nargis Cyclone Flooding



Source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19884

SWAT Analysis:

Hydrological model SWAT was used to simulate the river discharges at the desired locations. Figure 2-39 shows the two major water balance components namely water yield and evapotranspiration in the river catchment.

Figure 2-40 illustrates the spread and depth of fluvial flooding. Irrawaddy River flooding covers parts of Ayeyarwady and Yangon division. The Sittaung River flooding covers regions in and around Bago Division. The flood depth ranges between 1 to 2 m. Further, the spread and depth of the inundation along the coasts does include the possible effects due to storm surge.

In spite of the lack of time series, on ground information, from visual observation the spread of inundation is similar to the flooding of Nargis cyclone (as shown in Figure 2-38) and the results obtained through modeling (Figure 2-40) does exhibit high similarity. With more accurate observations and more data in place, the models will be able to replicate the observed inundation to a greater extent.

Figure 2-39: Hydrological Model Outputs – Water Yield and Evapotranspiration

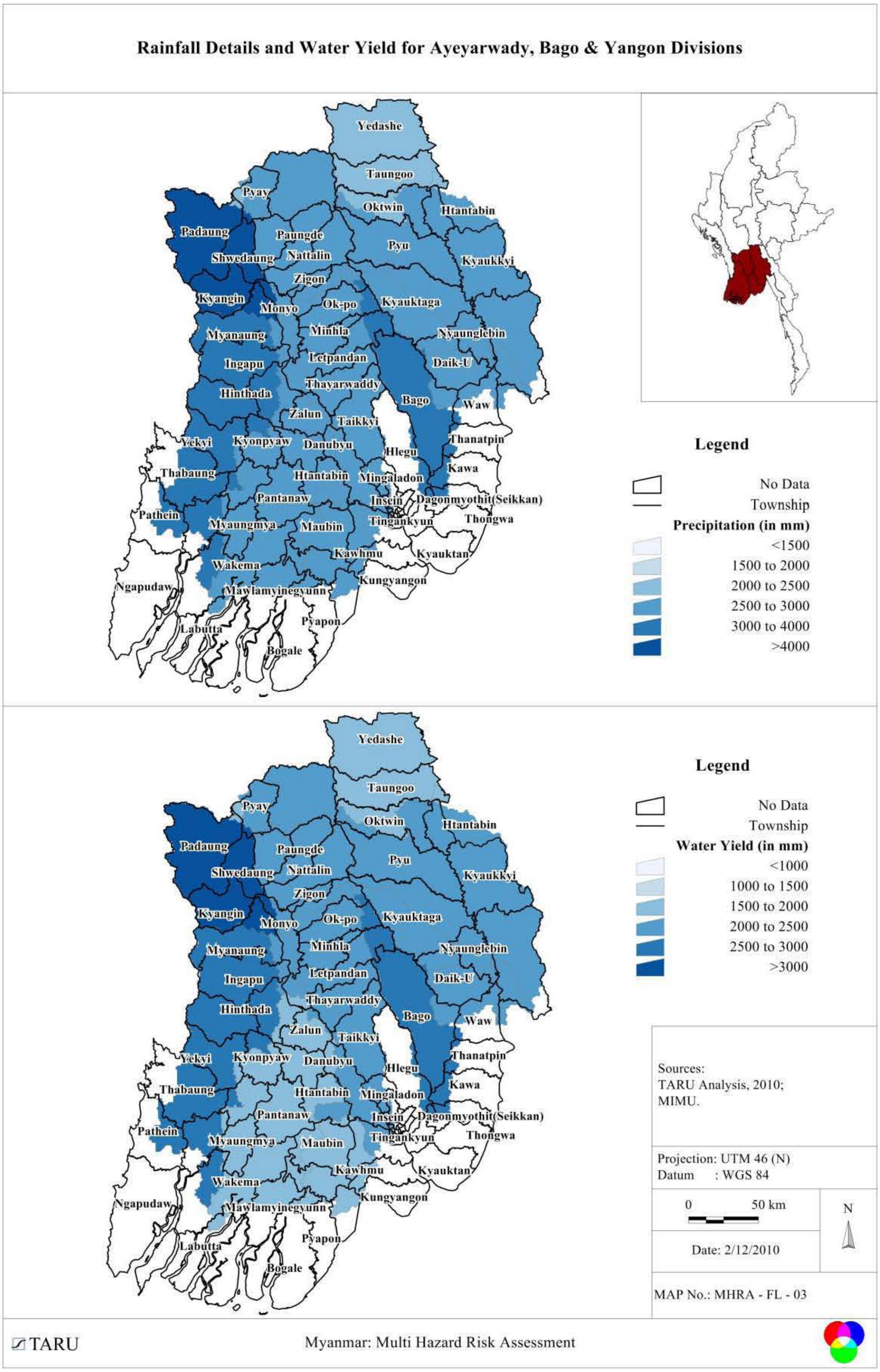
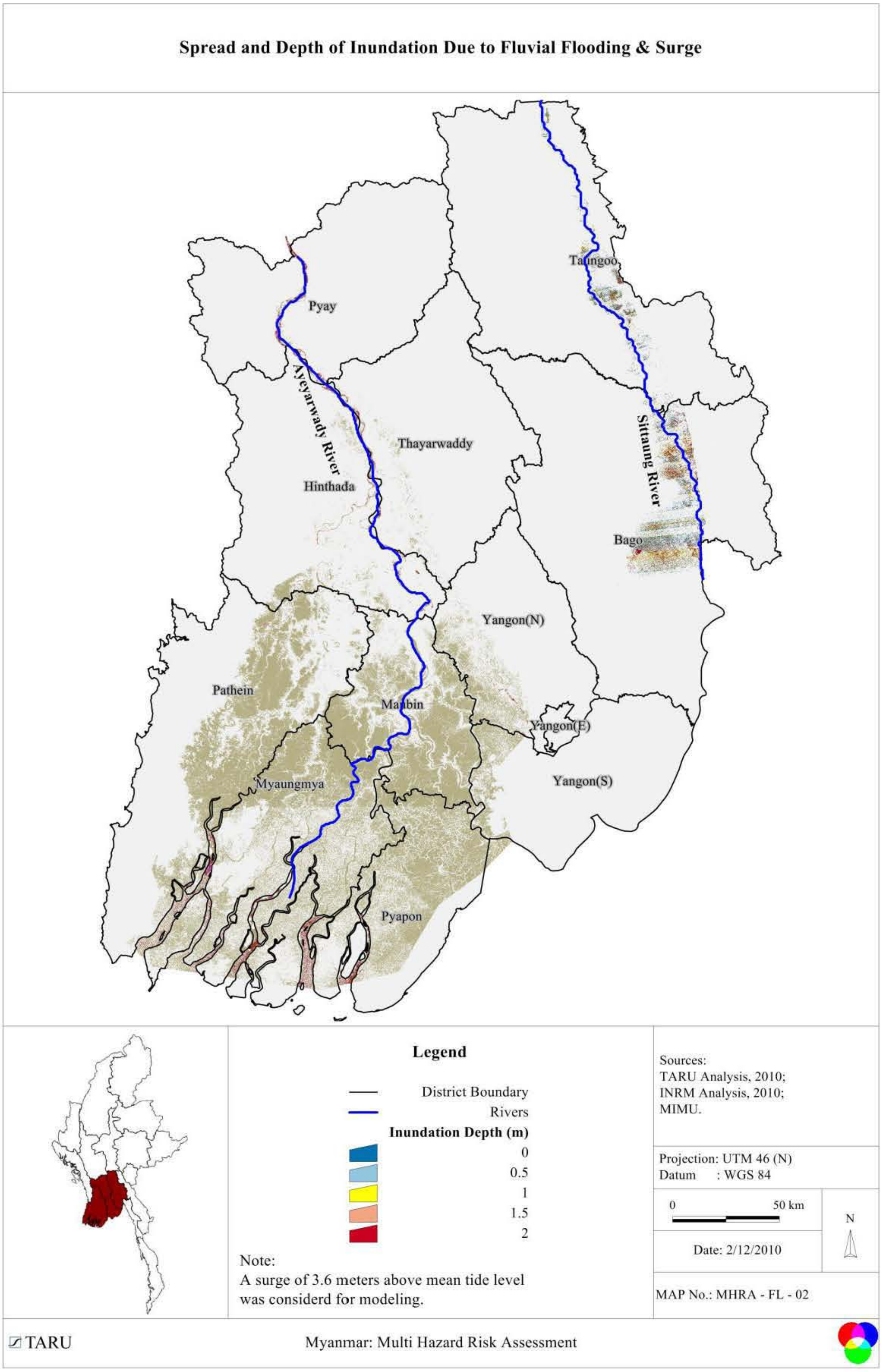


Figure 2-40: Spread & Depth of Inundation Due to Fluvial Flooding & Surge



Pluvial Flooding:

The third part of the modelling involving effect of local rain on flooding was taken up using urban storm water model SWMM. In the absence of urban infrastructure network (sewerage and drainage network) of the study area, the model was setup using natural drainage inside the study area as the drainage network. All river networks were taken as open rectangular drain and confluence of small stream with main Irrawaddy River was treated as junctions. Due to lack of actual observed rainfall in the study area, sensitivity analysis was carried out by increasing the rainfall by 50% and 100% on the rainfall pattern extracted from TRMM girded rainfall for the Nargis cyclone period.

Output of model shows flooding at a few places, but it does not depict the flooding of the Nargis cyclonic disaster. This may be due to the fact that the flooding was mainly due to storm surge which interspersed Nargis cyclone and absence of tidal effect incorporated in the SWMM modeling exercise. The depth of inundation is more than 1.5 m in some places and in general the inundation is below 0.75 m. The inundation map overlaid for 50 and 100% is shown in Figure 2-41 and Figure 2-42.

Figure 2-41: Spread and Depth of Inundation Due to Urban Flooding

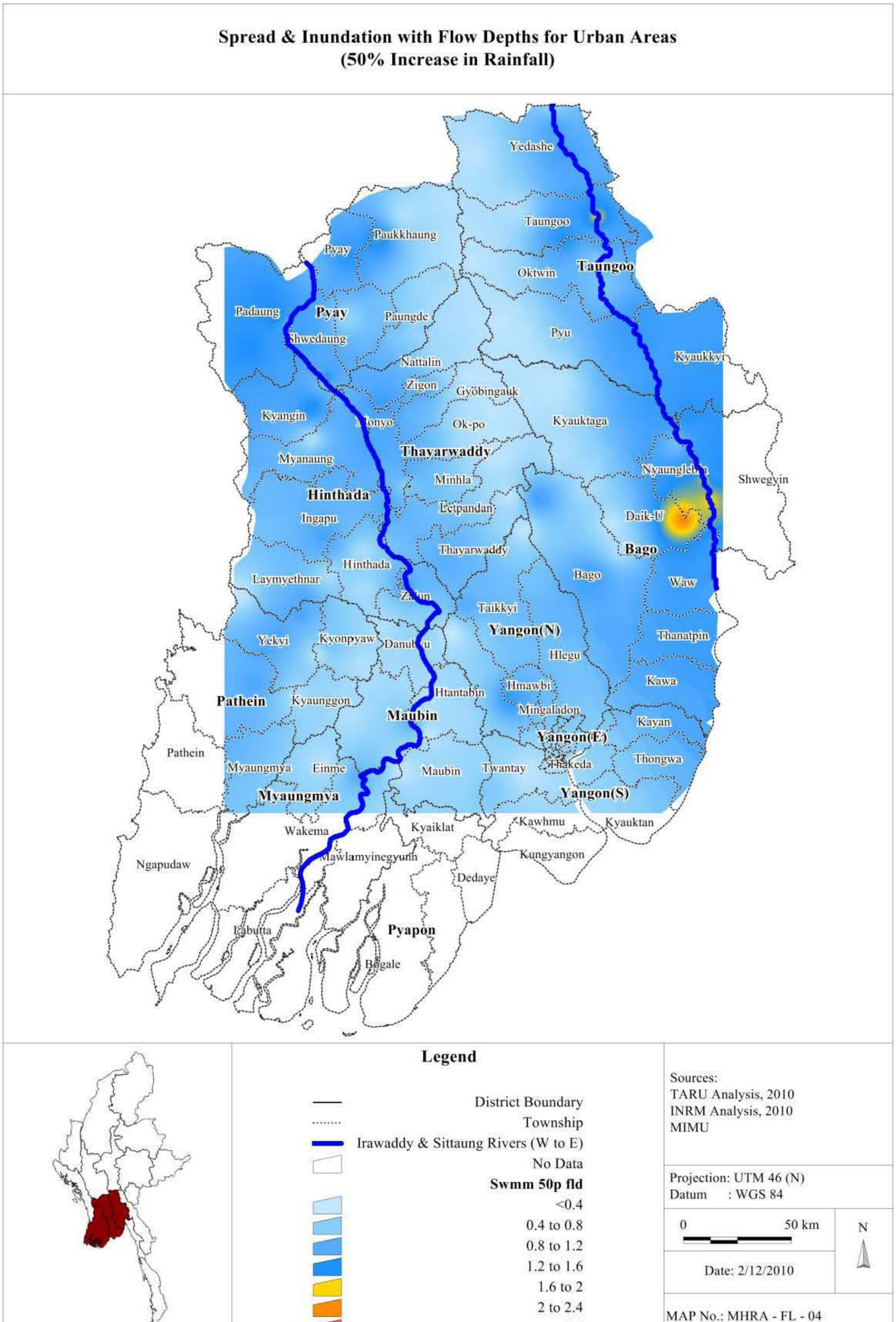
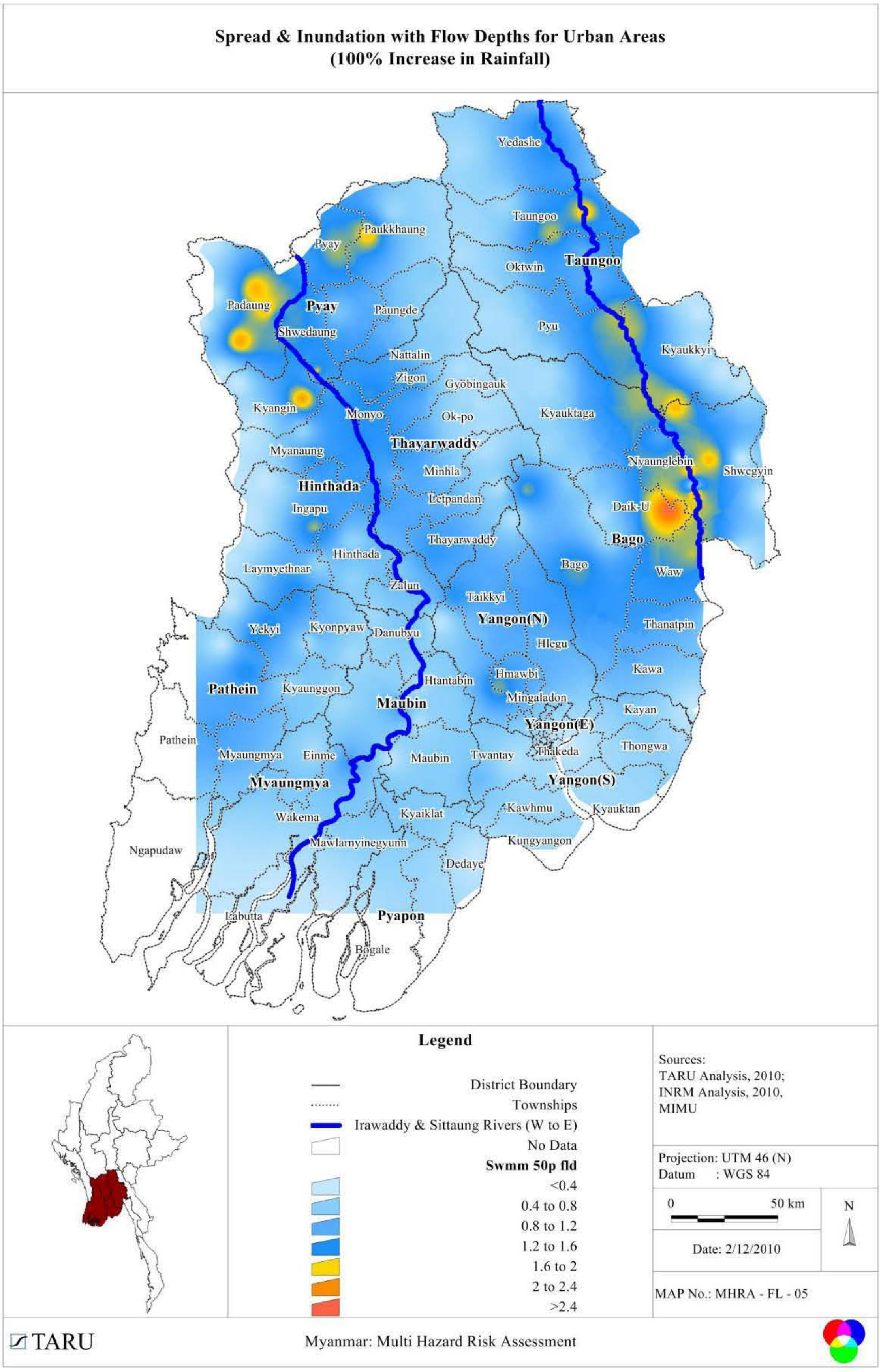


Figure 2-42: Spread and Depth of Inundation Due to Urban Flooding



2.6 CLIMATE CHANGE

2.6.1 Introduction

Climate change refers to a change in the state of the climate that can be identified by changes in mean or variability of its properties and that persists for an extended period (decades or longer)" (IPCC, 2007). This change is either due to natural variability or as a result of human activity or both.

The key factors influencing the anthropogenic climate change are the changes in the atmospheric concentrations of the green house gases (GHGs) and aerosols. A minor change in their concentration will alter the energy balance of the climate system and could contribute towards climate change. This will in turn initiate a chain reaction on other processes such as absorption, scattering and emission of radiation within the atmosphere and at Earth's surface.

Carbon dioxide (CO_2) is an important anthropogenic GHG. Its annual global emissions have increased between 1970 and 2004 by about 80% (IPCC, 2007). This rate of growth was found to be higher during the last decade. This increase in emission has been mainly due to increase in energy consumption, transportation and industrial expansion. This increase in GHG leads to increase in temperature. This increase in temperature in turn reduces terrestrial and ocean uptake of atmospheric CO_2, leading to the increase in anthropogenic emissions remaining in the atmosphere forming a cyclic reaction.

Current Trends and Future likely changes in Global climate (Rosenzweig et.al, 2007)

The temperature increase is widespread over the globe. Land surfaces have warmed faster than the oceans. These effects are greater at higher northern latitudes. Globally eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of the global surface temperature (since 1850). The linear warming trend over the last 50 years is nearly twice that of the past 100 years. These recent changes in temperature have had discernable impacts on the physical and biological systems. Increase in sea level are consistent with warming and has been increasing at an average rate of 1.8 mm per year over 1961 to 2003 and an average of 3.1 mm per year from 1993 to 2003. There has also been observed changes in the precipitation from 1900 to 2005 over large regions globally.

Based on the above changes in approach, the future projections based on IPCC fourth assessment report the changes that are pertinent to South East Asia in general and Myanmar in specific are as follows:

a) Freshwater resources (Kundzewicz et.al, 2007)

Climate and freshwater systems are connected in complex ways. One of the many pressures that is being exercised on these two systems is the anthropogenic change i.e. changes in population, lifestyle, economy and technology. Based on the observations on the current level of anthropogenic and climate change, freshwater resources would be one of the scarcest commodities in the near future.

b) Ecosystems (Fischlin et.al, 2007; Reid et.al, 2005)

"An ecosystem can be defined as a dynamic complex of plant, animal and micro-organism communities, and the non-living environment, interacting as a functional unit'"

Ecosystem provides many services such as provisioning services (food, fiber, medicine, etc), regulating services (carbon sequestration, water regulation, water/air purification, disease/pest regulation) and cultural services (spiritual and aesthetic appreciation). These services are likely to be threatened by change in the regional and global climatic change.

During the course of this century the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by the combination of global change drivers (especially land-use change, pollution and over-exploitation of resources), associated disturbances (e.g. flood, drought, wildfire and ocean acidification) and climate change.

Current Trends

- Changes in flowering pattern of the plants during spring
- Increase in 6% of global net primary productivity (NPP) from 1982 to 1999
- Mountain regions have experienced above average warming during the 20^{th} century. This has resulted in earlier and shortened snow-melt periods causing rapid water release and increase in downstream floods. Further, the variability in the water availability has led to plants and animals experiencing considerable water stress.
- Wetlands (lakes and rivers) are being subjected to increasing pressures due to human activity.

Future Scenarios

- Plant and animal species are likely to be at increasing high risk as global mean temperatures exceed a warming of 2 to 3 ^{o}C above the pre-industrial level.
- Climate change and ocean acidification may impair planktonic and shallow benthic marine organisms that use aragonite to make their shells or skeletons, such as corals and marine snails.
- The net biome productivity is predicted to increase till 2030 and decrease from then on.
- Plant and animal species in the mountain regions will be most threatened due to the inability to change or adapt due to climate change.
- Tropical lakes are projected to respond with a decrease in net primary productivity and a decline in fish yields.
- Migratory species can be affected by climate change in their breeding, wintering and/or critical stopover habitats.

c) Food, fiber and forest products (Basterling et.al, 2007)

40% of the Earth's land surface is managed for cropland. In developing countries, nearly 70% of the people live in rural areas where agriculture is the largest supporter of livelihoods. 30% (3.9 billion ha) of the land surface are covered with natural forests with just 5% of the natural forest area providing 35% of the global round-wood. The United Nations Food and Agricultural Organization (FAO, 2006) estimates that the livelihoods of roughly 450 million of the world's poorest people are entirely dependent on managed ecosystems services, especially fish which provides more than 2.6 billion people with at least 20% of their average per capita animal protein intake.

The distribution of climate variables such as temperature, radiation, precipitation, water vapor pressure in the air and wind speed does affect the physical, chemical and biological processes that drive the productivity of agricultural, forestry and fisheries systems. The latitudinal distribution of crop, pasture and forest species is a function of the current climatic and atmospheric conditions, as well as of photoperiod.

Total seasonal precipitations as well as its pattern of variability are both of major importance for agricultural, pastoral and forestry systems. Crops exhibit threshold responses to their climatic environment, which affect their growth, development and yield. Yield-damaging climate thresholds that span periods of just a few days for cereals and fruit trees include absolute temperature levels linked to particular developmental stages that condition the formation of reproductive organs, such as seeds and fruits. This means that yield damage estimates from coupled crop-climate models need to have a temporal resolution of no more than a few days and to include detailed phenology. Short-term natural extremes, such as storms and floods, inter-annual and decadal climate variations, as well as large-scale circulation changes, such as the El Niño Southern Oscillation (ENSO), all have important effects on crop, pasture and forest production.

Current Trend

- Notable increases in extreme weather events have led to the increase in health related mortality rate.
- Three quarters of the global fisheries are currently fully exploited, overexploited or depleted.
- Currently there exist multiple stresses on small holder agriculture such as population increase, environmental degradation, market failures, protectionist agricultural policies in developed countries, encroachment on grazing lands, state fragility and armed conflicts.

Future Scenario

- In mid to high latitude regions, moderate warming will benefit crop and pasture yields. On the other hand in dry and low latitude regions similar moderate warming will lead to decrease in yields.
- The potential for global food production will increase with increases in local average temperature over a range of 1 to 3 ^{o}C along with CO_2 concentration increase. But, above this range it is expected to decrease.
- Projected changes in the frequency and severity of extreme climate events have significant consequences for food and forestry production, and food insecurity, in addition to impacts of projected mean climate. Nevertheless, compared to 820 million undernourished today with the development in socio-economic conditions this number is projected to decrease according to the future scenarios.
- Smallholder and subsistence farmers and small scale fishermen will suffer complex, localized impacts of climate change.
- Globally, commercial forestry productivity rises modestly with climate change in the short and medium term, with large regional variability around the global trend.
- Local extinctions of particular fish species are expected at edges of ranges.
- Food and forestry trade is projected to increase in response to climate change, with increased dependence on food imports for most developing countries.

d) Coastal systems (Nicholls et.al, 2007)

Coasts are dynamic systems, undergoing adjustments of form and process at different scales of time and space in response to geomorphological and oceanographical factors. Coasts as such undergo natural variability. Coastal systems that are affected by regional events such as storms do return to the pre-disturbance morphology. But, in the recent years there has been an excessive migration of people towards the coast.

It has been estimated that 23% of the world population are currently staying within 100 Km from the coast that are < 100 m above sea level. This has exercised additional pressures on the coastal system. Some of the factors that contribute and accelerate the impacts on coastal areas include:

- Shoreline development
- Clearing of mangroves
- Mining of beach sand and coral
- Sediment starvation due to the construction of large dams upstream
- Pumping of groundwater and subsurface hydrocarbons

Impact and vulnerability of the coastal zone to storm surges and waves depends not only on the sea level change but also on land subsidence and changes in storminess. Apart from these direct changes in the physical characteristics of the land along the cost the effect is much adverse towards the biodiversity along and near the coast.

There have been studies that have expressed wide concerns about the impacts of climate change on coral reefs centre on the effects of the recent trends in increasing acidity via increasing CO_2, storm intensity and sea surface temperatures. Further this rising CO_2 has led to chemical changes in the ocean, which in turn have led to the oceans becoming more acidic.

Current Trends

- The direct impacts of human activities on the coastal zones have been more significant over the past century than impacts that can be directly attributed to observed climate change.
- 300 million people inhabit a sample of 40 deltas globally (about 500 people/km2)
- Annually about 120 million people are exposed to tropical cyclone hazards, which killed 250,000 people from 1980 to 2000
- The weather events such as ENSO has a strong impact on the regional vegetation patterns
- Rising CO_2 concentrations have lowered the ocean surface pH by 0.1 unit since 1750 although no significant impact has been found.

Future Scenarios

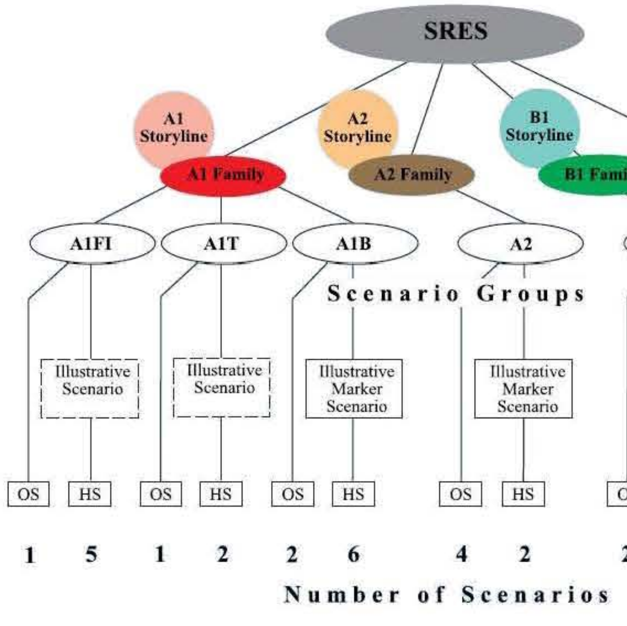
- The coastal population could grow from 1.2 billion people in 1990 to 1.8-5.2 billion people by 2080 leading to increased risks to human health and life.
- There will be a decrease of 33% to 44% in current coastal eco-system given a 0.36 m to 0.72 m rise in sea-level. On an average sea level may rise by 0.6 m or more by 2100.
- Sea surface temperature will rise by a minimum of 3 ^{o}C leading to increased stratification/changed circulation. This will cause increased coral bleaching and mortality; pole wards species migration and increased algal blooms.
- Altered precipitation and run-off increased flooding may lead to the degradation of water quality/salinity; altered fluvial sediment supply; altered circulation and nutrient supply.

e) Emission Scenarios (Arnella et al., 2000)

There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices the global GHG emissions will continue to grow over the next few decades. Since the GHGs are the primary drivers of climate change, special report on emission scenarios (SRES) has outlined storylines based on the expected emission levels. These emissions projections are widely used in the assessments of climate change. These underlying assumptions with respect to socio-economic, demographic and technological change would aid in assessing the vulnerability and impacts of a particular city/county/region.

Figure 2-43 below outlines the various SREC scenarios. The scenarios are broadly grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions. All these scenarios are equally valid with no assigned probabilities of occurrence. The set of scenarios consists of six groups drawn from the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterizing alternative developments of energy technologies for e.g. A1FI is fossil fuel intensive, A1B is balanced, and A1T is predominantly non-fossil fuel. In the Figure 2-43 within each family and group of scenarios, `HS' denotes scenarios that share `harmonized' assumptions on global population, gross world product, and final energy and 'OS' that explore uncertainties in driving forces beyond those of the harmonized scenarios. One of the main constraints of the SRES scenarios is that they do not include the effect of additional climate change policies above current ones.

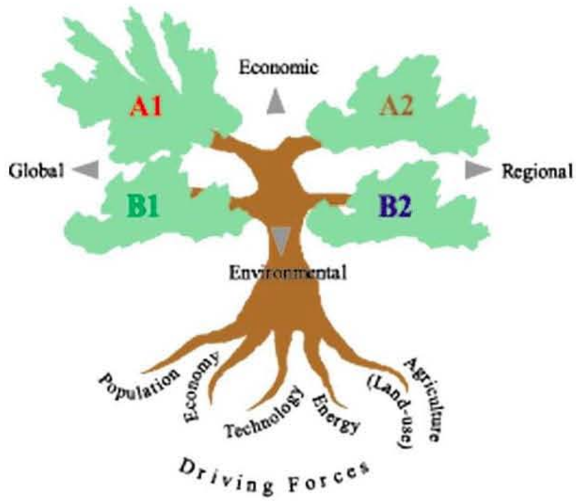
Figure 2-43: Schematic illustration of SRES scenarios structure



Source: SREC, 2000

There are around 40 storylines considering various combinations. Each combination is based on different assumptions. Broadly categorizing, most of the models are based on increased consumption of fossil fuel while the remaining is based on the use of alternate sources of energy. From the available storylines (40) IPCC has accepted four story lines i.e. A1, A2, B1 and B2 to develop future scenarios. The schematic illustration is presented in Figure 2-43 and the descriptions as provided by SREC are described below:

Figure 2-44: Schematic illustration of SRES scenarios A1, A2, B1 and B2



Source: SRES, 2000

- The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into four groups that describe alternative directions of technological change in the energy system.
- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.
- The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

From the four main storylines adapted by the IPCC, three storylines A2, B1 and A1B which are more applicable for the regional levels were adapted to scope the climate variability and climate change of Myanmar.

2.6.2 Objective

To analyze the possible changes in precipitation and temperature within Ayeyarwady delta under future climate change scenarios.

2.6.3 Data & Uncertainties

Following data sets were used analysis.

- Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Inter comparison Project phase 3 (CMIP3) multi-model dataset (Meehl *et al.*, 2007), were obtained from Santa Clara University. These data were downscaled as described by Maurer *et al.* (2009) using the bias-correction/spatial downscaling method (Wood *et al.*, 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003).
- The downscaled model results from 16 climate models namely: BCCR-BCM2.0, CGCM3.1 (T47), CNRM-CM3, CSIRO-Mk3.0, GFDL-CM2.0, GFDL-CM2.1, GISS-ER, INM-CM3.0, IPSL-CM4, MIROC3.2, ECHO-G, ECHAM5/MPI-OM, MRI-CGCM2.3.2, PCM, CCSM3 and UKMO-HadCM3 were explored with respect to the climate summary provided by Hydro-Met department, Myanmar.

Uncertainties

Due to intricate nature of the climate and its complex relationship with environmental parameters, the task of analyzing the inter-relationship between events that are occurring sporadically over space and time is difficult. This combined with the problem of choosing and predicting the future from various possible outcomes, complicates the task. Moreover, the presence of inherent uncertainty in data and models exacerbates the problems of predictions. Even though it is not possible to eliminate such uncertainties, it is much necessary for the decision makers to understand the presence of the same.

The uncertainty within the climate change modeling and analysis can be broadly classified into two main categories (a) uncertainty due to limitations within the secondary data sources, especially historic climate data and (b) uncertainty within the climate models. Uncertainty due to limitations within secondary data sources includes the Non-availability of historical weather data of Myanmar at daily/monthly levels. Therefore, the scenario and model baseline/results were compared with the available decadal temperature averages which were available. This generalization did lead to over smoothing of data.

Climate Uncertainty within the climate models include several dimensions ranging from the initiation parameters, the secondary data used for simulation to the selection of the globally suited results which may not necessarily be the best indicator for the region of interest.

2.6.4 Methods

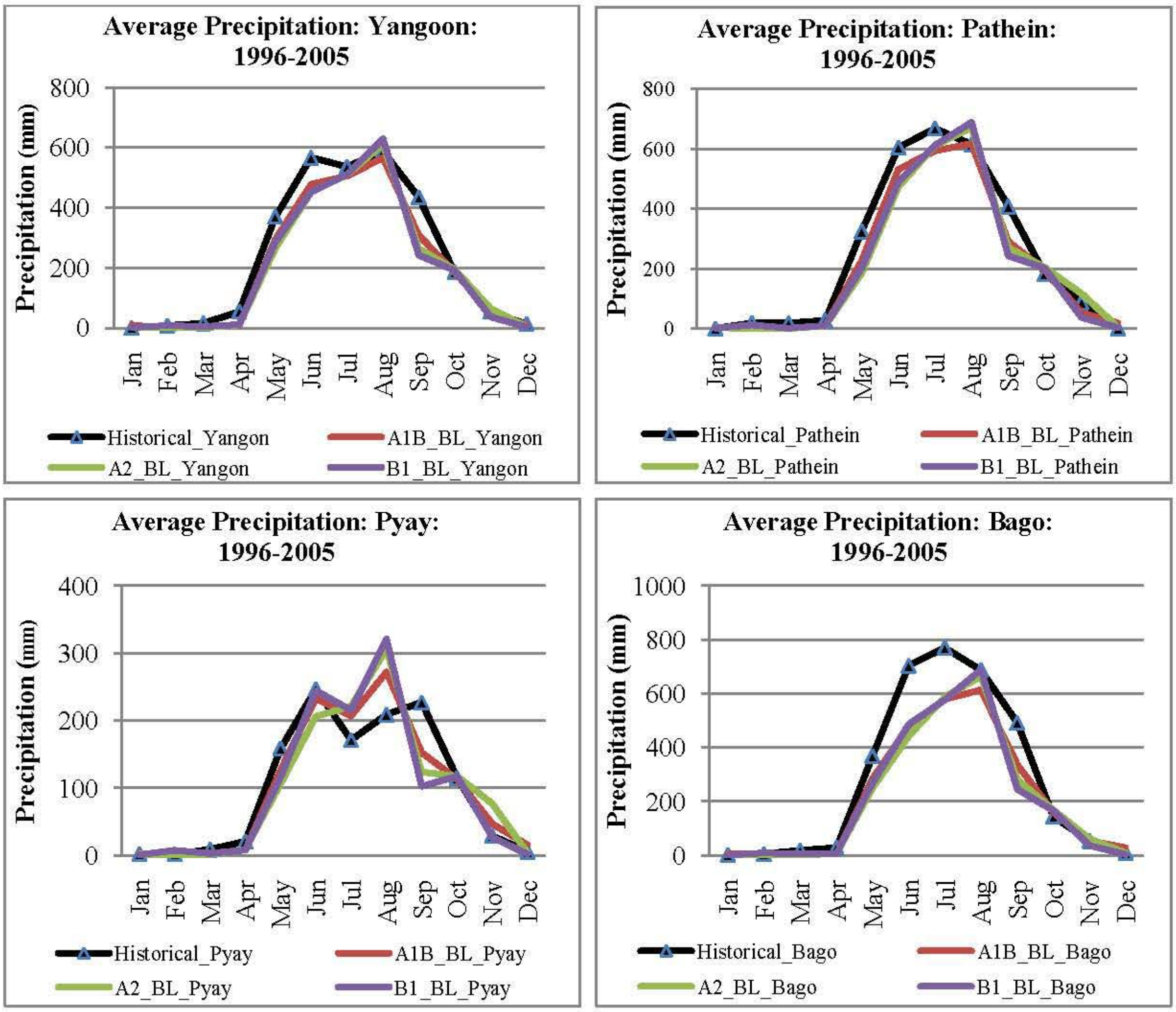
Earth's environment is a product of processes in space and time. The relationships between processes are multidimensional and any change in one process does have an effect on the rest. Advancements in the field of science and technology have encouraged earth scientists over the past two decades in attempts to model this complexity and quantify the symbiotic relationship between processes. But, the nature of the earth's environment and our current understanding of the same make this process difficult. Nevertheless, it is possible to identify the general drivers of the climate change based on the reverse modeling of the variables tested over the earlier climatic data. Based on such modeling , the anthropogenic forcing are contributing to changes in: temperatures, wind patterns, sea-level rise, hydrological cycle, extra-tropical wind storms in both hemispheres and large scale patterns of changes in land precipitation (IPCC, TAR, 2001). The method for climate analysis within this study follows three step approaches, which is described below:

1. Analysis of downscaled climate data and normalization of the same with respect to the historical (1990-2007) climate data.
2. Selection of appropriate models based on correlation analysis
3. Analysis of selected models for evidence of future changes in temperature and precipitation.

2.6.5 Results

Fifteen models were normalized and compared with the decadal temperature and precipitation trends of Myanmar. Out of the 15 models only one model i.e. GFDL did exhibit satisfactory correlation index. The correlation for the data near the historical stations within Myanmar (Delta region) ranged from 0.87 to 0.99. Based on the correlation and the trend analysis GFDL was selected for analysis of future changes in temperature and precipitation. The trend between the historical data (observed) and the models baseline data for monthly average precipitation and monthly average temperature between the years 1996 to 2005 are presented in the Figure 2-45.

Figure 2-45: Monthly Average Precipitation (1996 to 2005)

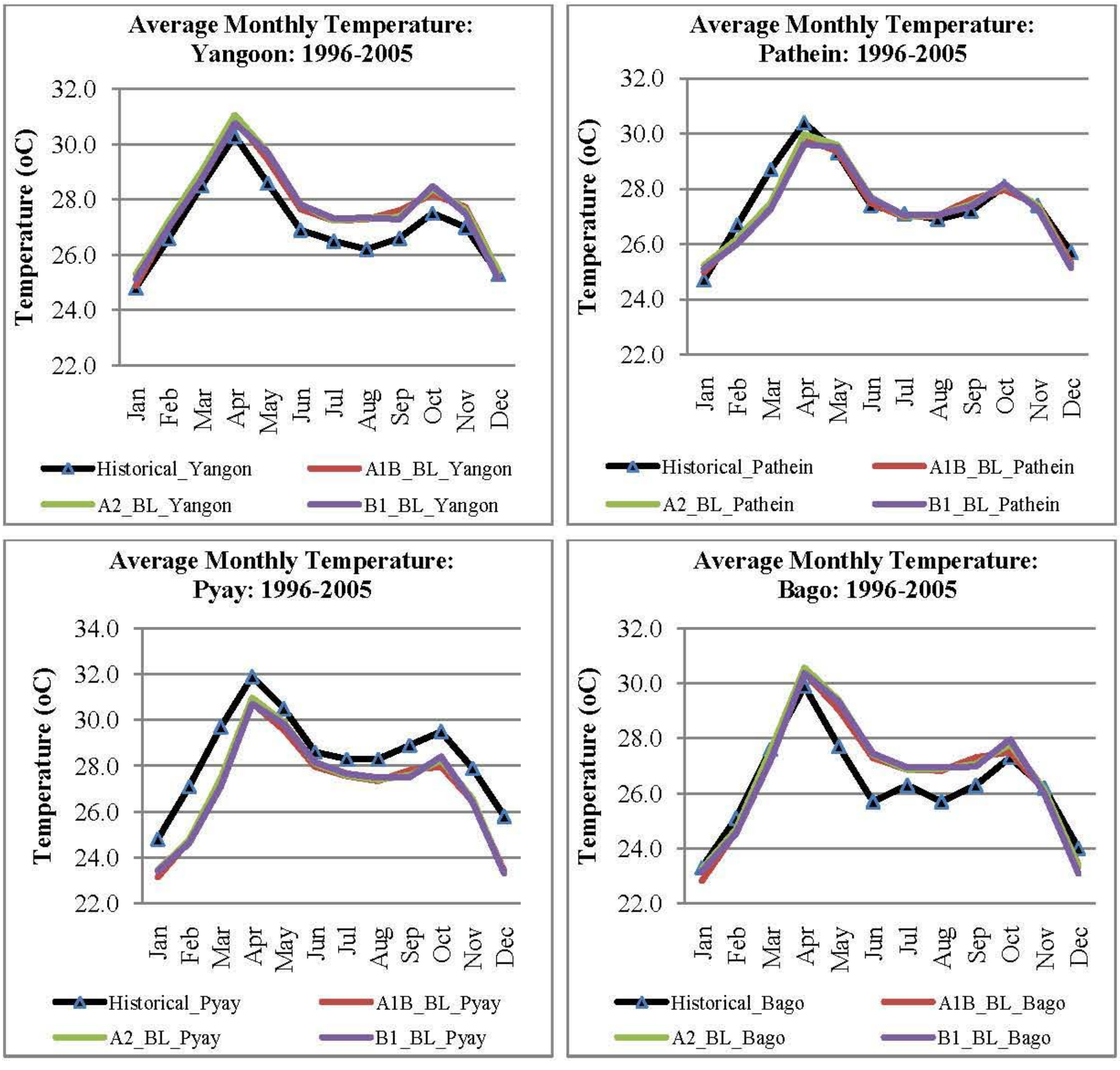


From the figures it is evident that the overall trend in average observed precipitation was not replicated by the model in spite of high correlation. The GFDL baseline results were able to capture the number of peaks within the rainy season. On the similar note, the model was not able to replicate the exact months of occurrence of peaks. This variation is prominent for the region of Pathein, Pyay and Bago.

Due to unsatisfactory performance of the other models within the correlation analysis and lack of data in spite of the variation GFDL was used for future climate analysis.

One can also observe from Figure 2-46, that deviations evident within average Temperature.

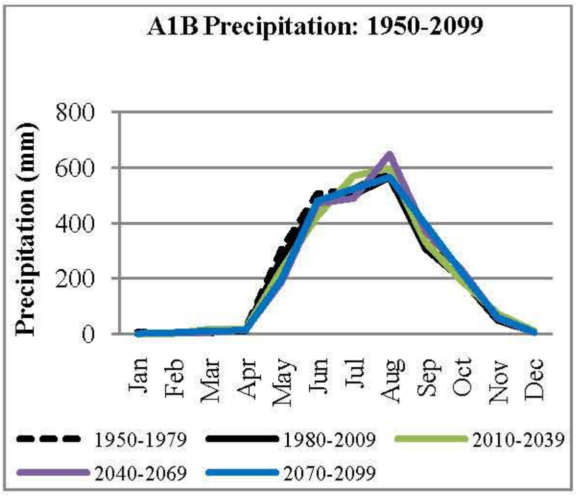
Figure 2-46: Average Monthly Temperature (1996 to 2005)

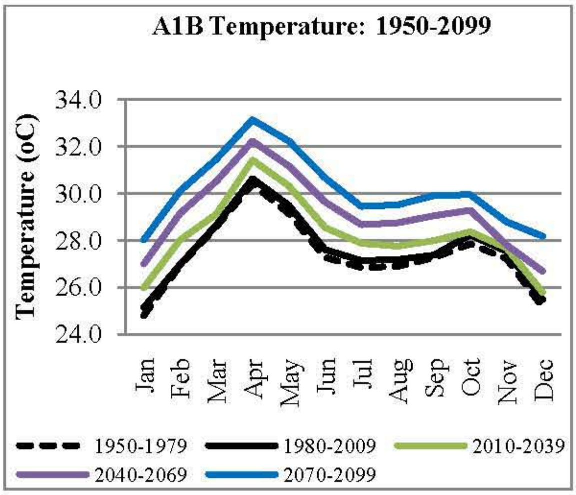


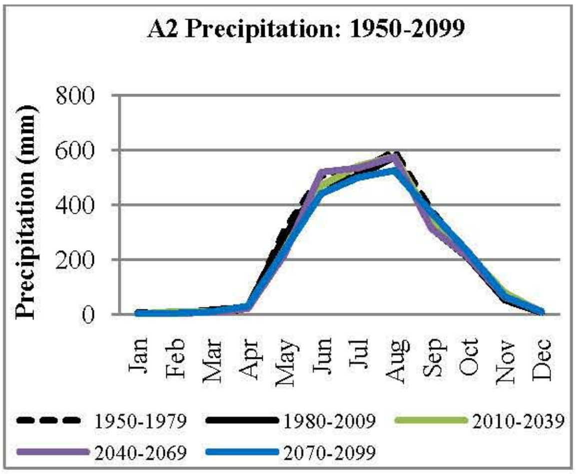
From the analysis it is evident that the trends within temperature analysis were well captured by the GFDL baseline. The peaks and the spread were evenly distributed with minor variation of less than 1^{o}C was evident between the model and historical temperature data.

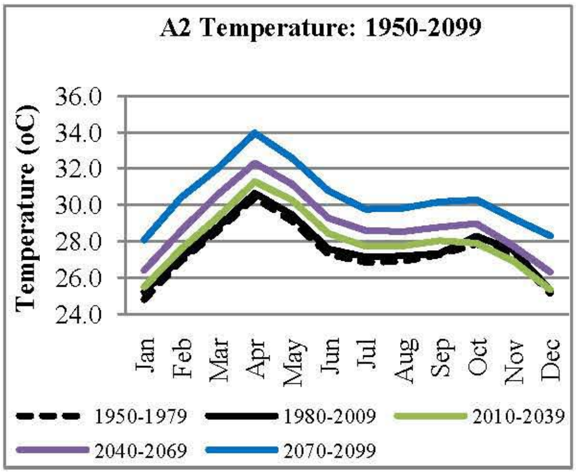
The results from the future precipitation and temperature analysis for these four regions are presented for respective regions in the following figures. Due to the abnormal variation in the precipitation trends of Pyay region, the results for this region were not included for subsequent analysis.

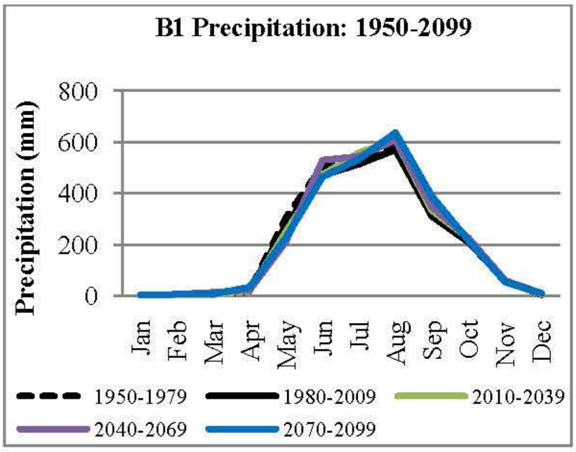
Yangon

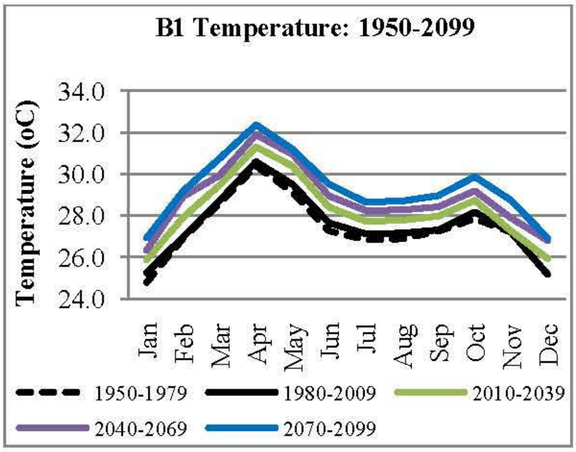








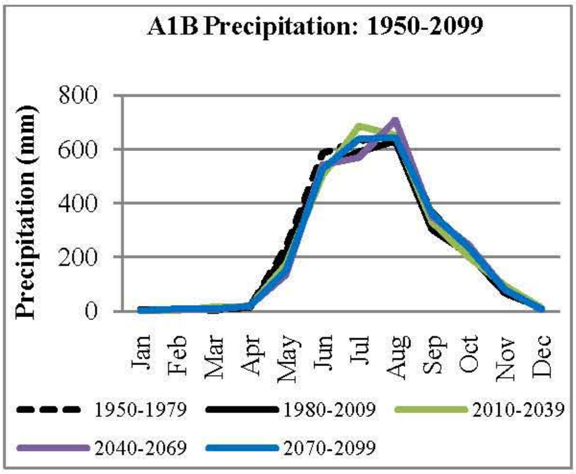


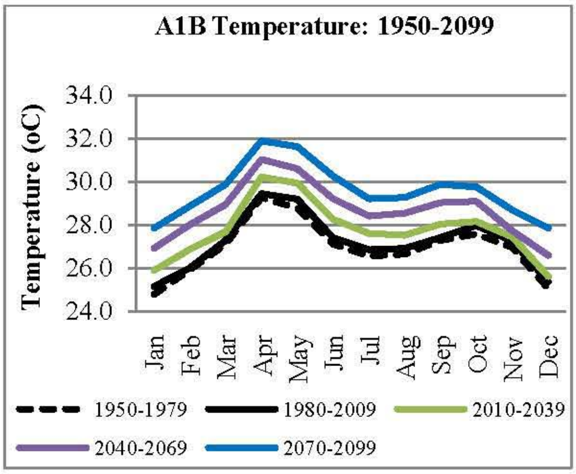


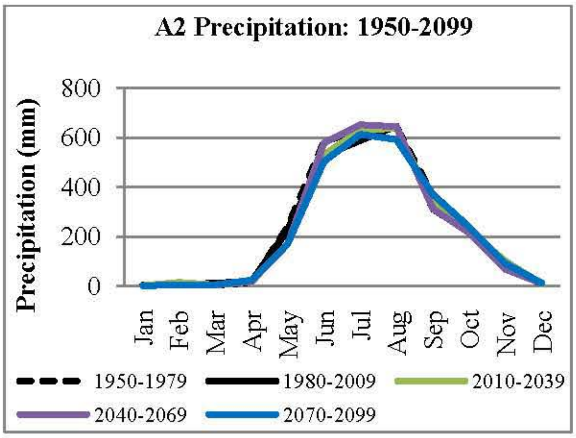
The results indicate that there is likely to be not much variation in the precipitation pattern within this century but a possible increase in the average monthly temperature.

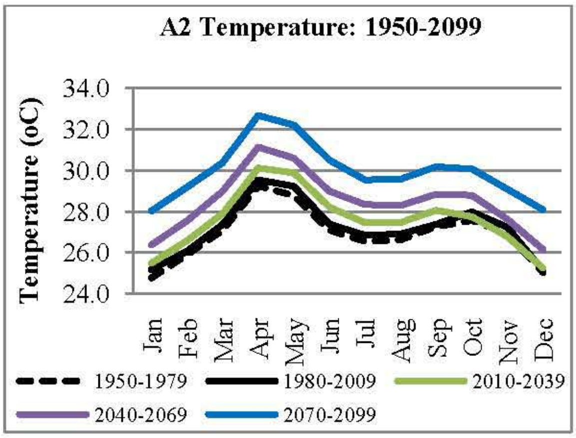
This increase in temperature will be of the order of around 0.5^{o}C within the next 30 years and may continue to increase to around 2^{o}C from current average temperature around the end of this century.

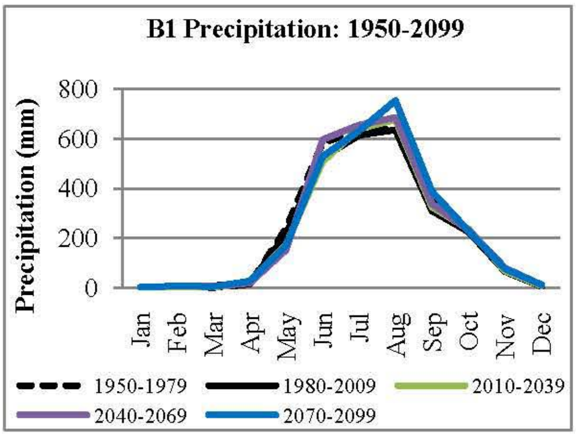
Pathein

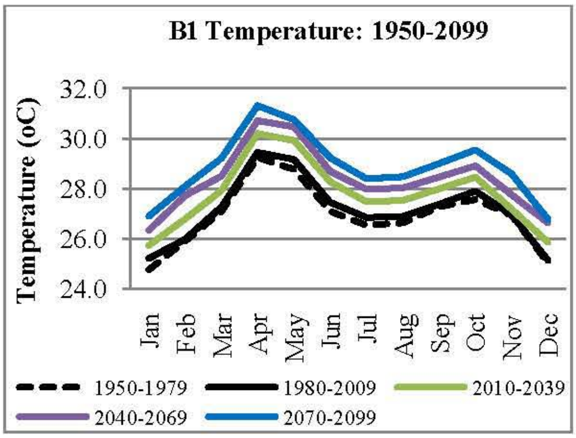








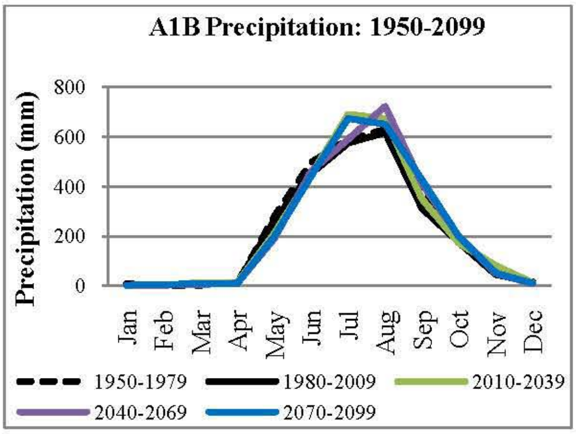


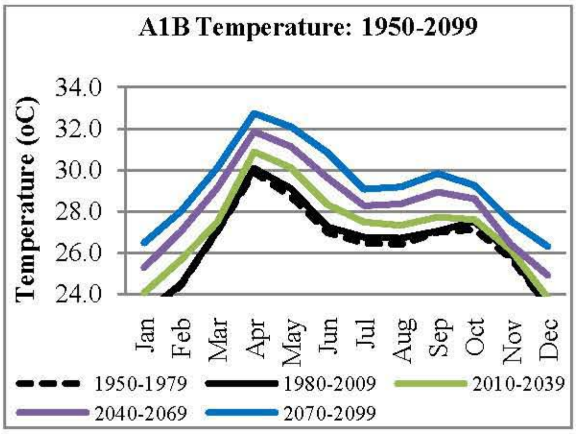


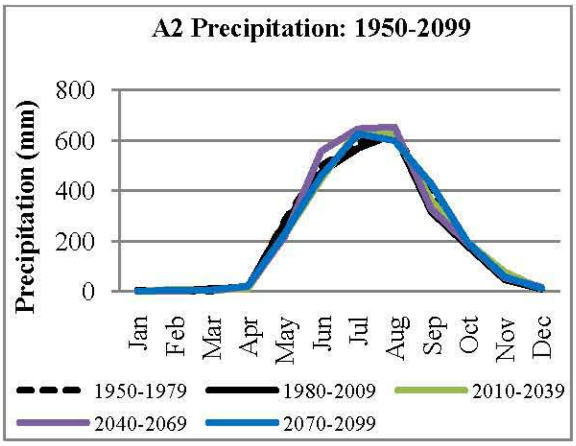
The results from Pathein region show a similar trend as that of Yangon with not much change in the precipitation patterns but considerable increase in the temperature.

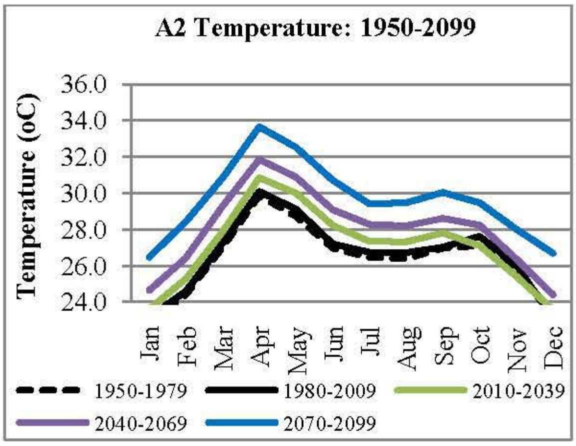
The order of increase in average monthly temperature is uniform within all models and across all months.

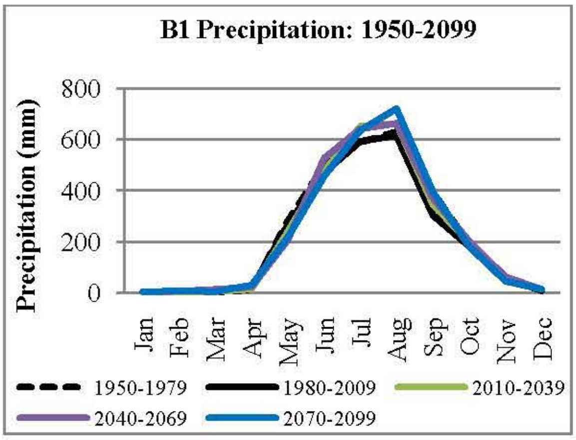
Bago

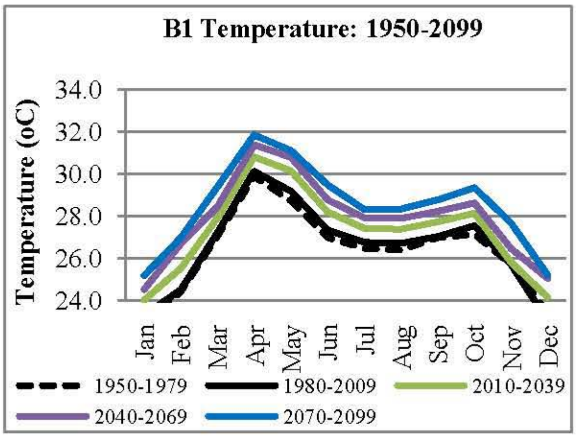












The future precipitation change patterns for Bago are similar to Yangon and Pathein for the next four decades. Beyond 2050, there are possibilities of change to the order of 50 to 100 mm in the monthly precipitation patterns especially during the peak rainy months i.e. June, July and August with a possible extension into the month of September.

The temperature change pattern are very similar to that of the other regions exhibiting a possibility of average increase in the order of 0.5°C for every three decades across all seasons. This increase may continue throughout this century.

The climate change results indicate that there may not be much change in precipitation trends within the delta region except for minor change in the precipitation pattern around the Bago division. On the other hand, the results indicate that there is high possibility of change in the average temperature across all seasons and this increase is expected to continue within this century. There is not much variation in the observed results between the scenarios. This could be either due to no effect of scenario on the future climatic outcome for Myanmar or due to the uncertainty within the modeled results. Due to the lack of historical data subsequent analysis was not performed to confirm the above.

2.7 SUMMARY

Tectonic set up of Myanmar delta region indicate high seismic risk. Seismotectonic processes of the region are very complex. The subductive nature of Indian plate, active spreading zone in south and an Sagaing an active fault in east of Yangon makes delta region vulnerable to high seismic risk. Historically, five major destructive earthquakes have occurred in Myanmar. This demands proper investigations pertaining to seismic hazard assessment of the Myanmar as a whole and also region specific studies.

In present study an attempt was made to determine the seismic hazard for Ayeyarwady, Yangon and Bago Divisions of Myanmar. Based on the extensive literature study and available data suitable earthquake catalogue was derived for the present study area with several assumptions. Probabilistic Seismic Hazard Assessment (PSHA) approach has been adopted for the current study. Based on the limitations within some of the earthquake attenuation model to include the bed rock conditions the PGA model as proposed by Si & Midorikawa (2000) was used. The results obtained during the analysis have been used to evaluate the seismic hazard based on the PGA values for 25, 50, 100 and 200 year return period. The PGA value for the study region varies between 0 to 0.25. The Spatial analysis indicates that the seismic risk is high for the Eastern delta region compared to Western delta region. This may be attributed to Sagaing fault which is an active fault.

Tsunami caused by Sumatra earthquake reached up to the coastal areas of the Southern Myanmar coastal areas. The dynamic tectonic setup in off shore Myanmar indicates the possibilities of the tsunami for the coastal areas of Southern Myanmar. Based on the previous experience of Sumatra tsunami, model prepared by ECW/DMH for hypothetical tsunami, present tidal conditions of the delta region; two possibilities were envisaged for tsunami and accordingly inundations maps were prepared for the delta region.

Time Stage relationship for storm surge conditions were developed based on observations during cyclone Nargis. Two scenarios i.e. tsunami heights and average tidal conditions and tsunami heights with maximum tidal heights were derived. It was observed based on the analysis that the hazard risk due to tsunami observed from the model is very low with the average tide level. The maximum tide for the study area is usually around the months of July to August. Occurrence of tsunamigenic earthquakes during this time period will increase the risk of the delta region with such event. The results obtained with the analysis of the tidal data and the spatial analysis indicate that the maximum number of villages i.e. 333 out of 335 (maximum tsunami heights and average Tide condition) in Ayeyarwady division is at more risk compared to Yangon division. In the case of maximum tsunami heights and maximum tides, 586 out of 634 villages fall within the Ayeyarwady division while the remaining 48 are within the Yangon division.

There are two prominent cyclone seasons for the country i.e. between April to May and October to December. Historical data points indicate that on an average, every ten years a major cyclone makes a landfall in Myanmar. For the present study probabilistic cyclone and wind hazard assessment for Myanmar delta region was carried out. Estimation of exceedence peak gust wind speed probabilities for 25, 50, 100 and 200 year return period have been calculated based on the combination of the widely referred Holland / Jelesniask wind field model based on its robustness in various goodness of fit test. The results were observed in light of two classification systems i.e. widely referred Saffir-Simpson (1971) scale and other one followed for the Indian ocean basin BIS Code: 875 (Part III), 1987. In each model run it is observed from the analysis that the wind speeds for 25, 40, 100 and 200 return period are mostly higher in the western delta provinces and it progressively diminishes across the eastern parts. 30 sec peak gust for 25, 50, 100 and 200 year return periods were developed.

Inundation/flooding in the coastal area can occur due to cyclonic condition which may result in storm surges. The coastal configuration (topography/bathymetry) and the water body near the coast greatly influence the inundation conditions for the coastal areas of Myanmar delta region. The present study area experiences diurnal tides in six hour time period. About 15 tidal gauge stations were considered for the present study. The tidal heights observed in the eastern side of the study area are higher than the western side of the study area i.e. Ayeyarwady delta region. This can be attributed to the coastal configuration in the eastern region i.e. Yangon region which might be amplifying the tidal heights. The average storm surge heights observations related to the Nargis cyclone was about 3.17m. based on the time stage relationship of about 6 hours for the cyclonic conditions storm surge map was generated for the delta region. The results obtained were viewed in context of vulnerable populations likely to be affected by storm surges in the Myanmar delta region. It is observed based on the results that Myaungmya, Pyanpon and Yangon along with Pathein districts shows higher possibilities of inundation due to storm surge conditions affecting large number of population. The present study represents the worst case scenario of the storm surge conditions and therefore there might instances of over estimations for storm surge conditions.

Flood analysis for the present study area aimed at modelling the impacts of fluvial flooding from Irrawaddy and Sittaung rivers flowing within the study area and pluvial flooding due to extreme rainfall and possible storm surges. Hydrological model was used to generate the flow series for the entire catchment of Irrawaddy and Sittaung river basins to analyze the implication of a flood along the river stretches and its neighborhood. The outcome of the modeling indicates maximum flooding near the downstream end of the river where it spreads into a fan shape. The combined spread and depth of inundation as modeled was similar to the flooding of Nargis cyclone. Due to non- availability of actual observed rainfall in the study area, sensitivity analysis was carried out by increasing the rainfall by 50% and 100% on the rainfall pattern extracted from TRMM girded rainfall for the Nargis cyclone period. The depth of inundation is more than 1.5 m in some places and in general the inundation is below 0.75 m due to pluvial flooding conditions for the selected study area.

The goal of climate change study was to analyze the possible changes in precipitation and temperature within Myanmar Ayeyarwady delta under future climate change scenarios. Due to intricate nature of the climate and its complex relationship with environmental parameters, the task of analyzing the inter-relationship between events that are occurring sporadically over space and time is difficult. The method for climate analysis within this study follows three step approaches which included a) Analysis of downscaled climate data and normalization of the same with respect to the historical (1990-2007) climate data, b) Selection of appropriate GCM based on correlation analysis and c) Analysis of selected models for evidence of future changes in temperature and precipitation.

Out of the 15 models only one model i.e. GFDL did exhibit satisfactory correlation index for present study area. Overall there is not much variation within the precipitation profiles across the divisions but the model indicates a possible change in the future temperatures which may range from 0.5 C to 2 C from current averages.

Chapter 3: URBAN VULNERABILITY ASSESSMENT

3.1 INTRODUCTION

Towns are characterized by social and economic heterogeneity. Vulnerability analysis in towns is defined by several parameters including livelihoods, key assets like houses and vehicles, literacy and skills and access to infrastructure and services. These parameters also define the resilience capacity of the households and communities. There is a large diversity in these parameters among the households. In addition to this, changes in overall economic base of the town influence the vulnerability pattern.

Town level urban vulnerability research was mostly limited to developed countries where significant property and social data exist. The country and global level assessments were some of the first efforts done by various authors (Satterthwaite, 2008). Mostly the published literature about city level vulnerability assessment is descriptive and is not very useful for city level planners (Wilbanks *et al.*, 2007). While research on town level vulnerability has made fundamental contributions to the exploration of different types of vulnerabilities and the causative factors that are embedded into broader structural and political conditions, understanding evolution of vulnerability across space and time requires more effective tools. It does not, for instance, address how exposure to changing hazards evolves over time (Lankao *et al.*, 2009).

Review of the literature suggests that vulnerability is understood to have two facets. First, is the external side of risk, shock or stress to which an individual or household is subjected to; and the other is the internal side which is defenselessness, lack of coping without damaging loss (Haki *et al.*, 2004). The present Vulnerability assessment has tried to combine the issues from the surveyed towns of delta region of Myanmar and an attempt has been made to bring realistic situation into analysis, to address issues at household and community level.

3.2 OBJECTIVE

Main objective of the urban vulnerability assessment is to address different facets of vulnerability across the different surveyed towns to inform possible adaptation framework.

3.3 SURVEY SCHEDULE, SURVEY TOOLS AND SAMPEL SIZE

The survey tools consist mainly of Myanmar/Delta region context specific questionnaires. They aim to capture the relevant socio-economic data and were developed by TARU. This was further improved and customized in vernacular language by MSR.

The questionnaires were prepared in February 2010 and were introduced to the team of field researchers through a training workshop. The final schedule and the sample size were shared with UNDP Myanmar (Feb/Mar 2010) Table 3-1 summarizes the schedule type, sections and sample size of each type of tools.

The indicators used for the analysis and their corresponding index/scaling are described in detail within the Annexure.

Table 3-1: Sample Size of Town Schedule

Schedule Type	Sections	Unit of enquiry	Total
Town Schedule	Section-1: Community / Neighborhood Schedule	3 neighborhoods per town of different SECs	15
	Section -2: Transect Survey	3 transects per town across SECs	15
	Section -3: Schedule of rates	5	5
	Section – 4: Trade / Small business economics	3 in each town	15
Town Household Schedule	Household Schedule	10 households along each transect	150
Industrial Schedule	Industrial Schedule	20	20
Case Studies		10	10

3.4 VULNERABILITY AND CAPACITY ASSESSMENT (VCA)

Vulnerability and Capacity Assessments (VCA) are based on relevant indicators for Delta Region. The main purpose of using capacity and vulnerability indicators were to compile comparative information across the samples and homogenous polygons using available data from the household and community level surveys. The survey data sets were used to derive the capacity and vulnerability indices. Table 3-2 provides a detailed description of the indicators.

Table 3-2: Data Sets Used for Deriving Vulnerability and Capacity Indicators

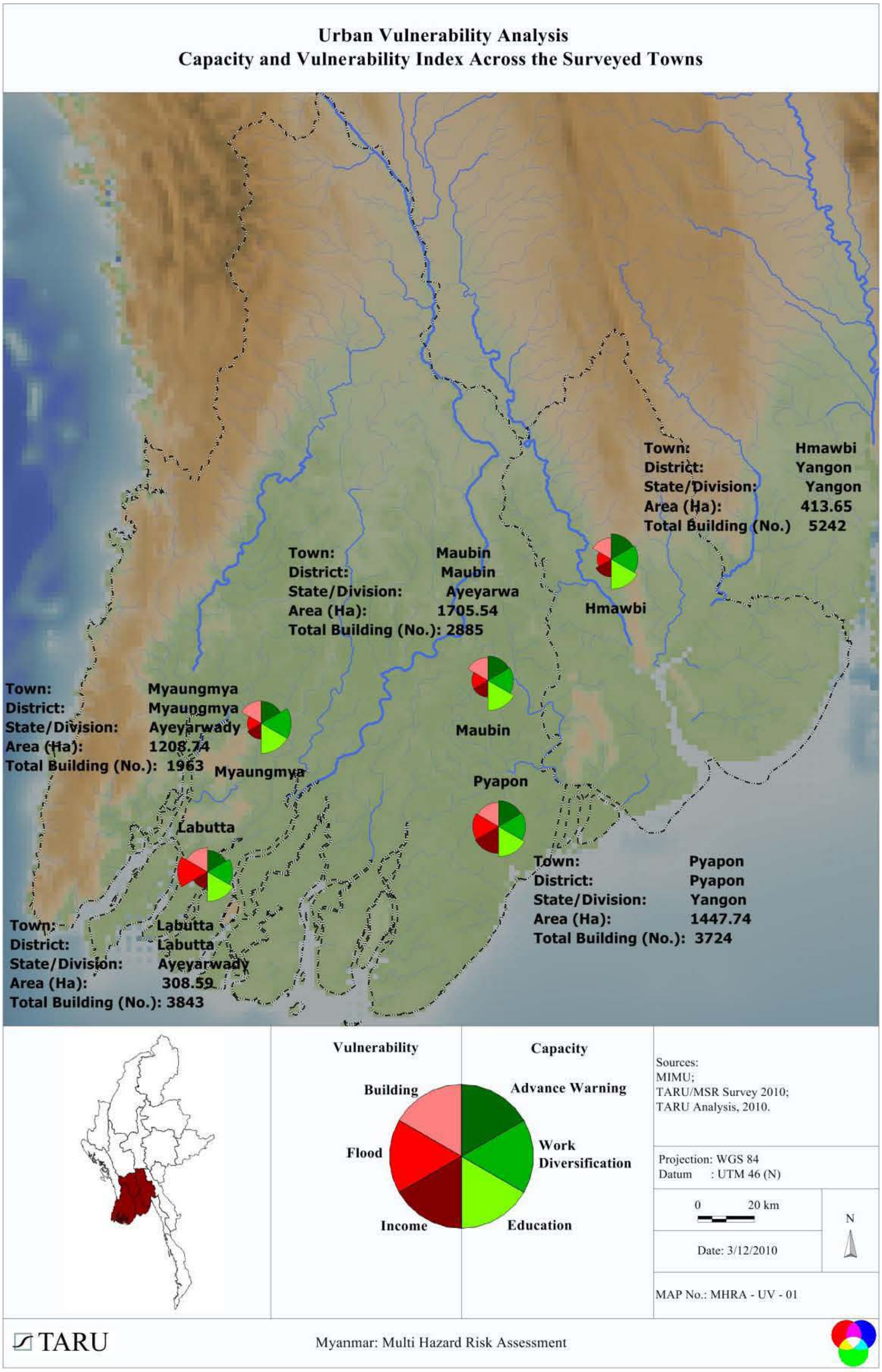
Indicator	Status	Data used	Comments
Education	Capacity	Level of education in a household (HH)	Higher level of education in household increases capacity to earn and also empowers next generation to benefit from education. Education also helps Government or Agencies to run CBDRM.
Work Diversification	Capacity	Ratio of total working member in HH and their occupation.	Work diversity provides resilience during disasters, and increases the redundancy.
Early Warning Mechanism	Capacity	Communication devices available within HH (TV, Radio, Land-line phone and Mobile phone)	People-centred early warning systems empower society and communities to prepare for and mitigate natural hazards.

Indicator	Status	Data used	Comments
Income Instability	Vulnerability	Per capita income of HH, ratio of highly stable, stable and unstable incomes and the dependency ratio within a HH.	Income stability provides resilience during disasters, and ability to invest in adaptation.
Building Typology and Accessibility	Vulnerability	Building construction material (roof and wall type), and Built-up area ratio in SEC	Building typology and accessibility is directly related to the physical vulnerability. Inaccessible and non-engineered buildings are most vulnerable during most natural hazards.
Flood and Water Logging	Vulnerability	Distance from river, depth of inundation during previous floods and duration of inundation	Provides snapshot of flooding events faced by the household and the associated risk.

Source: TARU Analysis, 2010

The urban vulnerability analysis in Myanmar with vulnerability and capacity index across the surveyed towns is presented in Figure 3-1.

Figure 3-1: Myanmar Urban Vulnerability Analysis



Source: TARU Analysis/MSR Survey, 2010

3.4.1 Education

Education System in Myanmar

Education has always been given high priority within Myanmar society since ancient times with the monasteries acting as the main centres of education. Because of its strong tradition of monastic education, the literacy rate has been high all throughout the history of Myanmar.

The educational system in Myanmar is operated by the Government through Ministry of Education. Primary, Lower Secondary and Upper Secondary Schools in Burma are under the Department of Basic Education. Primary education is mandatory. It lasts five years. Secondary education is divided into middle schools (standards VI – VIII), and upon passing the Basic Education Standard (VIII Examination), students continue onto high schools (IX-X standard). Secondary schools are inclusive of both middle and high schools. Snapshot of primary and higher education institutions in towns (within study area) are presented in Figure 3-2: Snaps of Educational Infrastructure.

Figure 3-2: Snaps of Educational Infrastructure

Primary Education Institution	Higher Education Institution
	

Source: TARU/MSR Primary Survey, 2010

Source: TCG Periodic Review III

Education Level

Level of education is one of the prime indicators, which reflects the knowledge capital and scope of development within any society. From the primary survey, it is evident that more than 23% members have education up to 5 years, followed by 50% of people having had 6 to 12 years of education. 21% of the Town dwellers are graduates while postgraduate-professional constitute only about 2%. People who have not had basic education are very low in number and constitute about 5% of the total urban (Town) population. The education level within the surveyed households in five towns is presented in Table 3-3.

Table 3-3: Education level

Sl. No.	Education Level	Person (Nos.)	Percentage
1	Illiterate	17	5%
2	Up to 5 years	81	23%
3	6-12 Years	179	51%
4	Graduates	73	21%
5	Post graduate	2	1%
6	Professionals	2	1%
Grand Total		354	100%
Total 75 HH (15HH in each town)			

Source: TARU Analysis/MSR Primary Survey, 2010

Education Index (Capacity)

Education index provides a basis for comparing different education level in surveyed towns. Within the surveyed towns, education index was derived considering the maximum level of education within a household. Different weights were assigned to different levels of education. It is important to note that the household members who had completed formal schooling (educational system approved by Ministry of Education) were only considered. Education index for five towns is presented in Table 3-4. The results from the analysis indicate that the literacy rates in towns are high. This can be due to the fact that town residents have better access to the educational infrastructure within towns.

Table 3-4: Education Index (Capacity)

Sl. No.	Education Index	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	1-2	-	-	8%	-	-
2	2-3	-	-	5%	-	-
3	3-4	6%	-	-	-	15%
4	4-5	13%	5%	6%	8%	34%
5	5-6	32%	59%	42%	11%	12%
6	6-7	41%	36%	19%	40%	34%
7	7-8	8%	-	19%	41%	5%
Total		100%	100%	100%	100%	100%
Total 75 HH (15HH in each town)						

Source: TARU Analysis/MSR Primary Survey, 2010

The results indicate that an average of 50% of household members in all surveyed towns have sufficient education level i.e. 5 or above in the education index category. Only few (less than 7%) have low education level (index value <= 2). Education level is used as one of the measures of capacity of households in this analysis. .

3.4.2 Occupation and Income

According to Bromley and Gerry (1979) in developing countries, employment scenario (occupation and income) is an important factor for assessing the capacity or vulnerability of the community. In this study two main aspects of occupation and income were taken into consideration to assess the employment scenario within the towns. First, the diversity in work within a household and second the level of stability present within the work done by various members of the household. Within this study, daily wage employments are considered to be unstable while employments within government or similar sectors, which guarantees pension, are considered to be highly stable. Classification of occupation is presented in Table 3-5.

Table 3-5: Classification of occupations

Very Stable Occupation	Stable Occupation	Unstable Occupation
Government (Lower level)	Agriculture and Fisheries	Wage labour (Skilled)
Government (Middle level)	Industry and Workshop	Wage labour (Unskilled)
Government (Upper level)	Private Transport Services	Agriculture labour
	Trade & Small Business	
	Saw Mill	
	Vendor and Street Stall Vendor	
	Sailor	
	Professional, Retired and Pensioner	

Source: TARU Analysis/MSR Primary Survey, 2010

It is observed that majority of industry workers are engaged in stable but diversified occupations in all surveyed towns. Nearly 66% are engaged in stable occupation. However, they are very much dependent on contractors, suppliers, employers owing to their lack of marketable skills. Subsequently, around 25% are engaged in unstable occupations. Unstable employment usually includes household members of low-income settlements. An increase in the level of unstable employment may lead to financial crisis during times of economic downturns, including the ones caused by disasters. Highly stable workers are very less constituting to about 9%of the population. Occupational profile of surveyed towns is presented in the Table 3-6.

Table 3-6: Occupational Profile (Sample Households)

Sl. No.	Category of Occupation	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	Very Stable Worker*	8%	9%	8%	13%	8%
2	Stable Worker*	64%	72%	55%	76%	64%
3	Unstable Worker*	28%	19%	37%	11%	28%
Total		100%	100%	100%	100%	100%

**Please see Table (5) for details*

Source: TARU Analysis/MSR Primary Survey, 2010

Pictures of occupational diversity are presented in Figure 3-3.

Figure 3-3: Pictures of Occupational Diversity

Boat Manufacturing

Pottery Works

Common Market Place

Rice Husking

Bamboo Works

Thanaka Manufacturing

Source: TARU/MSR Primary Survey, 2010

3.4.3 Occupational Diversity Index (Capacity)

Diversity in occupation at household level is one of the important indicators, which could help assess the capacity of households. The more diversified the household occupational profile; the more resilient it is to shock and stress situations. In other words, a household employing diversified livelihood strategies is less vulnerable and could recover more quickly in comparison with a household where members are involved in occupations of a similar kind.. Occupational diversity (capacity) index within this study was derived taking into consideration the total working member within a household and their occupational profile. Household members who have different sources of income were assigned maximum weightage while, households involved in similar occupational profile have been assigned low weightage. Occupational diversity (capacity) index of surveyed towns is presented in Table 3-7.

Table 3-7: Occupational diversity (Capacity) index

Sl. No.	Occupation Diversity Index	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	1-2	-	6%	-	-	-
2	>2-3	-	-	20%	-	-
3	>3-4	9%	19%	8%	23%	-
4	>4-5	-	16%	-	-	-
5	>5-6	44%	19%	32%	42%	48%
6	>6-7	25%	9%	24%	8%	-
7	>7-8	-	-	-	11%	-
8	>8-10	22%	31%	16%	16%	52%
Total		100%	100%	100%	100%	100%
Total 75 HH (15HH in each town)						

Source: TARU Analysis/MSR Primary Survey, 2010

Occupational diversity index is quite good within all surveyed towns. More than 80% households in all surveyed towns have high diversity (5 or more) in their occupational profile. Remaining 20% or less have less diversity in occupation and/or involved in similar occupation. Diversity in occupations in urban areas is presented Table 3-7 and Figure 3-3.

3.4.4 Income Instability Index (Vulnerability)

The income stability or instability indicator refers to the degree of uncertainty in the income. The index is a function of number of people within a household and the per capita income generated by the household. The following parameters were considered for the analysis: per capita income, income stability, number of working members and number of dependents within households.

The income instability Index is critical in assessing the resilience and/or investing capacity of the community. This index does not deal with the assessment of the current immovable assets of the households.

In the scale of 1 to 10, low weight (value 0) was assigned to household, in which at least one member or more are engaged in full time formal employment (e.g. government). Weight of 5 was assigned to households within which at least one member of the family is employed within private, NGOs, engaged in large scale self employment work (e.g. grocery shops, carpentry, masonry, technician, mechanic). Maximum weight (10) was assigned to households, which do not have any secure income (e.g. unskilled casual work).

The results of the Income instability (vulnerability) index analysis over the surveyed towns are presented in Table 3-8.

Table 3-8: Income instability (Vulnerability) Index

Sl. No	Income Instability Index	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	1-2	-	-	6%	7%	-
2	>2-3	7%	26%	21%	26%	-
3	>3-4	47%	6%	20%	20%	20%
4	>4-5	13%	47%	14%	34%	20%
5	>5-6	27%	13%	33%	7%	26%
6	>6-7	6%	8%	6%	-	27%
7	>7	-	-	-	6%	7%
Total		100%	100%	100%	100%	100%
Total 75 HH (15HH in each town)						

Source: TARU Analysis/MSR Primary Survey, 2010

3.5 EARLY WARNING MECHANISM

Early warning systems constitute an important risk mitigation measure and contribute towards reducing the loss of life substantially. However, the efficiency of such systems is to be measured in terms of lives saved and reduction in losses, which is directly related to the execution of an anticipated response by the people and institutions once a warning is issued.

In other words the effectiveness of the warning is directly proportional to people's ability to understand and interpret the warning generated and the time available for people to react to that warning (respite time). Increasing the respite time will be critical in preventing losses and also to move their valuable assets to safe places. Improving respite time with location specific warnings can help in greatly reducing losses to movable assets, in addition to life

In this study, primary survey was conducted and responses were sought to understand the warning systems, respite time and community responses during Nargis cyclone. The hazard warning (respite time) provided before Cyclone Nargis in five towns are presented in the Table 3-9.

Table 3-9: Reported Advance Warning Time

Sl. No.	Hazard Warning Time*	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	1-2 Hours	-	-	-	-	-
2	>2-4 Hours	35%	-	72%	-	30%

3	>4-6 Hours	34%	68%	28%	33%	-
4	>6-8 Hours	-	32%	-	-	-
5	>8-10 Hours	31%	-	-	67%	70%
Total		100%	100%	100%	100%	100%

**Received before Cyclone Nargis*

Source: TARU Analysis/MSR Primary Survey, 2010

During Cyclone Nargis, almost all the surveyed households received a respite time of around 10 hours or less. Nearly 60% of households received the warning with less than five hours of respite time.

From the table, it is evident that no sufficient respite time available for safe evacuation or movement of the people from the risk prone areas. Major source of hazard warning in these survey towns were provided by MRTV (local TV channel), TPDC or EWC

3.5.1 Mode of Early Warning Messages Dissemination

Early warnings messages must be clear and should cover all people at risk to initiate proper responses. Simultaneously, it is also very important to disseminate clear warning message through appropriate mode. Regional, national and community level communication television channels or radio system must be used to convey the message.

The community at the path of risk must also be able to comprehend the information and take suitable action (moving to higher ground, evacuation to safe haven, reduce the exposure of elements at risk). During Cyclone Nargis in 2008, the early warning messages were communicated to the people trough available media.

The effectiveness of the media in communicating the risk is presented in Table 3-10. From the results it is evident that radio and television were most effective towns. This indicates that unlike their rural counterparts, where the use of television is minimal, the people within towns are very receptive to the information that was disseminated trough electronic media televisions and radio.

Further, the presence of personal power backup sources within these areas also increases the usage and guarantees the operation of these devices even during emergencies and during power failures.

Table 3-10: Mode of Early Warning

Mode of Warning*	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
Radio	65%	32%	-	-	-
Television	-	68%	60%	100.00%	-
Mobile	-	-	-	-	38%
Loud Speaker	-	-	40%	-	62%
Human Chain**	35%	-	-	-	-
Total	100%	100%	100%	100%	100%

**Received before Cyclone Nargis, **Human Chain includes Government and Private Initiatives*

Source: TARU Analysis/MSR Primary Survey, 2010

3.5.2 Early Warning Mechanism (Capacity)

Presence of landline telephone, mobile telephone, radio or television at household level is very important to receive the hazard warning. Early warning index is derived from analysis of communication devices available at household level. The early warning index (capacity) ranges from 1 to 10. Weightage were assigned based on the availability of communication devices and the ability of the devices to communicate the information in a timely manner. Early warning mechanism index is presented in following Table 3-11.

Table 3-11: Early warning mechanism index

Sl. No.	Early Warning Mechanism Index	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	Nil	13%	6%	33%	7%	40%
2	1-2	-	-	-	-	-
3	>2-3	-	7%	-	7%	-
4	>3-4	-	-	-	-	-
5	>5-6	-	8%	7%	7%	7%
6	>6-7	20%	32%	20%	33%	-
7	>7-8	-	13%	13%	13%	7%
8	>8-9	-	-	-	-	-
9	>9-10	63%	34%	27%	33%	46%
Total		100%	100%	100%	100%	100%

Total 75 HH (15HH in each town)

Source: TARU Analysis/MSR Primary Survey, 2010

Within the surveyed towns, more than 60 % of household have TV, radio or mobile phone. On the other hand, on an average around 20% of households have no communication device (index value <=1The areas with low early warning mechanism index are to be priorities for setting up of early warning or public information dissemination system to aid them in times of need). As per the survey, Pyapon town lacks in communication systems (40%).

3.6 PHYSICAL VULNERABILITY

Physical vulnerability is material oriented and determined from location and construction types of buildings. Especially in towns, physical vulnerability is determined by assessing the construction typology of all buildings (roof and wall type) and built-up area vs. open area ratio with location, while analysing the physical vulnerability of towns in the Delta Region of Myanmar.

3.6.1 Building Typology

Building typology is one of the most important indicators of physical vulnerability. Towns in delta region depend upon the availability of local materials as well as local skills. In delta region of Myanmar, majority of buildings constructed by Wood / Bamboo on wall and Tin / Cement sheet or Biomass / Thatch / Bamboo on roof (Type III).

In all surveyed towns, more than 60 % of the buildings are constructed using Type III materials. Building stock by material of construction is presented in Table 3-12.

From the table it is evident that building vulnerability is high in Hmawbi and Maubin followed by Myaungmya, Pyapon and Labutta in the similar order. The vulnerability of the above mentioned areas are high during cyclonic and extreme precipitation events and low for earthquake.

Table 3-12: Building Stock by Material of Construction

Roof and Wall Type	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
Type-I*	-	7 %	0 %	10 %	7 %
Type-II*	-	30 %	17 %	23 %	26 %
Type-III*	100 %	63 %	83 %	67 %	67 %
Town Total	100%	100%	100%	100%	100%

Sample size: Total 75 HH (15 HH in each town)
Roof and Wall Type:
Type-I: Bricks(Wall)_RCC(Roof)
Type-II: Bricks(Wall)_Tin/ Ce-ment sheet or Tiles (Roof)
Type-III: Wood/ Bamboo(Wall)_Tin/ Ce-ment sheet or Biomass/ Thatch/ Bamboo(Roof)

Source: TARU Analysis/MSR Primary Survey, 2010

Different building categories (roof and wall) are presented in following Figure 3-4.

Figure 3-4: Different Building Types in Urban Centres

Source: TARU/MSR Primary Survey, 2010

3.6.2 Accessibility

Accessibility play very vital role, especially in unique geographic conditions such as delta or hilly regions during rescue and reconstruction operations. The lack of accessibility hinders the relief efforts such as aid in reaching the people/place of need. In present analysis accessibility index (i.e. open area index) was derived from total built-up area vs. available open land. Pictures of building density with roof type and accessibility condition are presented in following Figure 3-5.

Figure 3-5: High Building Density & Accessibility Conditions in Towns

Source: TARU/MSR Primary Survey, 2010

3.6.3 Building Vulnerability

The building vulnerability index was derived based on roof type of building (roof index) and accessibility of that area (open area index). Within the analysis low vulnerability index was assigned to areas with low built-up areas where movement of people and transportation could be possible and high vulnerability index were assigned to congested areas where there may be problems of mobility especially during/after a disaster. Similarly for the building typology based on roof index, high vulnerability values were assigned to un-engineered structures (Type III) and low vulnerability values were assigned to engineered or semi-engineered structures. Building vulnerability index of surveyed towns are presented in Table 3-13.

Table 3-13: Building Vulnerability Index

Sr. No.	Building Vulnerability Index	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	1-2	4%	-	1%	5%	1%
2	>2-3	1%	-	1%	3%	1%
3	>3-4	17%	10%	36%	30%	35%
4	>4-5	31%	18%	10%	7%	19%
5	>5-6	24%	8%	25%	12%	22%
6	>6-7	11%	10%	14%	11%	9%
7	>7-8	12%	54%	13%	17%	13%
8	>8-9	-	-	-	5%	-
9	>9-10	-	-	-	10%	-
Town Total		100%	100%	100%	100%	100%

Source: TARU Analysis/MSR Primary Survey, 2010

It can be inferred from above table that most of the buildings fall within the medium vulnerability index (3-6) except for Labutta where the percentage of highly vulnerable buildings (7-10) exceeds 50%. Building vulnerability of Hmawbi, Maubin, Pyapon Myaungmya & Labutta towns are presented in Figure 3-6.

Figure 3-6: Hmawbi Town Building Vulnerability

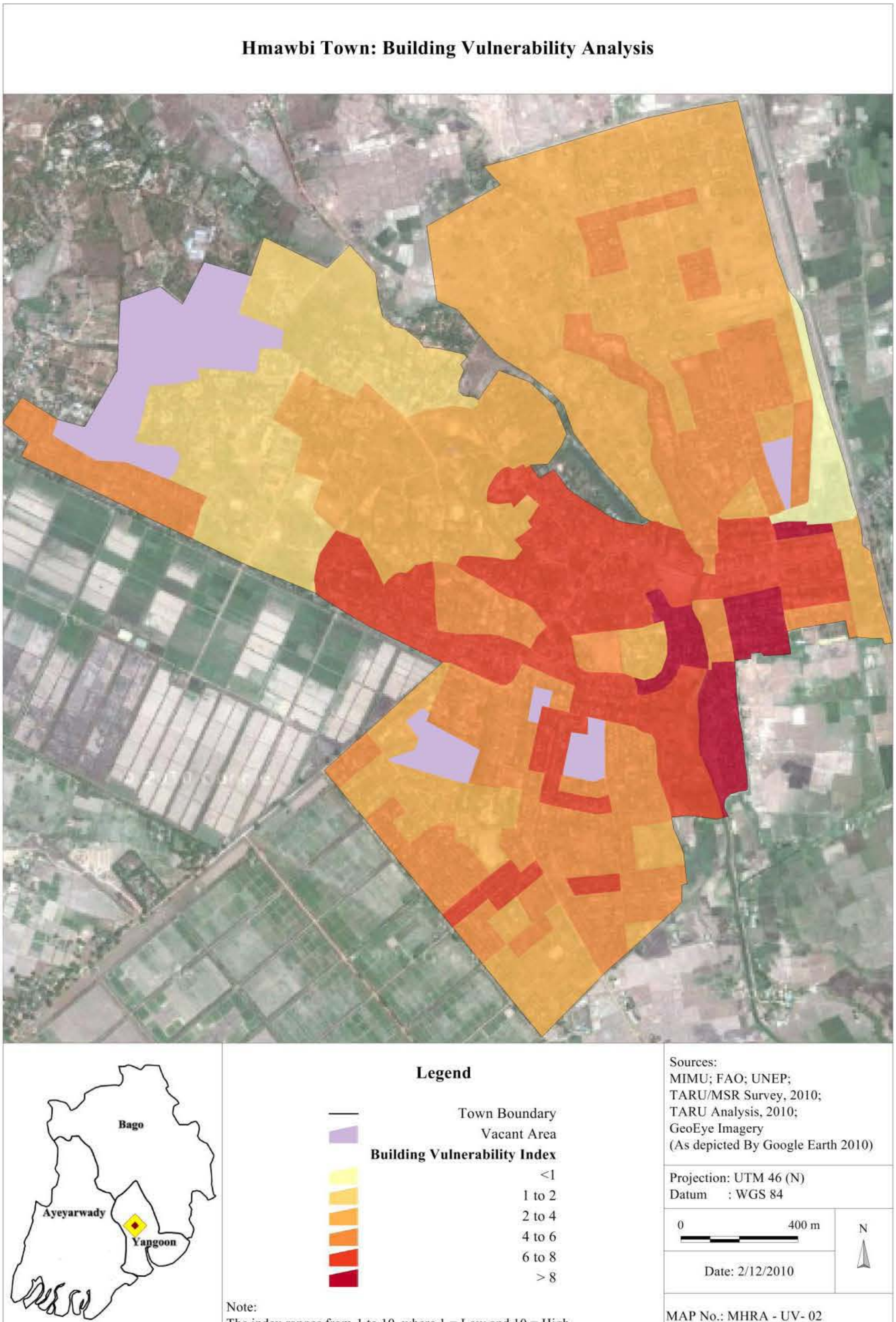


Figure 3-7: Maubin Town Building Vulnerability

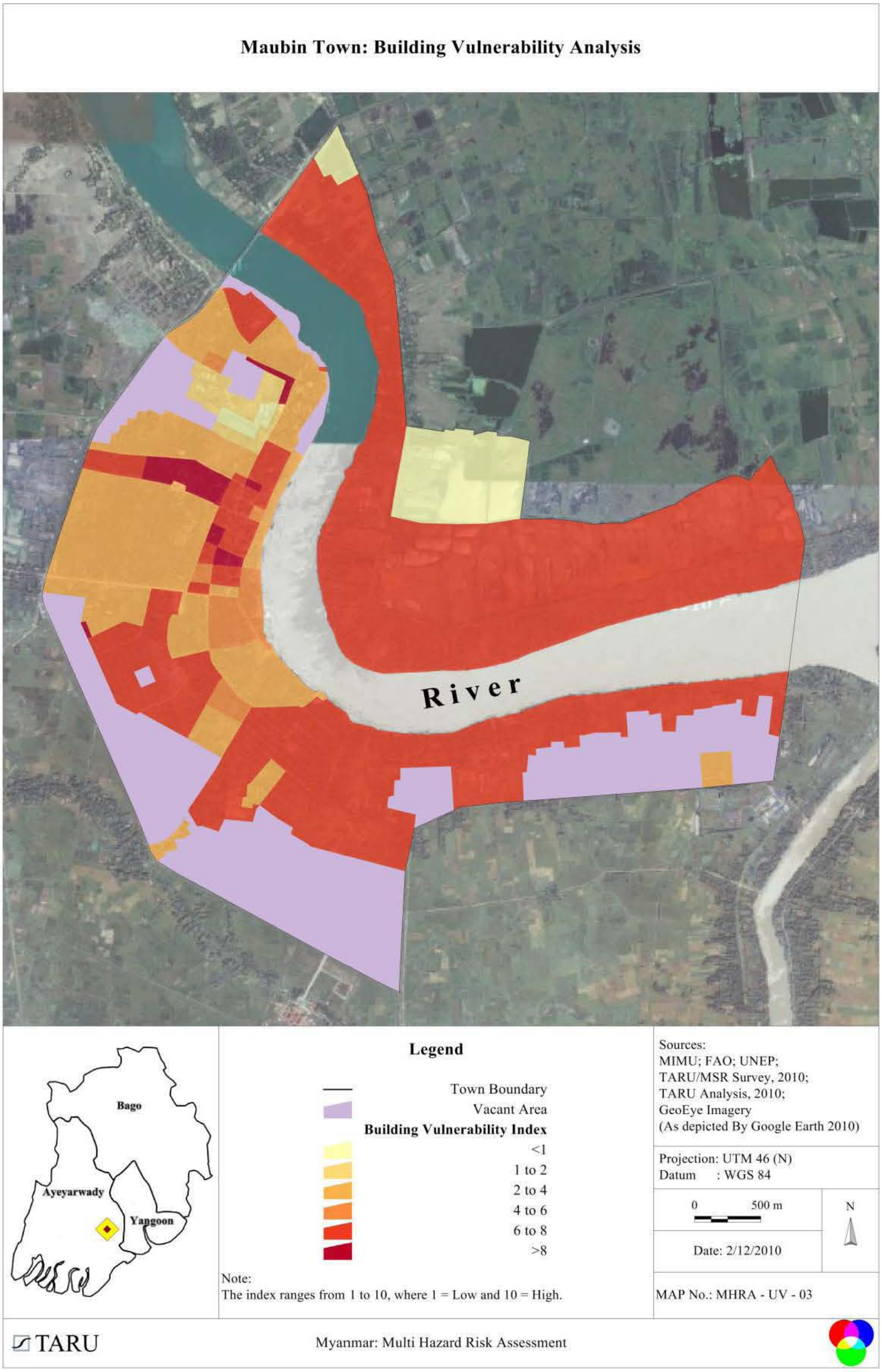


Figure 3-8: Pyapon Town Building Vulnerability

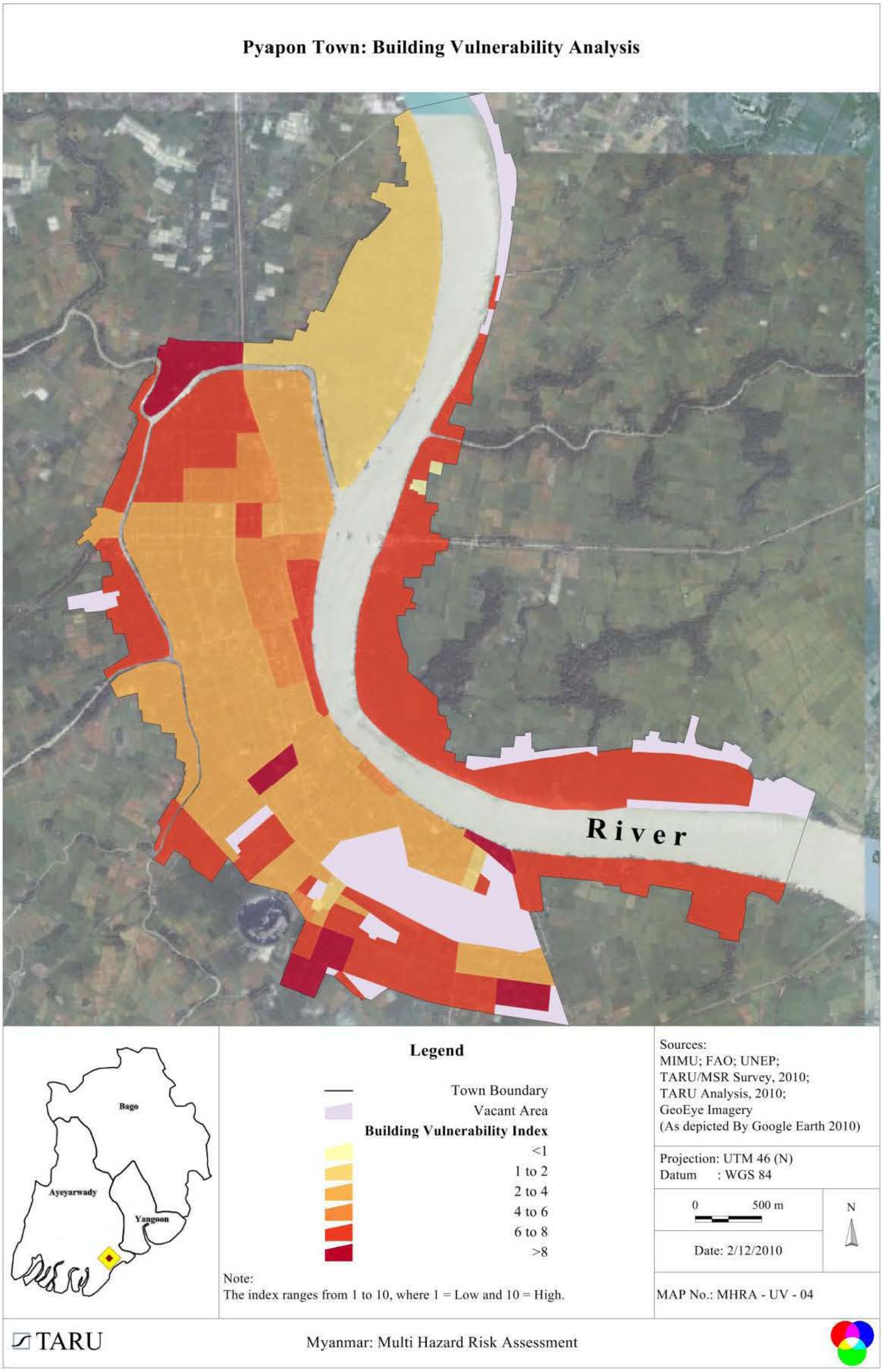


Figure 3-9: Myaungmya Town Building Vulnerability

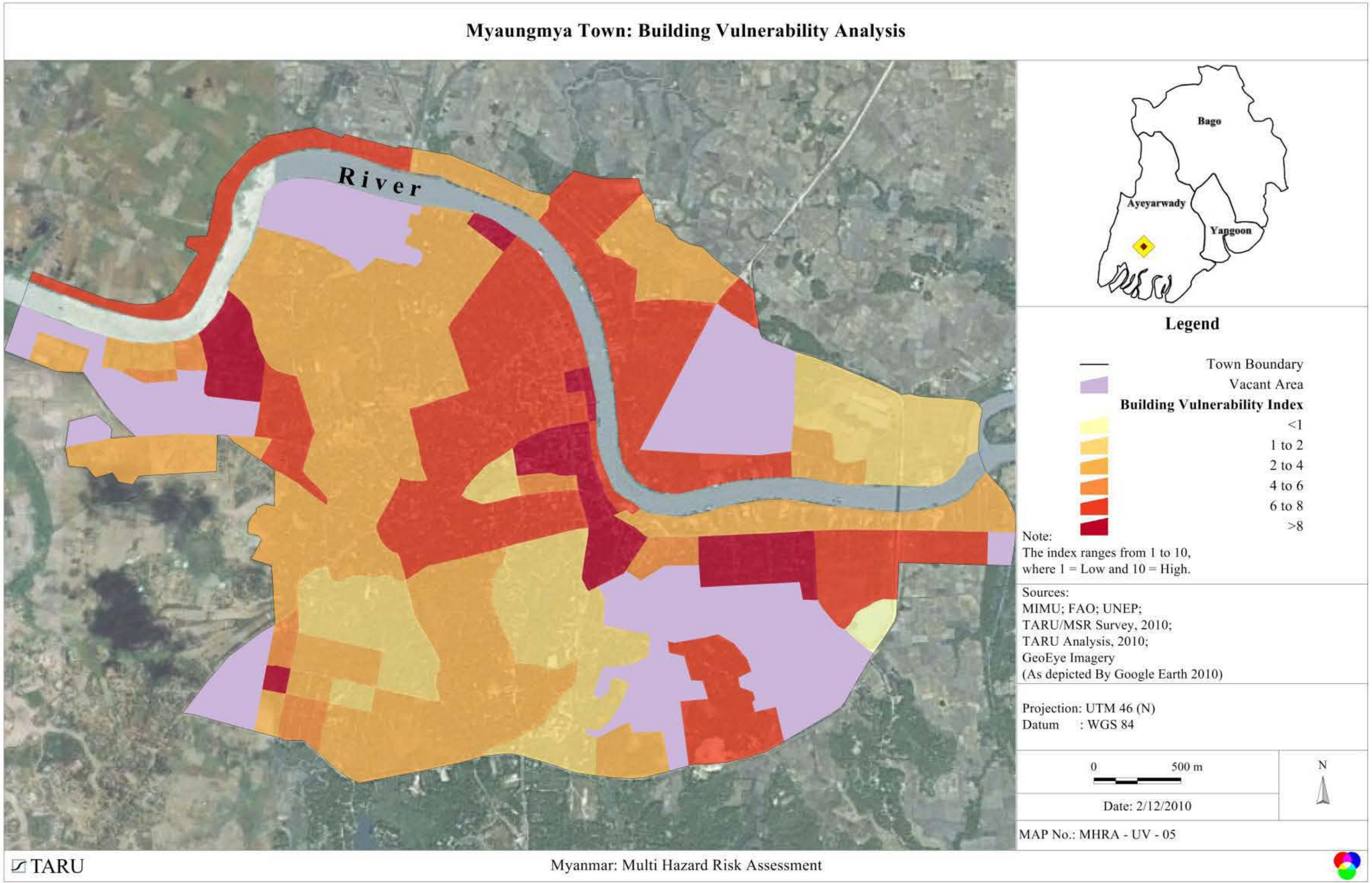
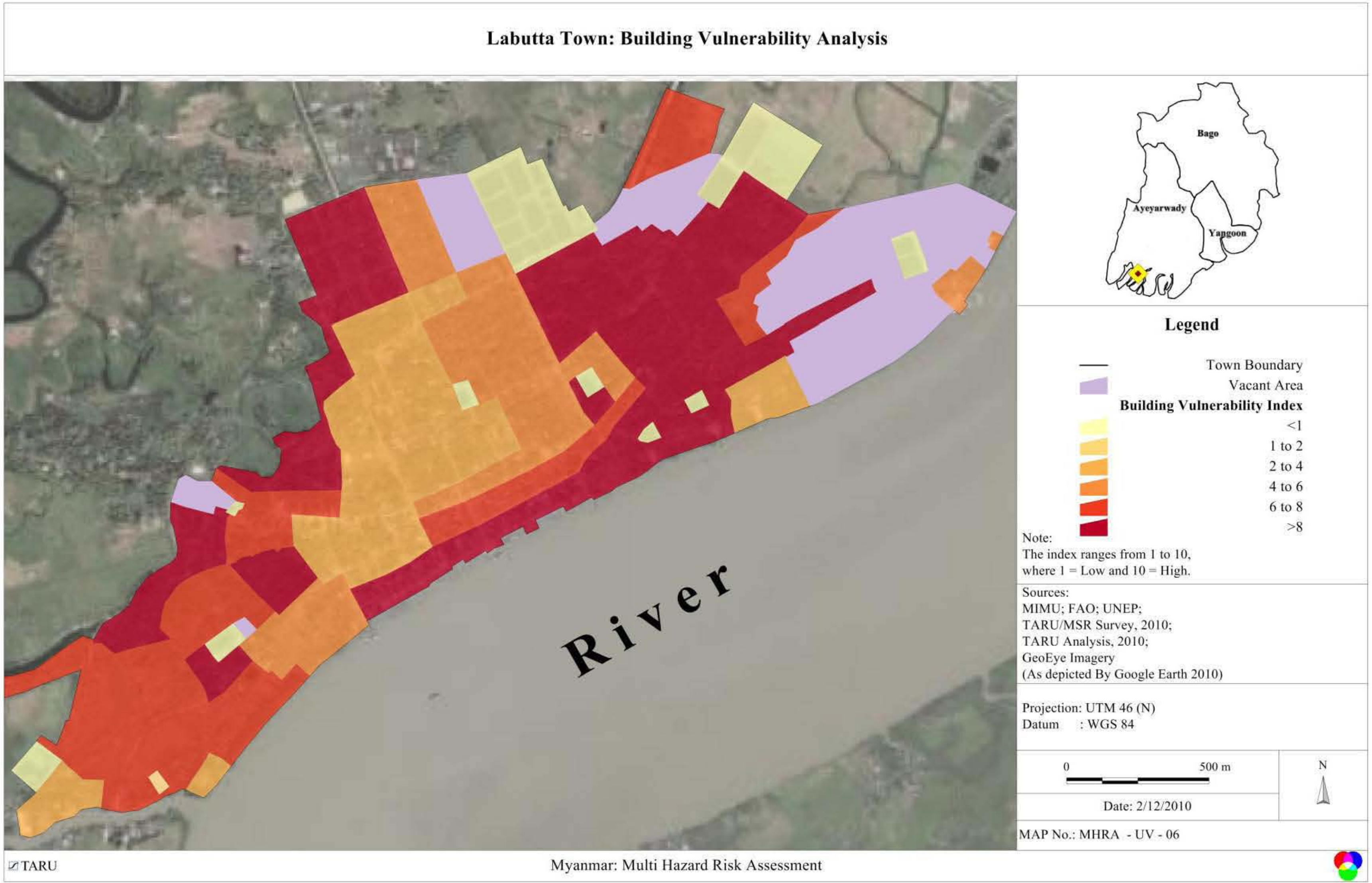


Figure 3-10: Labutta Town Building Vulnerability



Source: TARU Analysis, 2010

3.7 FLOOD AND WATER LOGGING (VULNERABILITY)

Floods and water logging by surge are one of the most common natural hazards faced by many settlements within the delta region in the Myanmar. The flood and water logging vulnerability index captures the vulnerability due to flood in terms of inundation and duration of flooding. The flood and water logging vulnerability index were derived from two-sub indicators i.e.

- Depth of inundation (in meters), and
- Duration of inundation (in days).

Equal weight was assigned to above sub indicators. Flood and water logging index for surveyed towns are presented in Table 3-14.

Table 3-14: Flood and Water Logging Index

Sl. No.	Flood & Water Logging vulnerability Index	Hmawbi	Labutta	Maubin	Myaungmya	Pyapon
1	1-2	70%	-	60%	68%	31%
2	>2-3	-	-	-	-	-
3	>3-4	-	-	-	-	-
4	>4-5	-	-	-	-	-
5	>5-6	-	-	-	-	-
6	>6-7	-	70%	-	-	-
7	>7-8	-	-	-	-	-
8	>8-10	30%	30%	40%	32%	69%
	Total	100%	100%	100%	100%	100%

Total 75 households (15 in each town)

Source: TARU Analysis/MSR Primary Survey, 2010

From the above table, it is evident that the vulnerability of the towns is either too high or too low. The towns of Labutta and Pyapon are highly vulnerable to flooding i.e. around 100% and 70% respectively. Further, the primary survey also indicates that parts of Labutta suffer from floods with an average 2.5 meter height, which lasts for around 80 days in any given year.

Such high vulnerability in these regions may be due to their nearness to coast and possible effects of tides, which may cause repeated or continued flooding. The rest of the towns are also highly prone to the flooding patterns mostly during the rainy season with over 30% of the household suffering on a periodic basis.

3.8 SUMMARY

The urban vulnerability assessment was carried out to address the different facets of risks and quantify the components of vulnerability across the different surveyed towns to inform adaptation framework. The assessment attempted in addressing the vulnerability and capacity issues in the surveyed towns of delta region of Myanmar.

Social aspects of vulnerability in town are very unlike from villages. Networks and reciprocity are usually more fragile and unpredictable due to high fragmentation and heterogeneity of the town population. The capability of individuals or households was assessed based on advanced warning mechanism used in previous hazards, such as human chain.

However, population in towns are highly benefitted by different types of educational intuitions and people who have not had basic education are very low in number and constitute just 5% of population. The results indicate that more than 23% members have education upto 5 years, followed by 50% of people having had 6 to 12 years of education. 21% of the Town dwellers are graduates while postgraduate-professional constitute only about 2%.

Occupations in towns are highly diversified and it was observed that members of household are engaged in different type of occupations and their stability. Nearly 66% are engaged in stable occupation. However, they are very much dependent on contractors, suppliers, employers to find work owing to their lack of marketable skills as well as exposure to frequent hazard events. Subsequently, around 25% are engaged in unstable occupations. Unstable employment usually absorbs household members of low-income settlements. An increase in the level of unstable employment may lead to problems during times of economic downturns including the ones caused by hazards. Highly stable worker are very less constituting to about 9%of the population.

It is very clear from above discussion that social and economic vulnerability/capacity are closely linked to the education, income and occupational diversity that a particular household is able to activate, in terms of both number of household members in the workforce, as well as educational background, skills acquired, health status, age and gender of the household members.

Buildings in urban areas are certainly the most important physical asset that a household can possess. More than 60% of the buildings are constructed using type III materials and therefore it was taken into consideration as physical vulnerability in towns. Analysis results indicate that building vulnerability is high in Hmawbi and Maubin followed by Myaungmya, Pyapon and Labutta in the similar order.

Chapter 4: RURAL VULNERABILITY ASSESSMENT

4.1 INTRODUCTION

Vulnerability assessment describes, who and what is exposed to the threat (hazard identification), and the differential susceptibility (the potential for loss, injury, harm, adverse impacts on livelihoods), and impacts of that exposure. The economy and livelihood of the Myanmar delta region mainly centers on agriculture and fisheries with Rice being the dominant crop. The region is also rich in its forest resources. This has encouraged people to construct their houses using local materials. This was identified as one of the capacity of the region. On the other hand, around 87% of the houses within the delta are constructed using timber, bamboo, thatch or their combination. These houses are highly prone to climatological hazards therefore do contribute to the regions vulnerability. In order to throw light into the on ground situation, apart from analyzing the risk, the goal of this study was extended to analyze some of the indicators which contribute to the regions vulnerability and capacity.

4.2 OBJECTIVES OF THE ASSIGNMENT

The main objective of this section of the study is to assess the vulnerabilities of communities to natural hazards as well as determine their degree of exposure to future events. The studies identify prevalent natural hazards in the delta area and map/assess multi hazard risk that can inform the design of sectoral recovery program and ongoing CBDRM activities in delta region of Myanmar.

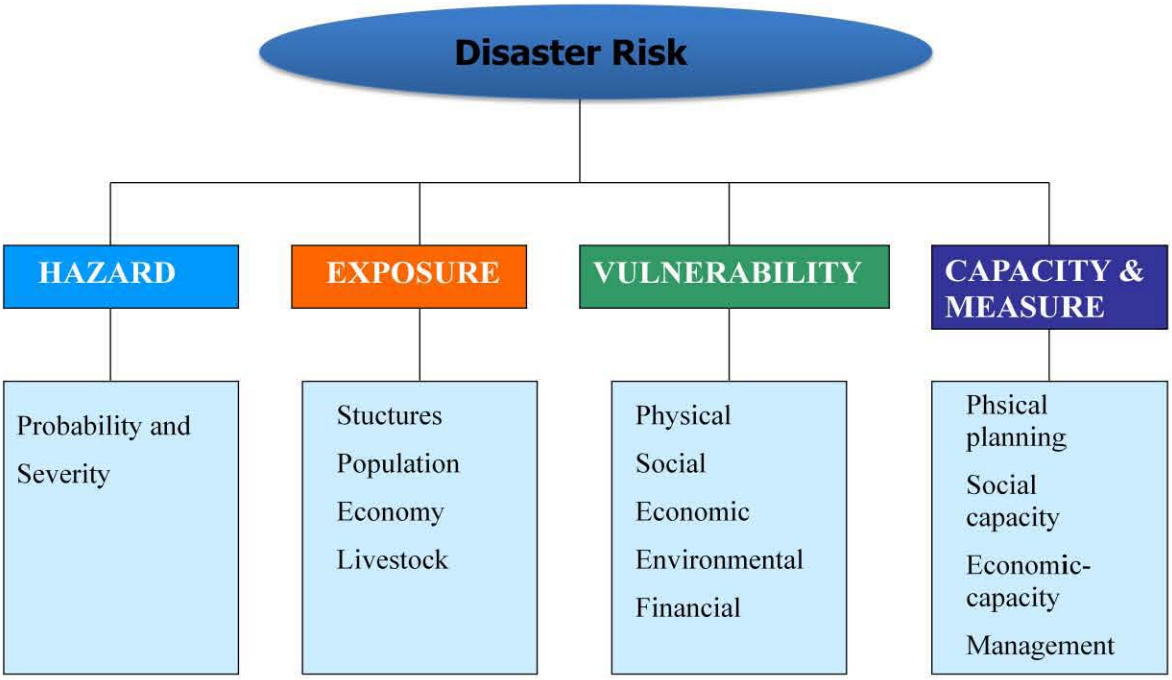
4.3 VULNERABILITY ASSESSMENT

Vulnerability assessment describes a diverse sets of methods used to systematically integrate and examine interactions between humans and their physical and social surroundings. There are few methods for assessing socio-economic vulnerability to multiple hazards. The most common framework for social vulnerability uses three broad sets of parameters: social (community, networks), physical (location, housing types and infrastructure) and psychological (ability to cope with loss) status of households (Anderson & Woodrow, 1989). This approach is inadequate to capture the range of factors that result in differential vulnerability to multiple hazards: *hydro-meteorological, geological and agricultural* origin. In contrast to a global vulnerability and risk assessment which focus necessarily on a very limited number of indicators, the Figure 4-1 shows a local disaster risk index approach using various variables.

The Sustainable Rural Livelihoods (SRL) approach provides a framework for analysis of household capabilities from a more holistic perspective. The ability of a household to cope with and recover from stresses and shocks (arising also from natural hazards) and maintain or enhance its asset base and capabilities, determines the extent of its capacity and resilience.

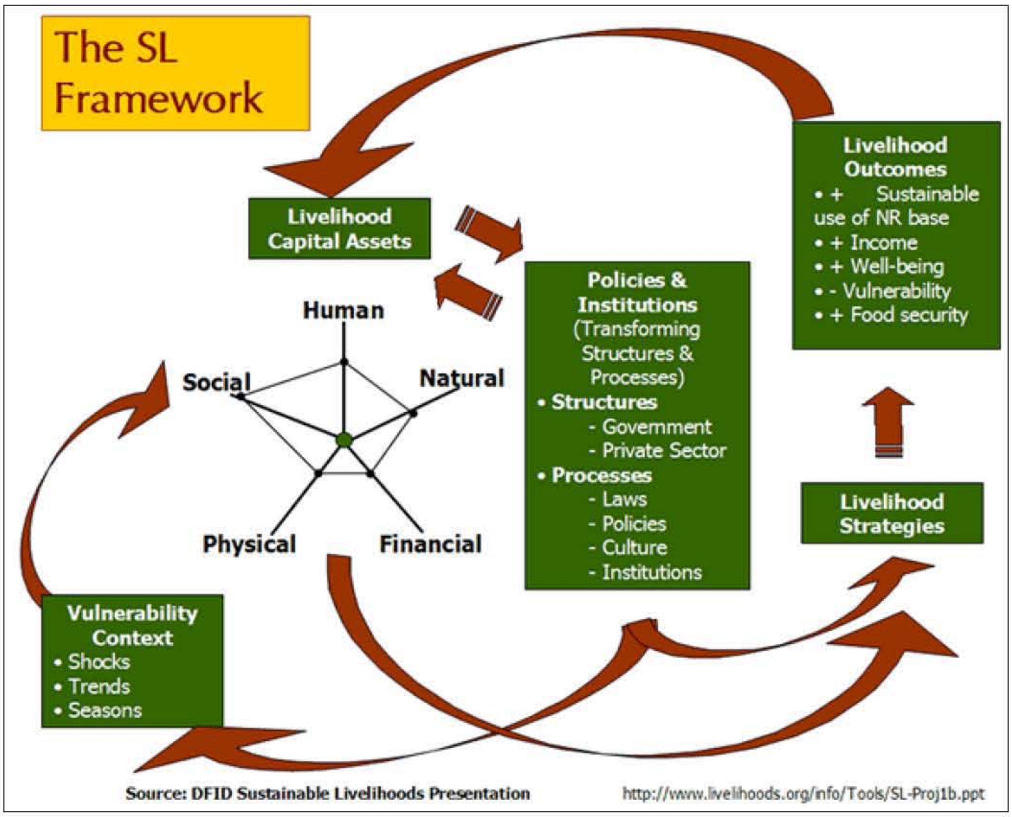
The Capital Assets (CA) of a livelihood comprise Natural, Social, Human, Physical and Financial assets and capabilities. This framework was developed by DFID in response to challenge of commitment to promoting sustainable rural livelihoods and has been used by different donors to develop poverty reduction strategies, but has not been used as a tool for vulnerability assessment in the past.

Figure 4-1: Disaster Risk Index Approach



TARU in several round of analysis (in both urban and rural settings) have referred to the SRL framework and has successfully demonstrated the use of the indicators for Vulnerability Analysis. The five capitals of the SLF Framework are presented in following Figure 4-2.

Figure 4-2: Livelihood Based Framework

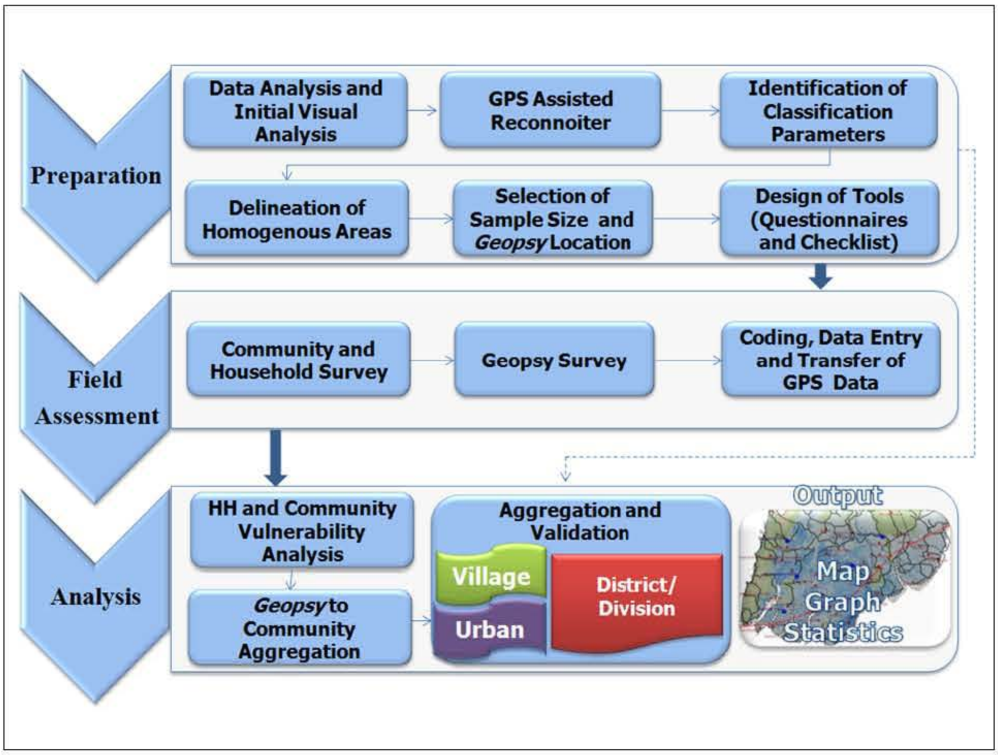


Source: DFID, Sustainable Livelihoods Framework

4.4 VULNERABILITY ASSESSMENT METHODOLOGY

The vulnerability assessment was carried out for elements at risk by hazard intensity based on analysis of historical data, field surveys and recall case studies, using established hazard intensity scale. A sample of 5% of the settlements has been surveyed in detail with a set of tools developed by TARU to get qualitative and quantitative information on different facets of vulnerability. MSR conducted the field level surveys. Methodology framework for vulnerability assessment is presented in following Figure 4-3.

Figure 4-3: Methodology Framework



Source: TARU Analysis, 2010

4.5 SURVEY DESIGN AND DESCRIPTION

Unit of Enquiry and Sample Size of Schedules

The cluster identification for vulnerability assessment (population, community asset, community livelihoods) was carried out including several parameters to select representative sample of the delta region. The settlement selection was done with followings set of criteria:

- Upstream and the downstream settlements in the Delta region (upper / lower delta),
- Size of the agglomeration – small, medium and large towns,
- Location: near and away from the coast,
- Settlements near the small and big streams,
- Settlements which lack basic infrastructure support/near to hazard source, and
- Highly vulnerable settlements.

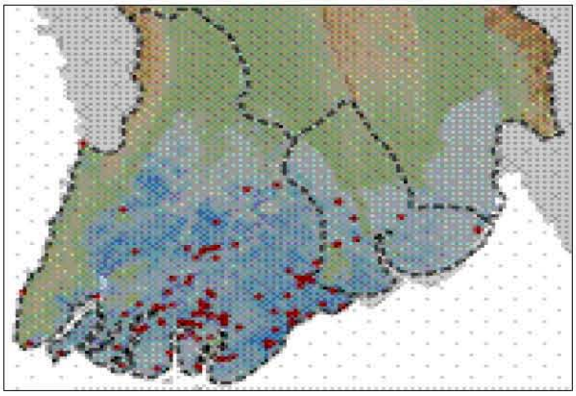
In each settlement, a rapid community level assessment was conducted to select household level sample. This was predominantly based on:

- Prevalent socio-economic classes,

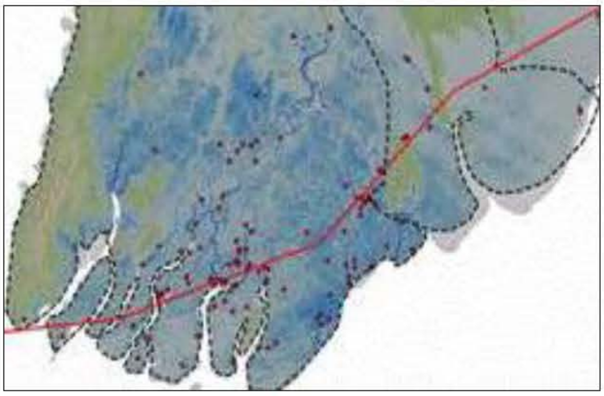
- Livelihood and asset base.

These criteria were shared in the Introductory Workshop on MHRA in Myanmar, organized by UNDP in Feb 2010. GIS based analysis was used to select the villages based on series of criteria (refer Figure 4-4). The selection process and listing of the villages was undertaken with the support of the local partner and was informed to UNDP and key informants during the course of the work schedule (Feb 2010 – June 2010).

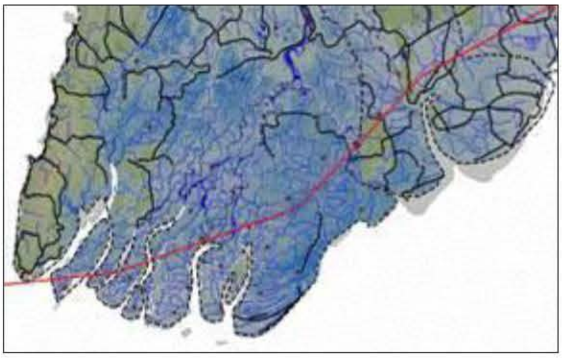
Figure 4-4: Selection of Villages for Vulnerability Assessment Survey



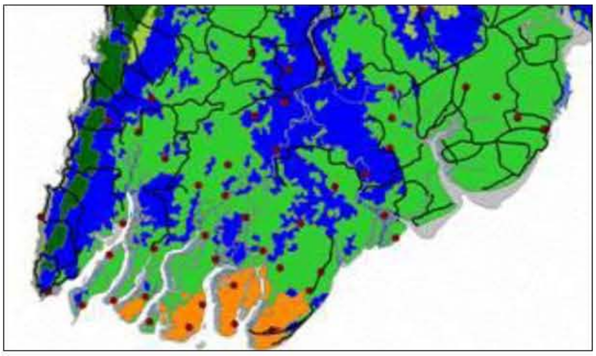
Village Selection <= 3 meters height



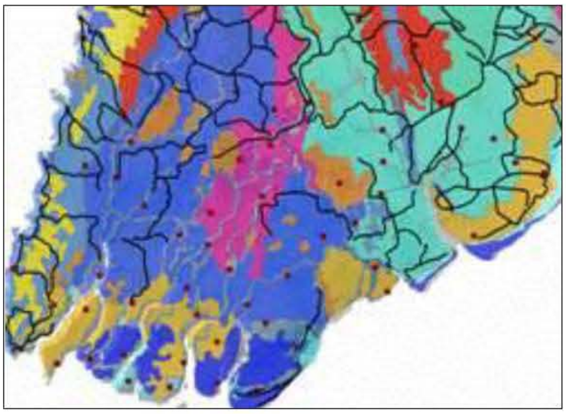
Village selection along Nargis cyclone track



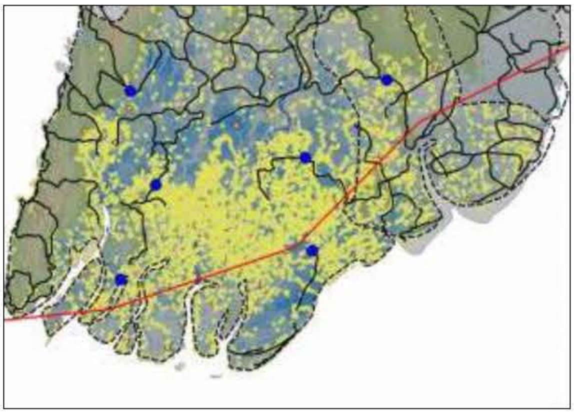
Selection based on proximity to road, river, coast with special inclusion of villages along the Nargis track



Village selection (sub-criteria include land use, land cover, distance to river)



Village selection with respect to soil type



Township selection based on a similar approach used for village selection

Source: TARU Analysis, Feb 2010

The selection of households within each village followed a systematic random sampling method as outlined below:

Step 1: Total numbers of households in the selected village were counted on the field. If a selected village was too big to count the number of households, then, the village was divided into four parts (for example, northern part, southern part, western part, and eastern part) and one of the parts was selected at random to carry out the survey.

Step 2: The total number of households arrived at from step 1 was used to derive the interval (total number / sample size = interval).

Step 3: A starting point of the survey was then chosen based on site feasibility.

Step 4: A random number was generated (between 1 and the selected interval) and was used for the selection of sample households. For example, if the random number is three, the third household from the starting point were selected for the first interview and so on.

For the selection of respondents within each households, the household head or/and mother or/and a household member who can answer most questions about the household were interviewed. Upon the unavailability of such person, the selected household was eliminated from the survey results. Figure 4-5 shows final selected urban and rural settlements.

Figure 4-5: Final Map of Villages and Towns Surveyed

Source: TARU Analysis (February 2010)

TARU's survey was modified to gather information from the field. Primary studies, were conducted by MSR (based in Yangon), by using established participatory methods such as Participatory Rapid/Rural Appraisal to provide qualitative information so as to get a better understanding of the complex linkage between various social and economic conditions that result in the heightened vulnerability of certain social groups. The spatial diversity of the livelihoods has been incorporated in the design of field exercise. Training was imparted to the field researchers along with reconnoiter and field testing was conducted to test and improve tools. Tools such as Transect Analysis, Community and Household level questionnaire and other PRA techniques (seasonal calendar) were used for understanding the vulnerability factors. The tool for VA essentially captures the five key capital assets - *human, social, physical, natural and financial.* Primary data has been collected through the field visits in all 60 identified locations.

The Survey Tools consisted mainly of questionnaires developed specifically to the context of Myanmar/Delta region. The questionnaires consist of several sections aimed to capture the relevant socio-economic data. These tools were developed by TARU and were further improved and screened and customized in vernacular language by MSR. The survey schedules were prepared in Feb 2010 and were introduced to the team of field researchers through a training workshop. The final schedule and the sample size were shared with UNDP Myanmar (February /March 2010). Detailed descriptions of the tools are provided within the Annex C. Table 4-1 summarizes the schedule type, sections and sample size of each type.

Table 4-1: Sample Size of Schedule

Schedule Type	Sections	Unit of enquiry	Total
Village Schedule	Section-1: Village profile	55	55
	Section-2: Schedule of rates	20	20
	Section-3: Crop economics (6 crops)	20	20
	Section-4: Seasonal calendar	20	20
	Section-5: Fishery economics	15	15
	Section-6: Trade/ small business economics	20	20
Rural Household Schedule	Household Schedule	8 households per village	440
Town Schedule	Section-1: Community/Neighborhood Schedule	3 neighborhoods per town	15
	Section -2: Transect Survey	3 transects per town	15
	Section-3: Schedule of rates	5	5
	Section-4: Trade / Small business economics	3 in each town	15
Town Household Schedule	Household Schedule	10 households along each transect	150

Schedule Type	Sections	Unit of enquiry	Total
Industrial Schedule	Industrial Schedule	20	20
Case Studies*	-	10	10

Note: * Case studies examine informal institutional mechanisms or local/indigenous formations existing or experiences shared by the individuals/groups that may have played a crucial role in disaster response, early recovery, coping strategies/adaptation measures that has enhanced and strengthened the communities/individuals. As part of overall resilience building strategy, such stories/cases were suggested to be captured during the conduct of the survey so as to create hope among other communities within the delta.

4.6 MEASURING VULNERABILITY AND CONSTRUCTING INDICES

Developing a universal indices or measurement tool for vulnerability assessments across all disciplines is challenging given the ever-present definitional ambiguity along with the dynamic nature and changing scale of analysis (temporal and spatial). However, there has been a shift from more qualitative work centered on conceptual models and frameworks to more quantitative or empirical measures and approach of vulnerability.

The Sustainable Livelihoods Framework defines vulnerability in terms of five parameters namely; natural, social, financial, physical, and human capital (Chambers and Conway, 1992).It is an approach used to design development interventions at the community level. This framework has proven useful for assessing the ability of households to withstand shocks such as natural hazards or epidemics.

The indicators and their parameters were selected based on the followings set of criteria:

- Preliminary Observation: a preliminary round of observation of community and households level data set provides an opportunity to understand the variability of datasets of primary survey. In the preliminary round, for each indicator, questions were prepared and parameters were selected to get appropriate answer for the same.
- Variation Level in Parameters:

  Low variation, even distribution, High variation
- Usability of Selected Indicators and Parameters for Geopsy Method,

Final selected indicators, their parameters, weightage assigned and specific comments are presented in Following Table 4-2.

Table 4-2: Final Selected Indicators for Analysis

Indicator	Parameters	Weightage	Comments
Location (Vulnerability)	Population in village, and Location of Village	Low weightage to hilly and flat villages(low vulnerability to hydro-met disasters) , where as high weightage to island and Coastal villages	Population on island, along coast and river bank are exposed to location vulnerability compare to flat or hilly location

Indicator	Parameters	Weightage	Comments
Accessibility (Vulnerability)	Type of road, and Accessibility of Road	Low weightage to Tar road and accessible in all months, whereas high weightage to mud road and seasonal roads open only during non rainy months.	In case of any natural hazard, will residents be able to reach at safe place or nearest hazard shelter in worst weather conditions or any external support can help villagers in village on time.
	Distance from Boat, and Accessibility of Boat	Low weightage to accessibility by boat at village and accessible throughout the year, whereas weightage increase according to distance (10 weight to distance > =4 km) and not accessible in any given month.	
Flood Inundation (Vulnerability)	Depth of inundation during last floods and duration of inundation	Increase with depth and duration of flooding/storm surge	Provides a snapshot of flood/water logging/surge events faces by HH and drainage conditions
Social Network (Capacity)	No. of Social Groups in Villages and Member (in % of total population)	Low weightage to no group in village and no membership. Whereas weightage increase as with number of groups and memberships in village	Capacity to access the network critical in group level resilience
Education Level (Capacity)	Maximum Education in HH and aggregated as average community level	Low weightage up to 5 years education, then increase rapidly with 10 for postgraduate/ professional	Higher levels of education increases capacity to earn, to understand the CBDRM programs and also help next generation to benefit from education
Income Stability (Capacity)	Per capita income, more than 1 working member in HH, Stability of Income (Highly stable, stable and unstable income) and dependency ratio	Equal weightage to all four parameters	Income stability provides resilience during disasters, and ability to invest in adaption
Natural Capacity (Capacity)	Agricultural land/HH, % HHs with land>1 Acre Boats across sample HHs, Average boat per household.	Natural capacity index, Based on Land and fisheries	Higher level of natural capacity shows availability of natural resources and ownership pattern

4.7 ELEMENTS AT RISK

a) ***Physical elements***: housing, community asset, critical buildings and social infrastructure

b) ***Socio-economic elements***: various categories of population, especially the economically and socially vulnerable *(landlessness)*.

c) ***Economic elements***: economic vulnerability of households and small businesses, productive assets and activities esp. agriculture, fisheries, poultry, livestock, craft, industry and other livelihoods, employment and income.

4.8 VULNERABILITY ANALYSIS

The vulnerability assessment methodology have been established from a multiple series of disaster and vulnerability assessments undertaken by TARU over past two decades (earthquake damage assessment studies/flood damage assessment studies/cyclone and wind damage assessment studies/storm surge damage assessment studies).

4.8.1 Physical Vulnerability

The primary challenge to physical vulnerability assessment in Delta Region is that overwhelming proportion of structures/housing is non-engineered or partially engineered. Damage records indicate that buildings erected in conventional materials also behaved as partially engineered structures as observed in the damage reports. Vulnerability assessment of the housing stock was carried through the combination of roof-wall type and vulnerability curves for broad types were built using TARU datasets and secondary sources. Since more than 90% of the houses are of biomass, even the winds less than 30 m/sec can damage the houses in open areas. Most of the surviving houses were located in the wind shadow zones. Therefore the physical vulnerability (housing) in the rural areas are uniform throughout the study area.

Table 4-3: Distribution of Types of Rural Houses Across 55 Sample Villages (% of Location Types)

Location	Coast	Flat Land	Hilly	Island	River Bank	All samples	Sample Size
Brick walls - RCC Roof	0%	0%	0%	0%	1%	0%	52
Brick wall & Tin/ ACC sheet Roof	1%	13%	0%	0%	15%	13%	1,549
Brick Wall-Tile Roof	0%	0%	0%	0%	0%	0%	1
Brick Wall- Biomass Roof	0%	1%	0%	0%	0%	1%	85
Wood/Bamboo Wall-/ Tin/ ACC sheet Roof	48%	26%	4%	0%	27%	27%	3,282
Wood/Bamboo Wall-Biomass Roof	50%	60%	96%	100%	58%	59%	7031
Total	100%	100%	100%	100%	100%	100%	12,000

Source: TARU-MSR Survey, 2010

Table 4-3 shows that out of all sample villages about 86% of the houses are made of Biomass walls and highly vulnerable roofs (Biomass, tin, ACC sheets), which cannot even withstand wind speed of 33-40 m/Sec wind speeds (Safir Simpson Scale 1). In the absence of any strengthening measures, tiles, ACC sheets and tin sheet roofs also are very vulnerable.

4.8.2 Location based Vulnerability

Locational vulnerability analysis is an assessment of linkages (such as road, river and coast) which can enable timely and safe evacuation of population at risk during or before the hazard incidence. The analysis was conducted considering the minimum distance (i.e. proximity) one has to travel (average walk time for able bodied) to reach evacuation linkages. Locational vulnerability analysis in this study considered the following linkages:

- Minimum distance from road (all weather roads),
- Minimum distance from river network,
- Minimum distance from coast, and

The topography of the region predominantly consists of low elevation flat terrain with many interweaving distributaries of Irrawaddy River leading to sea. The West and Northern part of the study area is highly forested. The settlements are mostly located in three types of environments; coastal, river banks and interior flat lands. The coastal and river side settlements are at higher risk to floods and storm surges, while, the flat lands are relatively less prone. The distribution of settlements based on MIMU village point data base is presented in the following Table 4-4.

Table 4-4: Distribution of Population Across Different Types of Villages

District	Coastal	Flat land	River Banks	Total
Hinthada		12%	4%	16%
Labutta	1%	5%	1%	7%
Maubin		8%	2%	10%
Myaungmya	0%	6%	2%	8%
Pathein	1%	12%	3%	15%
Pyapon	1%	7%	2%	10%
Yangon (East)		0%	0%	0%
Yangon (North)		12%	6%	18%
Yangon (South)	1%	12%	2%	15%
Grand Total	**4%**	**74%**	**22%**	**100%**
Total population: 10.92million				

Source: TARU Analysis (2010), MSR primary study, MIMU village location maps

The table indicates that about three fourths of all population resides in either flat land or along minor creeks. These regions are at relatively low risk to floods and storm surges compared to river bank and coastal areas.

The result of locational vulnerability of rural settlements are presented in the Table 4-5 and Table 4-6. The result indicates that locational vulnerability is highest (31%) in Yangon (North) district. The district lies over hilly terrain where settlements are far away from all weather roads, river and coast. Lowest location vulnerability was observed in Labutta district.

Table 4-5: Location Vulnerability of Villages in Study Area

District	Total villages	Vulnerable villages	% vulnerable villages
Hinthada	280	69	25%
Labutta	977	9	1%
Maubin	479	73	15%
Myaungmya	858	60	7%
Pathein	551	41	7%
Pyapon	1262	143	11%
Yangon (East)	8	-	-
Yangon (North)	299	92	31%
Yangon (South)	678	130	19%
Grand Total	**5392**	**617**	**11%**

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO.

Table 4-6: Location vulnerability of rural population across the study area (in 1000s)

District	>0-2	>2-4	>4-6	>6-8	>8-10	Grand Total
Hinthada	818	531	198	76	118	1,741
Labutta	745	49	6	-	-	800
Maubin	749	143	75	32	98	1,097
Myaungmya	693	167	54	9	1	924
Pathein	1,200	304	100	57	8	1,669
Pyapon	806	168	77	42	31	1,124
Yangon (East)	14	-	-	-	-	14
Yangon (North)	1,038	330	409	76	80	1,933
Yangon (South)	887	444	182	55	32	1,600
Grand Total	6,950	2,136	1,101	347	367	10,923

Note: 10 highest vulnerability

Source: TARU Analysis (2010), MSR primary study, MIMU, FA.

The analysis indicates that nearly 64% of the populations in the study area are very low vulnerable (index value of 0 to 2), whereas nearly 3% of the populations are very highly vulnerable (index value of >8 to 10) to flood and storm surge risks. This is largely due to high population density in the middle delta region where inhabitants have at least one mode of safe evacuation. Districts which lie in hilly region are more vulnerable due to less proximity to road, river and coast.

The Delta's economy depends heavily on rice production, which accounts for 65% of Myanmar's total rice production. The Storm surge risks are high in the saline areas compared to the mixed and fresh water regions which are situated in the interior of the delta. The saline zones are single crop areas and therefore events of storm surge can result in loss of at least one year's farm income, on which more than three fourth of the population/livelihood depends upon. The population located in different zones is presented in the Table 4-7.

Table 4-7: Population residing in different agricultural zones (in 1000s)

District	Fresh	Mixed	Saline	Grand Total
Hinthada	1,327	416	-	1,743
Labutta	134	263	403	801
Maubin	736	363	-	1,099
Myaungmya	316	610	-	926
Pathein	180	1,453	37	1,671
Pyapon	42	624	459	1,126
Yangon (East)	14	-	-	14
Yangon (North)	1,936	-	-	1,936
Yangon (South)	1,145	69	387	1,603
Grand Total	5,833	3,801	1,288	10,923

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO Township database (1998-2002).

About 10% of the populations residing in Saline zone are prone to storm surge risks, which can cause damage to at least one year's farm outputs, especially if the cyclones occur in the early monsoon period. The storm surge event can also affect the productivity for up to two years (if cyclone occurs at the end of monsoons). The severe storm surges like the one experienced during Cyclone Nargis, can have an impact extending till the intermediate zone (North of delta). The Table 4-8 shows the reported loss at district level.

Table 4-8: Agricultural crop loss reported across districts from Sample study (%)

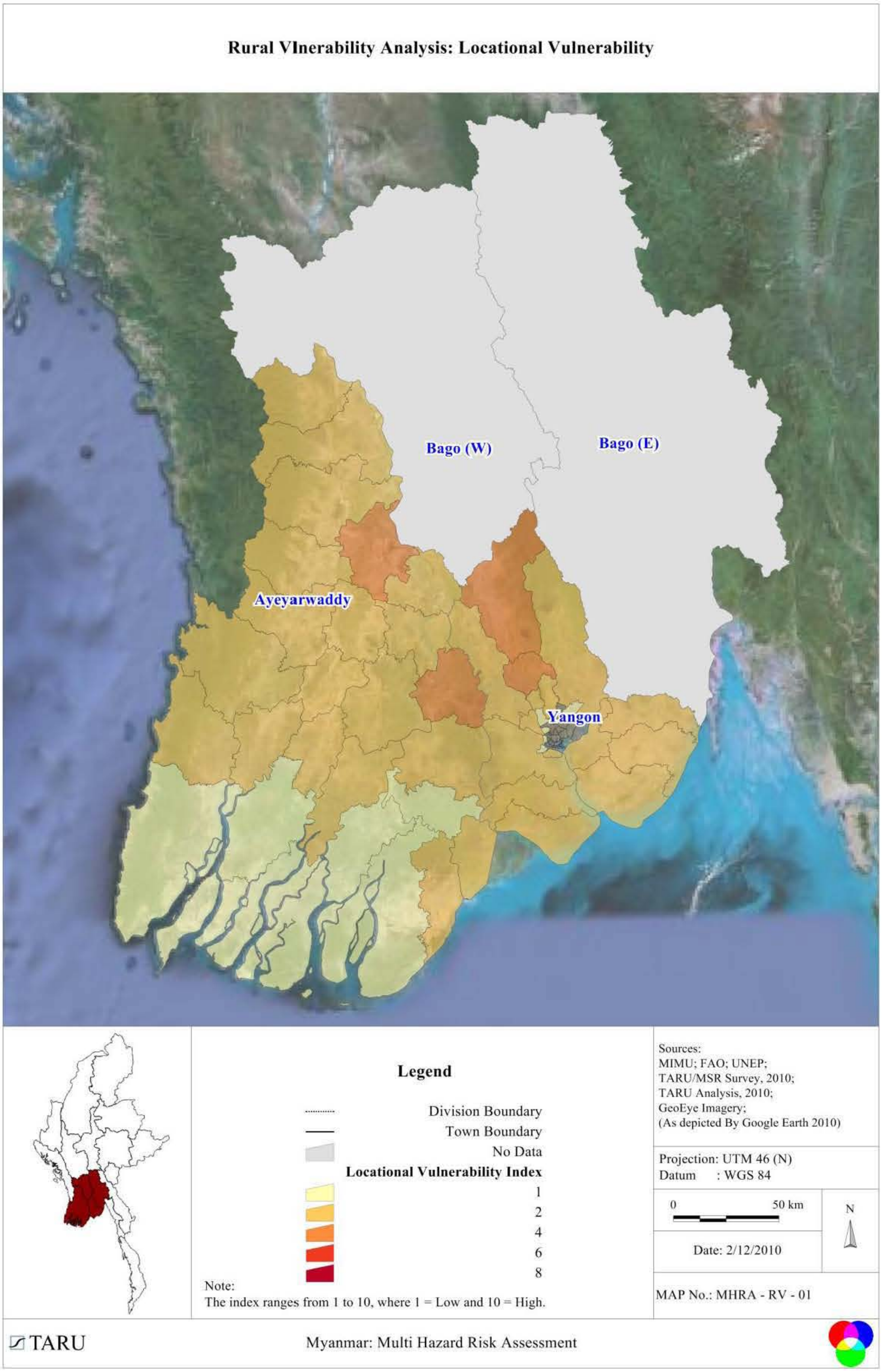
District	Average loss (%)	Maximum loss (%)
Labutta	57	100
Maubin	47	100
Myaungmya	24	75
Pathein	23	50
Pyapon	73	100
Yangon (North)	17	100
Yangon (South)	28	100
Total	**42**	**100**

Source: TARU Analysis (2010), MSR primary study

Cyclone Nargis occurred during the pre-monsoon season, the damage was a combination of loss to summer and plantation crops as well as storm surge damaging the land for the monsoon season crops.

Figure **4-6** indicates the locational vulnerability of the study area.

Figure 4-6: Locational Vulnerability Analysis



4.8.3 Accessibility based vulnerability

Boats are mainly used for human as well as material transport. This can be mainly due to the reason that road construction is costly due to high ratio of bridge length to total road length. Further, the maintenance costs of infrastructure are high due to floods and soil conditions. Therefore only the major towns are connected by the roads in the Ayeyarwady delta. Most of the material transport (e.g. ice, fish, food grains) to the towns and rural areas are done using the water transport system. This is one of the major reasons for most of the settlements being located along the river. Most of the river side settlements have boats for both personal transport and for fishing (livelihood). With the availability of cheap Chinese made engines; a majority of boats are mechanized with local technical support. Availability of boats and road transport is critical for both evacuation as well as relief activities after any disaster. Therefore one of the vulnerability indicators was chosen was the availability of transport facilities.

The accessibility vulnerability indicator was derived from the distance to boat landing points from the village, seasonality of boat availability, type of road (if available), and seasonality of road connectivity. The minimum of road and boat access was used as the Accessibility vulnerability indicator. The score of 10 indicates least accessibility while score of 1 indicates all season availability of either road or boat. The results are presented in the Table 4-5.

Table 4-5: Distribution of Population Across Average Accessibility Indicators and Districts (% of total district population)

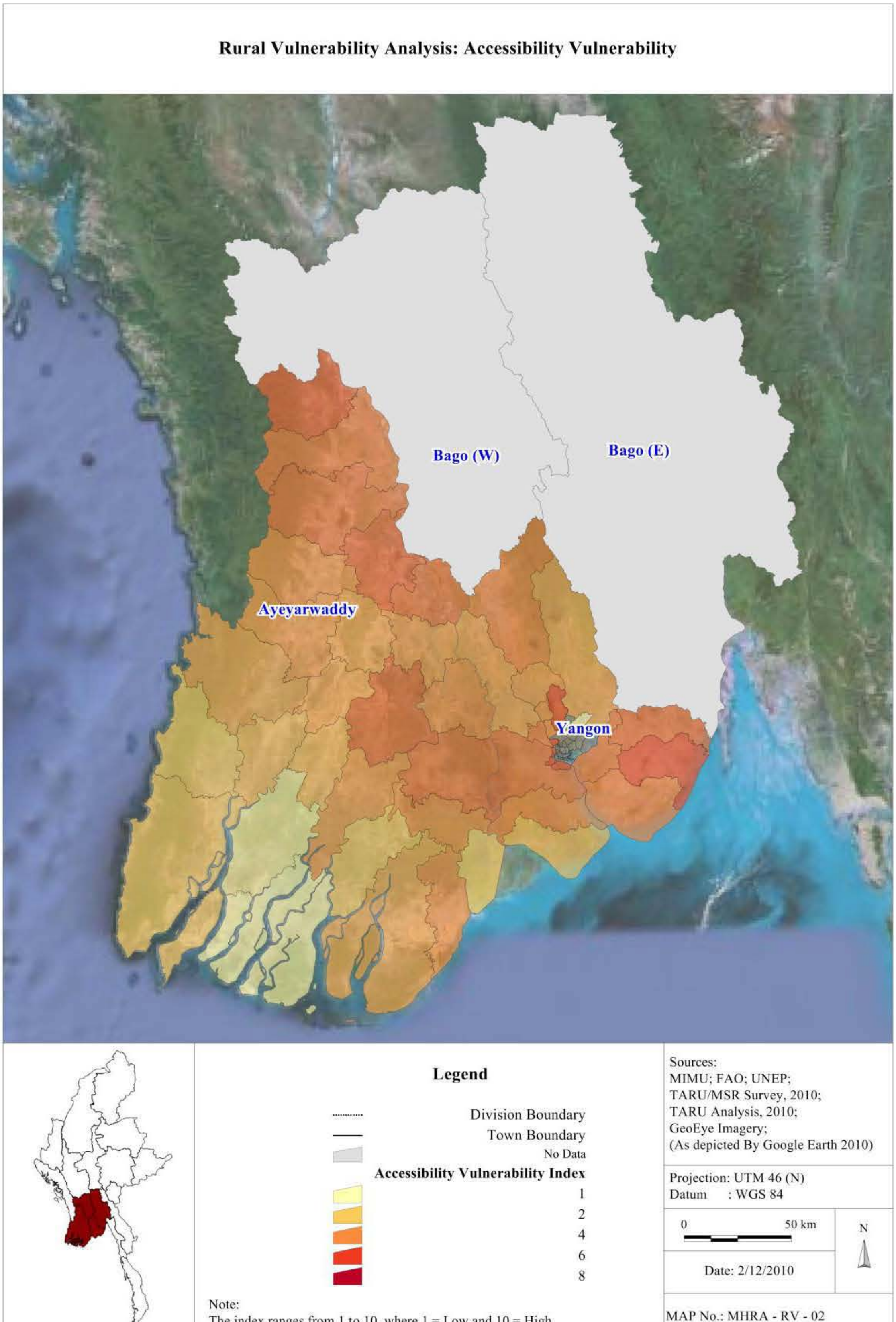
District	1 to 2.5	2.5 to 5	5 to 7.5
Hinthada	8%	22%	71%
Labutta	81%	8%	10%
Maubin	22%	14%	64%
Myaungmya	51%	28%	21%
Pathein	42%	41%	17%
Pyapon	50%	10%	40%
Yangon (East)	100%		
Yangon (North)	25%	24%	51%
Yangon (South)	14%	21%	65%
Total population	32%	23%	46%

Note: 10 indicates least accessible

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO.

The table indicates that nearly half the population currently has fairly good accessibility either by boat or road. The populations with 5-7.5 scores have access to only seasonal mud roads or water transport. Most of the mud roads in delta are accessible during fair weather only with insufficient bridges and culverts, especially across paleo-channels that get inundated during rainy seasons. Some of the streams are seasonal, especially in the upper delta and there are no regular boat services even during rainy seasons. Such villages have to heavily rely on roads away from the villages. Further, some of the areas are located in the hilly regions where road accesses are also poor. Figure 4-7 illustrates the accessibility index within the study area.

Figure 4-7: Accessibility Vulnerability Index



4.8.4 Flood vulnerability

Floods and water logging are common problems in the delta. Heavy rains in flat terrain can result in pluvial floods and fluvial floods resulting from upstream rainfall. Many settlements located along the closed paleo-channels (observed as oxbow lakes and swamps) with no outward drainage can be subjected to prolonged inundation during the rainy seasons.

The flood and inundation vulnerability was derived from the reported incidences of floods and water logging from the primary survey. About 50% of the sample villages reported flooding at least once during the last decade. About 35% of the sample villages also reported water logging which occurs seasonally (every year). The water logging may not affect the settlement, but may affect parts of agricultural lands.

The flood vulnerability index (exclusive of Nargis) was derived from the reported flooding as well as the duration of reported floods. This was done to exclude rare events like Cyclones. A score of 1 indicates no flooding and 10 indicate flooding upto depths of more than 10 feet for about 10 days or more, with a frequency of at least once in the last decade.

The sample based flood index data was extrapolated on MIMU village data by transfer to neighborhood villages based on type of similar type of environments. The results are presented in the following Table 4-6.

Table 4-6: District wise Average Flood Inundation Index Across Households

District	1 to 2.5	2.5 to 5	5 to7.5	7.5 to 10
Hinthada	75%	-	5%	20%
Labutta	14%	8%	40%	38%
Maubin	34%	0%	39%	27%
Myaungmya	14%	24%	59%	3%
Pathein	40%	1%	21%	38%
Pyapon	3%	-	15%	82%
Yangon (East)	-	-	100%	-
Yangon (North)	70%	17%	8%	6%
Yangon (South)	53%	1%	44%	2%
Grand Total	44%	6%	25%	25%

Note: 10 indicates most flood prone

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO.

The analysis indicates about 25% of the population in the study area is vulnerable to severe flooding, while nearly half the population are least vulnerable to flooding. Most of the houses in the rural delta region are stilted, which is an evidence of flood losses. The decay of wooden stilts is one of the possible reasons for house collapse during hazard events (e.g. cyclonic winds).

Table 4-7: Proportion of Houses With Stilts

District	0.3-0.4	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Labutta	-	5%	1%	20%	17%	57%
Maubin	-	-	-	-	-	100%
Myaungmya	-	-	-	-	-	100%
Pathein	-	-	-	-	-	100%
Pyapon	-	-	-	-	9%	91%
Yangon (North)	37%	-	12%	15%	-	36%
Yangon (South)	-	-	-	11%	6%	83%
Grand Total	16%	1%	5%	12%	5%	61%

Sample size: Total houses 12,287 houses across 55 villages

Source: TARU Analysis (2010), MSR primary study

Average stilt heights among the surveyed samples were 1 m (3 feet) with maximum of 1.2 m (4 feet). After the Cyclone Nargis, few donor agencies have provided concrete stilt blocks to increase the life of these wooden stilts. The agricultural losses from floods are mostly from single crop. This crops loss can result in scarcity up to a year, in case of saline and coastal farmers, who grow single crop. Another major element at risk is livestock. The extent of damage depends on the intensity of the floods. Cyclone Nargis caused severe losses to live stock. The losses across the sample villages in terms of house damage is indicative of both wind and inundation damagers, which is difficult to disaggregate after two years of the disaster. Indicative house damage across the sample villages provides a glimpse of the house vulnerability as presented in the following Table 4-8.

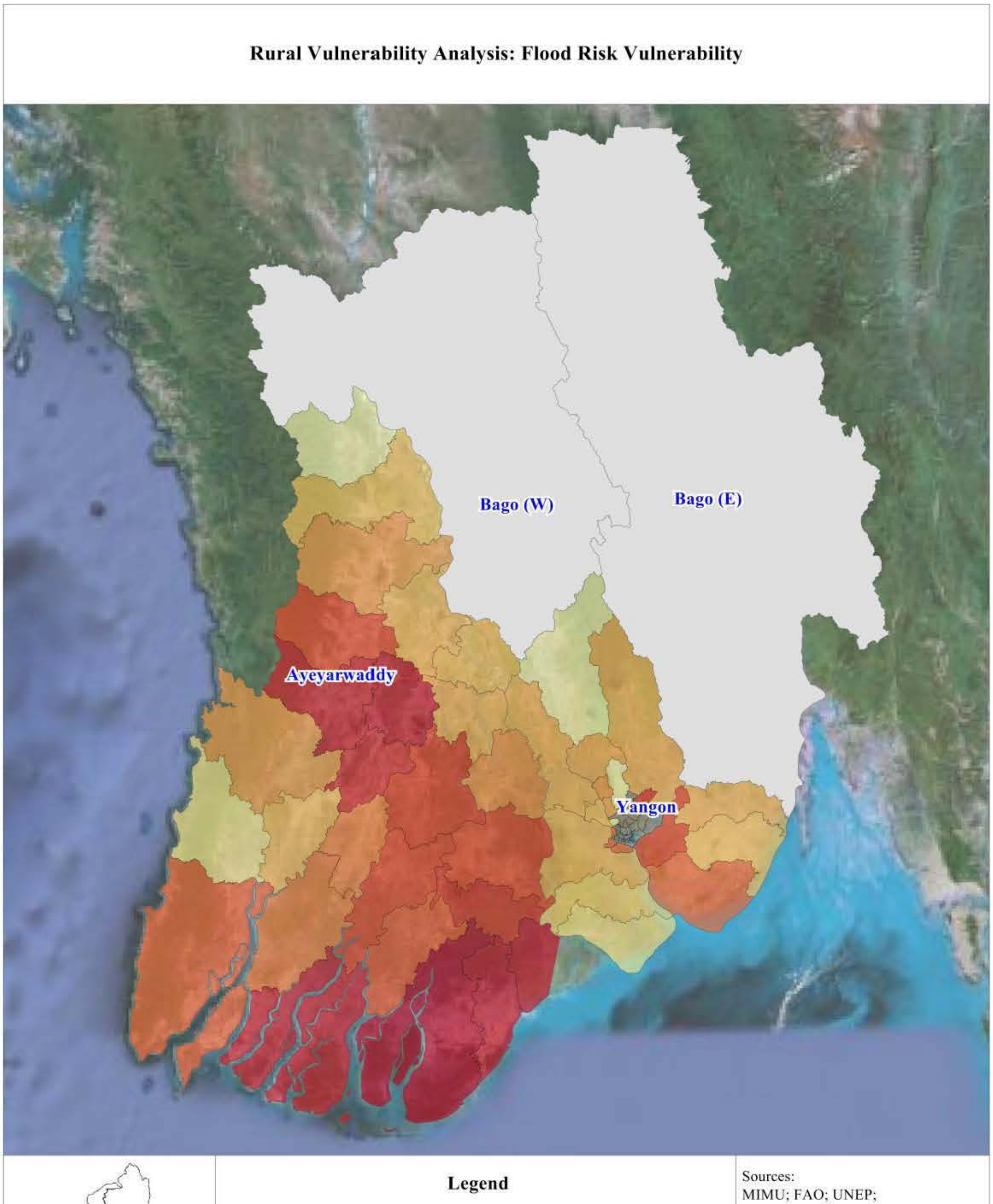
Table 4-8: Proportion of Houses Damaged Due to Floods or Storm Surges During Last Two Decades

District	Damaged houses (% of total houses in the village)				Total Sample villages
	1 to 25	>25 to 50	>50 to 75	>75 to 100	
Labutta	5	-	-	9	14
Maubin	1	1		-	2
Myaungmya	2	2	1	1	6
Pathein	1	-	-	1	2
Pyapon	-	-	-	11	11
Yangon (North)	-	1	-	1	2
Yangon (South)	-	-	-	2	2
Grand Total	9	4	1	25	39

Total sample villages-55 (14 villages no damage reported from floods/Storm surge)

Source: TARU Analysis (2010), MSR primary study

Figure 4-8: Flood Risk Vulnerability Index



The analysis shows bias towards Nargis related damage, where most of the damage was reported, which may include wind damage. Nargis alone accounted for 26 of the 39 villages that reported house damages in flood/storm surge affected areas. Figure 4-8 is to illustrate the flood vulnerability within the study area.

4.8.5 Income Capacity

In rural Delta region, the paddy cultivation and fisheries and agricultural labor are the main sources of livelihoods. Other livelihoods include labor in salt pans and migration. Table 4-9 illustrates the land holding distribution pattern. The results from survey indicate that the land holding distribution is skewed.

Table 4-9: District Wise Effective Agricultural Land Holding Distribution

District	Landless	>0 to< 1Acre	>1-2.5 Acre	>2.5- 5 Acre	>5-10 Acre	>10-20 Acre	>20 Acre	Total Households
Labutta	82%	1%	2%	1%	5%	5%	3%	2,012
Maubin	68%	-	2%	5%	12%	8%	5%	657
Myaungmya	56%	-	1%	8%	19%	12%	3%	213
Pathein	45%	6%	9%	12%	15%	10%	4%	755
Pyapon	76%	-	1%	3%	7%	10%	3%	1,482
Yangon (North)	81%	5%	2%	4%	4%	3%	1%	5,189
Yangon (South)	68%	1%	4%	2%	10%	10%	5%	1,979
Total sample	75%	3%	3%	4%	7%	6%	3%	12,287

Note: Total sample villages- 55. Data obtained from community survey within these villages.

Source: TARU Analysis (2010), MSR primary study

The results indicate that more than ¾ of the households in the sample villages are landless and have to rely on labor or fisheries or other non-steady livelihoods. Considering the single crop based agriculture in saline areas, the instability of income is a major issue in these rural regions. The livelihoods across the sample villages are presented in the Table 4-10.

Table 4-10: District wise Household Livelihood

Activity	Labutta	Maubin	Myaungmya	Pathein	Pyapon	Yangon (North)	Yangon (South)	All samples
Agriculture	14%	32%	57%	58%	29%	21%	33%	27%
Fisheries	39%	32%	13%	12%	24%	0%	2%	12%
Labor	41%	34%	30%	29%	43%	57%	59%	50%
Handicrafts	-	-	-	-	-	1%	5%	1%
Animal husbandry	0%	-	-	-	0%	2%	-	1%
Salt Industry	0%	-	-	-	-	-	-	0%
Trade	4%	2%		1%	3%	17%	2%	9%
Services*	0%	-	-	-	-	1%	-	1%
Total households	2,012	657	213	755	1,528	5,143	1,979	12,287

Note: Total sample villages- 55. The results are % of total samples across districts.
*Services include (Jobs, Transportation)

Source: TARU Analysis (2010), MSR primary study

The results indicates that fisheries is an important activity in some districts (coastal as well as inland fisheries), while labor accounts for one third to two thirds of the livelihoods. The secondary and tertiary sector is weak, therefore any damage to agriculture and fisheries are going to affect more than 90% of the households. Migration is an important source of livelihoods for about 5- 15% of the households as shown by the analysis of 55 sample villages. There are no reported out-migrants from Pyapon district sample villages, while the highest out-migration was reported from Pathein district. The results are presented in the Table 4-11.

Table 4-11: Outmigration pattern reported from sample villages

District	Number of Whole Families migrating	Families with Only working members migrating	Total HHs in the sample
Labutta	1%	5%	2012
Maubin	2%	11%	657
Myaungmya	0%	11%	213
Pathein	2%	14%	755
Yangon (North)	0%	5%	5403
Yangon (South)	2%	4%	1979
All samples	1%	6%	11019

Note: Total sample villages- 55

Source: TARU Analysis (2010), MSR primary study

The analysis indicates that the outmigration is important only for about 5- 15% of the households based on sample village studies. The remittances are important especially for the households migrating out of the country. About two third of the remittances are from migrants working outside the country. Income capacity index was derived based on the per capita incomes, stability of the incomes, dependency ratio and number of workers per family. The results of the analysis using Geopsy method is presented in the Table 4-12.

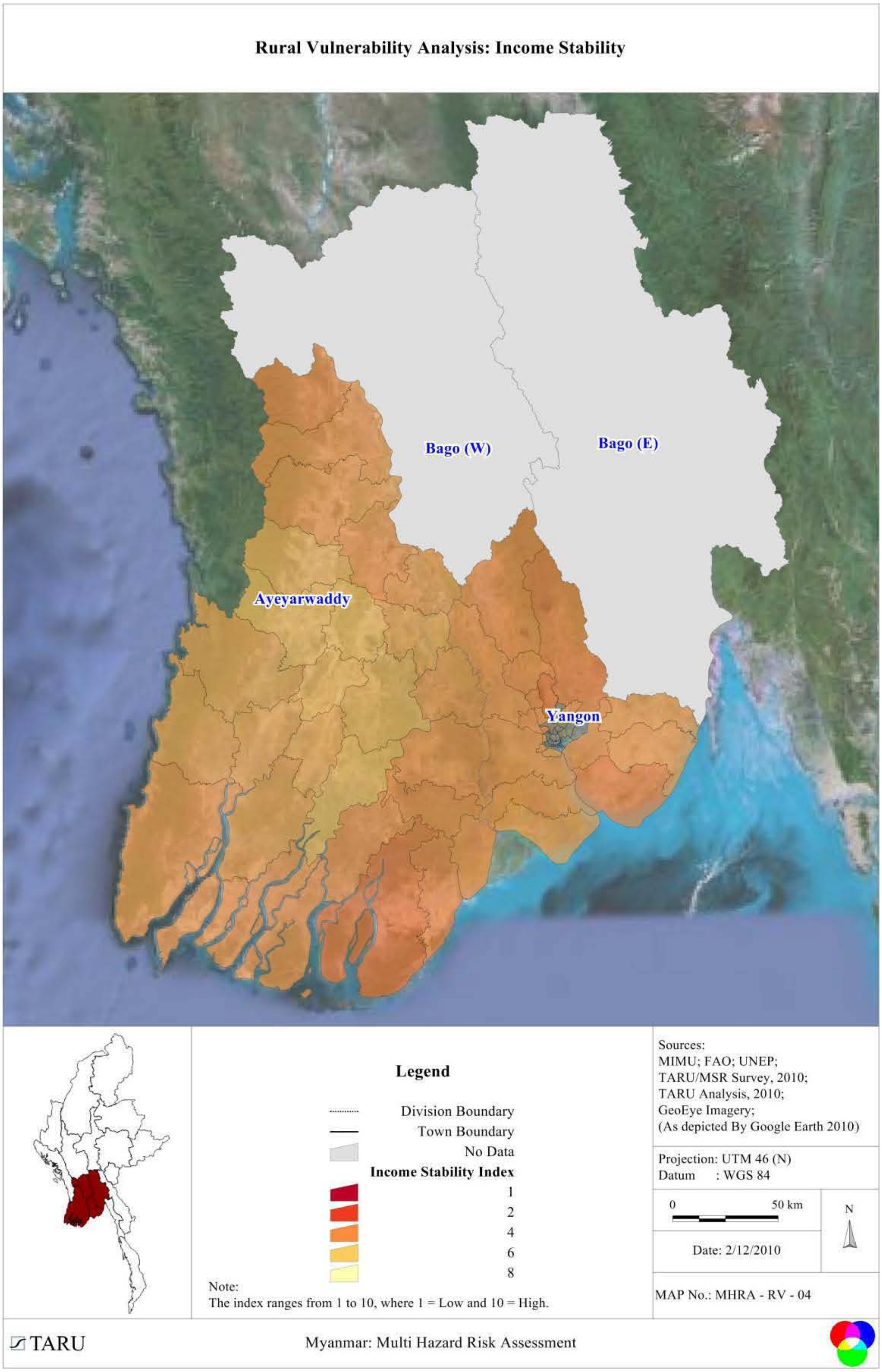
Table 4-12: Population Distribution Based on Average Income Capacity Index

District	>2-3	>3-4	>4-5	>5-6
Hinthada	-	65%	10%	25%
Labutta	8%	22%	42%	27%
Maubin	-	31%	28%	41%
Myaungmya	-	9%	38%	53%
Pathein	-	7%	40%	53%
Pyapon	4%	81%	14%	1%
Yangon (East)	-	-	100%	-
Yangon (North)	-	58%	42%	-
Yangon (South)	-	25%	75%	1%
Grand Total	1%	39%	37%	23%

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO.
Note: 10 indicates highest capacity. The results are % of Total District Population.

Income capacity is low to medium across most of the districts. Myaungmya and Pathein districts exhibit best income capacity with half of the population having index in the range of 5-6. Pyapon district exhibits the lowest income capacity index with about three fourths of the population exhibiting 3-4 income capacity indexes and one percent exhibiting more than 5. The ranges of indicators within the study villages show much higher distribution. The land holding distribution is highly skewed with 50% to 80% of the households being landless. More detailed studies are necessary to understand the income vulnerability, which is beyond the scope of this study. Figure 4-9 illustrates the income capacity index within the study area.

Figure 4-9: Income Capacity Index



4.8.6 Education Capacity

As reported earlier section, the primary activities (agriculture/aquaculture/fisheries) are the main source of income in most of the rural delta region. Also poor transport and communication connectivity are major issues in rural areas. Basic education is accessible to the majority of the population within delta region, but higher education is inaccessible or unaffordable for the most. The education infrastructure is poor and the colleges are far away from the rural areas and the students have to stay in the towns even for accessing secondary education. Low incomes, lack of work opportunities in service sector also restricts the incentives for opting for high education. The distance of middle schools from sample villages provide is an evidence of distance being a constraint to education. On an average, it takes more than two hours per trip to access schools which are more than 5 km away. Table 4-13 indicates the accessibility of middle schools within different districts.

Table 4-13: Distribution of Distance of Villages from Middle Schools

District	In the village	<3 km	3-5 km	5-10 km	>10 km
Labutta	18%	55%	18%	9%	-
Maubin	-	-	83%	17%	-
Myaungmya	-	75%	25%	-	-
Pathein	-	67%	-	17%	17%
Pyapon	-	30%	30%	20%	20%
Yangon (North)	56%	11%	22%	11%	-
Yangon (South)	44%	11%	33%	11%	-
All samples	20%	33%	29%	13%	5%
Note: Total sample villages- 55					

Source: TARU Analysis (2010), MSR primary study

The education levels of members in each family within the sample households (8 each per village) across 55 villages were studied. The sample indicates that the illiteracy is less than 14%, persons with less than 5 years education is 48%, persons with 5-12 years education is 35% and only 3% are graduates.

Education capacity index was worked out based on the maximum education level in each sample families with weights given to the years of education ranging from 0 for illiterates to 10 for post graduates. The average education capacity index was less than 4 in all villages indicating 5-12 years of education in all the villages.

4.8.7 Natural Resource Accessibility

Since majority of livelihoods are natural resource based (farming and fisheries and related labor), the land and fishery resource availability was used to assess the natural capital. The agriculture is mostly labor intensive and single, double and three crop farming is practiced across the delta depending on soil type and fresh water availability. In the saline region near the coast, single crop farming is practiced, while three crop farming is practiced in fresh water zones in the interior. The framing as well as fisheries is labor intensive. Fertilizer usage is minimal. This natural resource accessibility index was derived based on gross cropped area per capita, land holding distribution across the villages, average number of boats per sample families and percentage households owning boats. In case of villages not dependant on fisheries, only land related parameters were used. The Average Natural Resource Accessibility Index across the districts based on samples is presented in the Table 4-14.

Table 4-14: Natural Resource Accessibility Index

District	Natural Resource accessibility Index		
	Average	Minimum	Maximum
Labutta	3.6	1.3	6.3
Maubin	5.0	3.0	8.7
Myaungmya	6.0	4.7	7.5
Pathein	5.7	2.5	7.5
Pyapon	4.6	1.3	10.0
Yangon (North)	2.8	1.0	7.5
Yangon (South)	4.9	2.0	7.3
All Samples	4.4	1.0	10.0

Note: Total sample villages- 55

Source: TARU Analysis (2010), MSR primary study

The analysis indicates that there is significant variation in accessibility to natural resources across the districts. The geopsy based transfer and aggregation of the Natural Resource Accessibility Index results are presented in the Table 4-15.

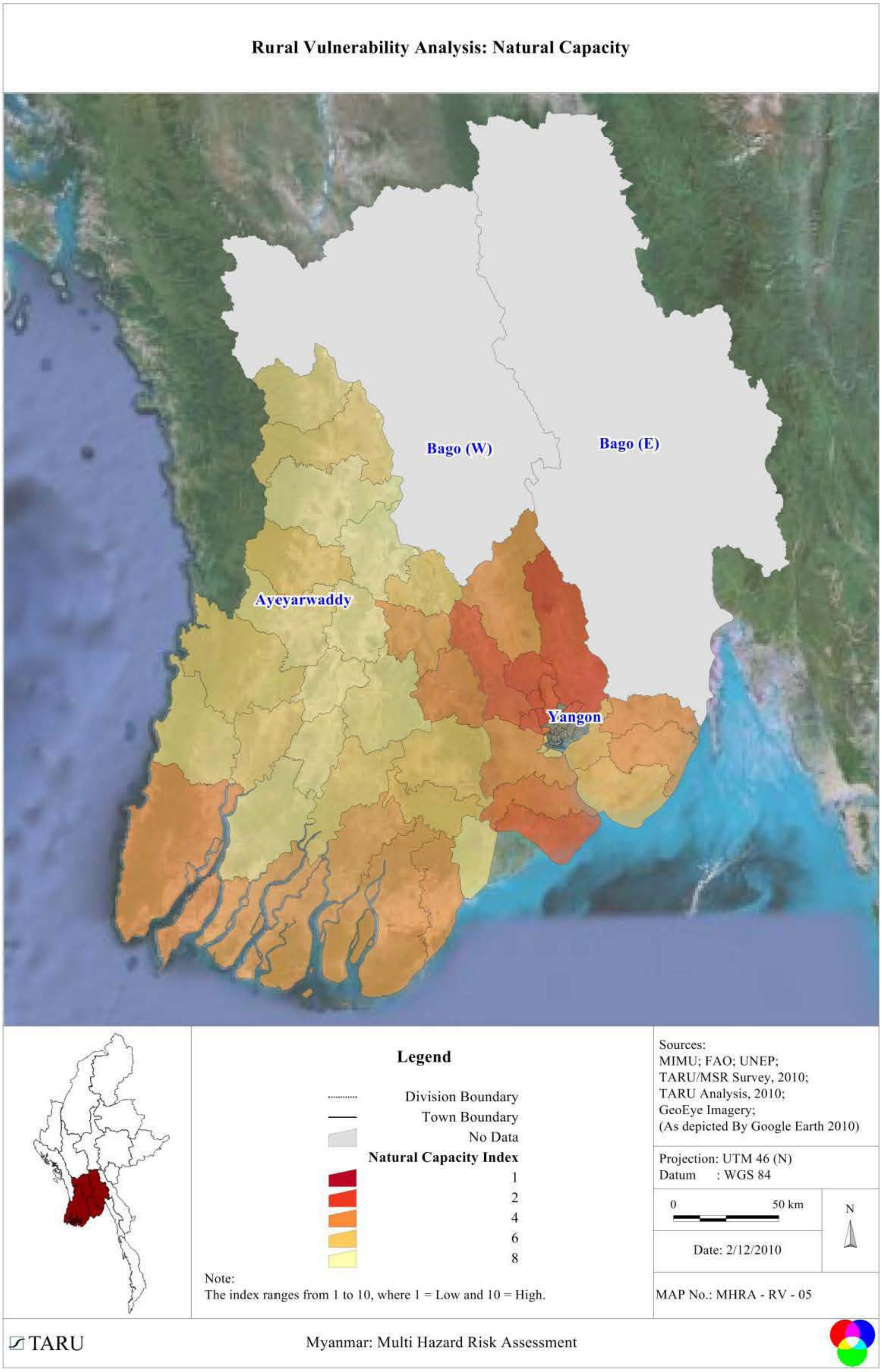
Table 4-15: Index of Population Having Access to Natural Resources

District	1 to 2.5	2.5 to 5	5 to 7.5	7.5 to 10
Hinthada	-	10%	5%	85%
Labutta	9%	53%	35%	3%
Maubin	1%	38%	32%	29%
Myaungmya	-	4%	48%	49%
Pathein	2%	2%	53%	44%
Pyapon	21%	13%	53%	13%
Yangon (East)	-	100%	-	-
Yangon (North)	32%	62%	-	6%
Yangon (South)	10%	48%	42%	-
All districts	10%	29%	30%	30%

Note: 10 indicates highest resource availability. Total sample villages- 55

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO.

Figure 4-10: Natural Capacity Index



The analysis indicates highest natural resource accessibility in Hinthada district, which has the advantage of low population density and also being located in the fresh water zone. However, due to access and other constraints, the households may not be able to take advantage of the resource availability advantages. Figure 4-10 illustrates the natural capacity index across the study area.

4.8.8 Social Networking Capacity

Myanmar villages have a fairly well knit society with predominantly Buddhist population. The social cohesion is fairly high in the society, even though formal institutions are not common. The local monasteries provide a variety of services to the villages including basic education. The civil society organizations are only few in number and donor/development project created institutions are mostly young (< 10 years old) and are in early phase of evolution.

The older organizations reported by the respondents include Union Solidarity and Development Association, Myanmar Maternal and Child Welfare Association, Myanmar Woman's Affairs Federation and Fire Brigade, Basic Health Association and Social Welfare committee. These organizations as well as donor funded CBOs have played very important role in relief and rehabilitation activities immediately after disaster.

The social network index was derived from the presence of social organizations including donor funded CBOs and the membership. It is based on household and community level surveys. The distribution of social network index across the sampled districts is presented in the Table 4-16.

Table 4-16: Distribution of Social Network Index

District	Maximum	Average	Minimum
Labutta	6.8	3.9	1.0
Maubin	3.5	2.4	1.5
Myaungmya	6.3	5.2	2.5
Pathein	6.8	4.1	1.0
Pyapon	3.0	2.0	1.0
Yangon (North)	5.3	2.3	1.0
Yangon (South)	6.8	4.5	1.5
Grand Total	**6.8**	**3.3**	**1.0**
Note: Total sample villages- 55			

Source: TARU Analysis (2010), MSR primary study

The analysis indicates very high variation across the sample villages, with some villages having virtually no social organizations that can provide support in community based disaster preparedness. The membership to existing organizations is low in these villages.

The Geopsy based transfer of the values to similar villages were done to explore the possible distribution of social networking index across the study are. The results are provided in the Table 4-17.

Table 4-17: Index of Population Under Various Categories of Social Network

District	0-2.5	2.5-5	5-7.5
Hinthada	67%	33%	-
Labutta	28%	42%	30%
Maubin	51%	48%	1%
Myaungmya	21%	29%	50%
Pathein	38%	51%	10%
Pyapon	46%	54%	-
Yangon (East)	-	100%	-
Yangon (North)	51%	41%	8%
Yangon (South)	37%	37%	26%
Grand Total	45%	42%	13%

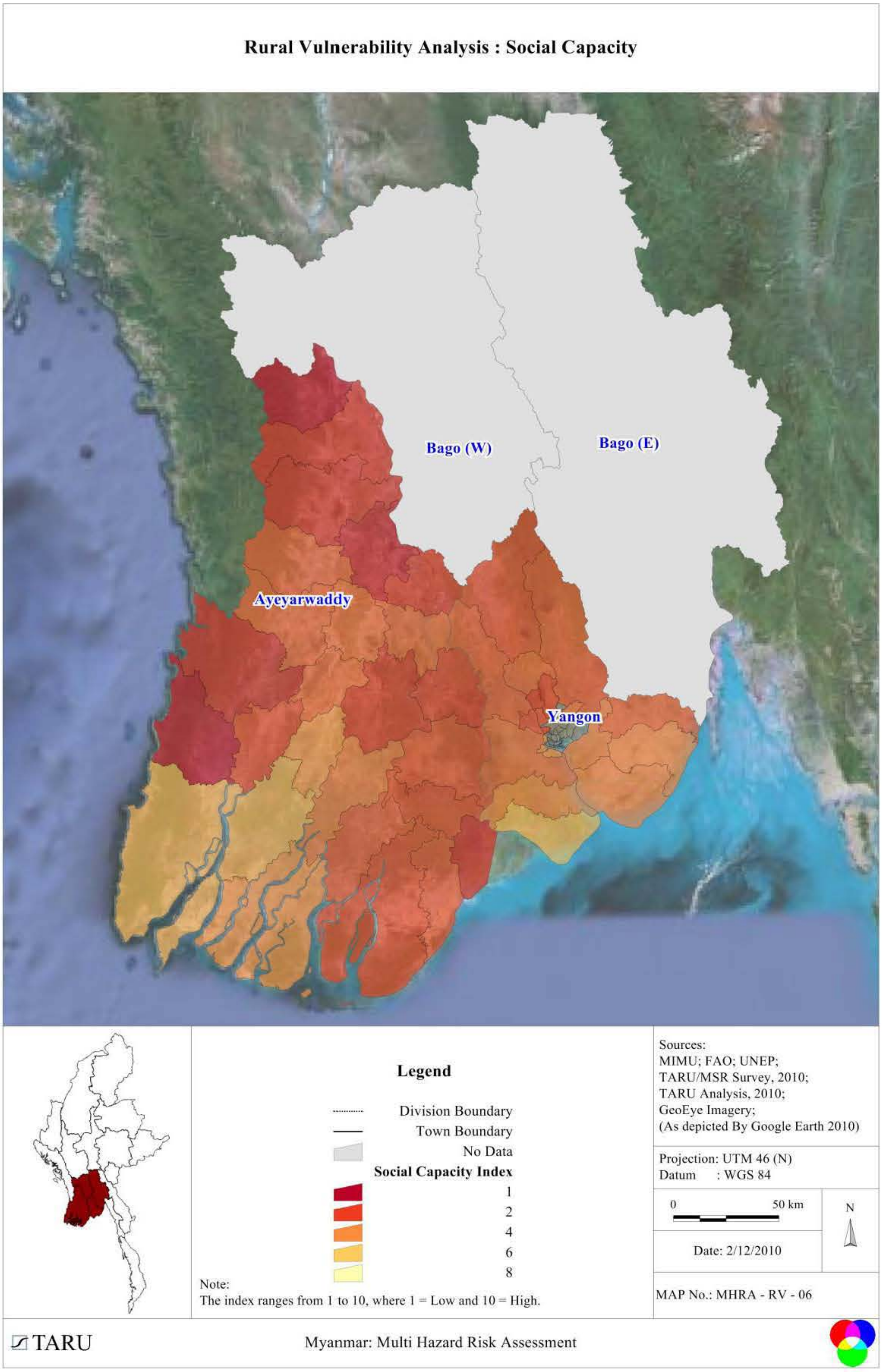
Note: 10 indicates highest social networking capacity

Source: TARU Analysis (2010), MSR primary study, MIMU, FAO.

The analysis indicates that there is a gap in CBO/NGO presence and reach to the communities. In the prevailing conditions, and challenges posed by recurrent disasters, there is urgent need for extending the reach of national and donor funded organizations to deliver services to improve livelihoods and build capacities to undertake community based disaster preparedness and mitigation activities.

Reviving and strengthening the older organizations, where they are available as well as forming new ones where there are few or none needs to be done in a sustained manner. Given the low productivity of land, low coverage of lifeline services and constraints posed by the geo-physical and climatic constraints, these organizations can provide services and share the lessons between the communities and provide support in improving livelihoods and safety. Figure 4-11 illustrates the social capacity index of the study area.

Figure 4-11: Social Capacity Index



4.9 SUMMARY

The rural vulnerability analysis was based on indicators addressing the Sustainable Livelihood Framework (SLF) of DFID. The indicators selected include five capitals which control the livelihoods of poor namely physical, human, financial, social and natural capitals.

The rural settlements in the Delta Region are highly vulnerable due to their geographical locations. Majority of area is in low elevation flat terrain with many interweaving distributaries of Irrawaddy River. The coastal and river side settlements are at higher risk to floods and storm surges. The results show that nearly 60% of the population in the delta region is vulnerable to flood and storm surge risks. Another major challenge of physical vulnerability assessment in the Delta Region is the overwhelming proportion of non-engineered or partially engineered buildings. Majority of the buildings are made of Biomass or Tin or ACC Sheets walls/roofs. These structures are vulnerable to wind speed >33 m/s.

Accessibility is critical for evacuation before the hazard, and for providing timely relief after disaster. Accessibility through roads in Delta Region is a major issue because most of the mud roads in delta are only accessible during fair weather. Due to insufficient bridges and culverts, most roads do get inundated during rainy seasons. Water ways are the only source of transportation which is highly relied upon by people within the delta. In spite of its functionality during fair weather similar to roads, the use of waterways during the occurrence of a severe weather event will be an issue of concern.

Within the Delta, the land holding distribution is highly skewed. The results indicate that 50% to 80% of the households in surveyed villages are landless and therefore have to rely on agriculture sector or fisheries or other non-steady source of employment including working in salt pans for their sustenance. Paddy cultivation and fisheries are the main sources of livelihoods for the people within the rural regions of the delta. High out migration (movement from rural to urban areas) is evident within the delta and the migratory population contributes to about 15% of the economy (among sample households).

Secondary and tertiary sectors are weak and contribute to less than 10% of people's livelihood. Therefore, any damage to agriculture or fisheries may affect more than 90% of the households in the Detla region. Analysis results also indicate that single crop based agriculture in saline areas, are relatively more vulnerable due to their lack of income diversity, security and savings.

Nevertheless, rural settlements in the Delta region are highly benefited from proximity of natural resource (including river or forest). This provides a source of livelihood to majority of population. The analysis indicates highest natural resource accessibility (85%) in Hinthada district, which has the advantage of having low population density and being located within fresh water zone.

Rural settlements in delta are fairly well knit, with large Buddhists population. The social cohesion is very high within the societies, which establishes good social networks. Local monasteries provide variety of services to the communities especially in improving the basic education. Apart from the education provided by the monasteries, the government run institutions also cater to the basic education. Therefore, primary education is accessible to the majority of the population within delta region. Unfortunately, due to lack of infrastructure (accessibility), higher education is inaccessible to the majority of the villagers. The results indicate that illiterates are less than 14% and around 48% having primary education. People with secondary education including high school account for 35% of the population but only 3% are graduates. This shows that it would be easy for agencies in conducting awareness programs.

Chapter 5: COMPOSITE RISK ASSESSMENT

5.1 URBAN COMPOSITE RISK ASSESSMENT

5.1.1 Building: Flood Hazard Risk Exposure

Flood hazard risk and vulnerability of the buildings were analyzed for three out of the five survey towns (Hmawabi, Maubin and Myaungmya). The analysis was not carried out in Labutta and Pyapon due to the lack of climate information.

Based on the hazard risk models simulations of 50% and 100% increase in observed maximum precipitation, the vulnerability of the buildings within Hmawbi, Maubin and Myaungmya were analyzed. The buildings were divided into three types based on the material used for the construction of roofs and walls. The results from the flood risk exposure of the building are presented in Table 5-1 to Table 5-3. From the tables it is evident that the level of inundation is less than a meter. Considering that most buildings within these regions have either a high plinth or rest on struts, which are elevated to around a meter, the level of vulnerability of these buildings is quite reduced. Nevertheless, considering the location of these buildings and the standard of construction an increase in the rainfall leading to severe precipitation may cause damage.

Flood risk exposures of buildings in Hmawbi Town are presented in Table 5-1. From the results it is evident that in Hmawbi Town 99% and 100% of the buildings are exposed to flooding/inundation > 0.4 m for 50% and 100% increase in observed maximum Rainfall events respectively.

Table 5-1: Hmawbi Town: Flood Risk Exposure to Buildings

Sl. No.	Flood Height (m)	Building (Nos.)	Buildings (%)
Flood Height with 50 % Increase in observed maximum Rainfall events			
1	<= 0.4	36	1%
2	> 0.4	5206	99%
Total		**5242**	**100%**
Flood Height with 100 % Increase in observed maximum Rainfall events			
1	>0.4	5242	100 %
Total		**5242**	**100%**

Source: TARU/INRM Analysis, 2010

In Maubin town, 100% of the buildings are exposed to floods. However, the level of vulnerability of these buildings is quite low due to possible inundation level (less than 0.4 meters) and also due to stilt or high plinth buildings that take care of current flood risks. The situation does not change much even with the 100 percent change in average rainfall. Flood risk exposures to buildings in Maubin Town are presented in Table 5-2.

Table 5-2: Maubin Town: Flood Risk Exposure to Buildings

Sl. No.	Flood Height (m)	Building (Nos.)	Buildings (%)
Flood Height with 50 % Increase in observed maximum Rainfall events			
1	< =0.4	2885	100%
Total		2885	100%
Flood Height with 100 % Increase in observed maximum Rainfall events			
1	<= 0.4	2510	87%
2	> 0.4	375	13%
Total		2885	100%

Source: TARU/INRM Analysis, 2010

Flood risk exposures to buildings in Myanugmya Town are presented in Table 5-3. From the table it is evident that in Myaungmya town around 20% of buildings are vulnerable to flood > 0.4 meter inundation.

Table 5-3: Myaungmya Town: Flood Risk Exposure to Buildings

Sl. No.	Flood Height (m)	Building (Nos.)	Buildings (%)
Flood Height with 50 % Increase in observed maximum Rainfall events			
1	< = 0.4	1560	79.5%
2	> 0.4	403	20.5%
Total		1963	100%
Flood Height with 100 % Increase in observed maximum Rainfall events			
1	< = 0.4	355	18%
2	> 0.4	1608	82%
Total		1963	100%

Source: TARU/INRM Analysis, 2010

Building Loss Due to Cyclone (100 Year Period)

Apart from strong winds, the cyclone events are usually accompanied by inundation due to precipitation or surge. Considering the deltaic environment and the typology of the buildings within these areas, in this study the damage due to cyclonic windstorms were analyzed discounting the events that follow including floods due to precipitation. This was done since the roof damage invariably precedes damage from floods and storm surge. In significant proportion of buildings, the damage to the assets (grains, household materials) inside the house is often higher than that of the building itself, as observed in most towns and villages. Further, since the earlier section covers flood in detail, a deliberate attempt has been made to limit this section to highlight the possible loss that could arise due to cyclonic winds (100-year return period).

Limitations

1. The building type estimation was done using the High resolution satellite imagery. This method is unable to provide reliable information of the number of stories as well as type of the wall materials or ceiling of the intermediate floors. The interpretation was done based on sample survey, field observations and neighborhood context. This is especially true of Middle and upper SEC multi storied houses with tin roofs.
2. Average costs of building materials were used for estimating the loss. The costs used were based on Summary of Costs questionnaire. The costs may vary based on distance of transport as well as availability of some of the materials locally.
3. The losses of materials/assets inside the buildings could not be considered, which may be higher than the loss to buildings.

This method provides a framework for analysis of monetary damages and as and when more site specific data is available, more accurate assessment can be made.

Estimated Damages

Cyclone damage losses of buildings in Kyat are presented in Table 5-4. In this study, buildings in the study area were classified into three types based on the material used for construction. Type I includes builds composed of reinforced cement concrete (RCC) on brick and RCC on RCC; Type II includes corrugated galvanized iron sheets (CGI) / asbestos cement concrete (ACC) /Tin or Tiles on Brick; and Type III includes dwellings/structures made out of Biomass on Biomass.

From the Table 5-4 it is evident that even though the numbers of building of Type III are higher, the percentage contributions of Type -II buildings to the losses are far greater. The analysis also indicates that the losses in Hmawbi account for the highest followed by Pyapon.

Table 5-4: Building Loss Due to Cyclone (100 Year Return period)

Town	Type I	Type II	Type III	Total
	Loss (in Million Kyat)			
Hmawbi	446	36,523	66	37,035
Labutta	NA	14,031	1,655	15,686
Maubin	228	18,944	1,126	20,298
Myaungmya	648	16,041	2,125	18,813
Pyapon	135	25,184	1,583	26,901
Total	1,457	110,723	6,555	118,734

Source: TARU Analysis, 2010

Following Figure 5-1 to Figure 5-5 shows the building loss analysis due to cyclone.

Figure 5-1: Hmawbi Town: Building Loss Analysis Due to Cyclone

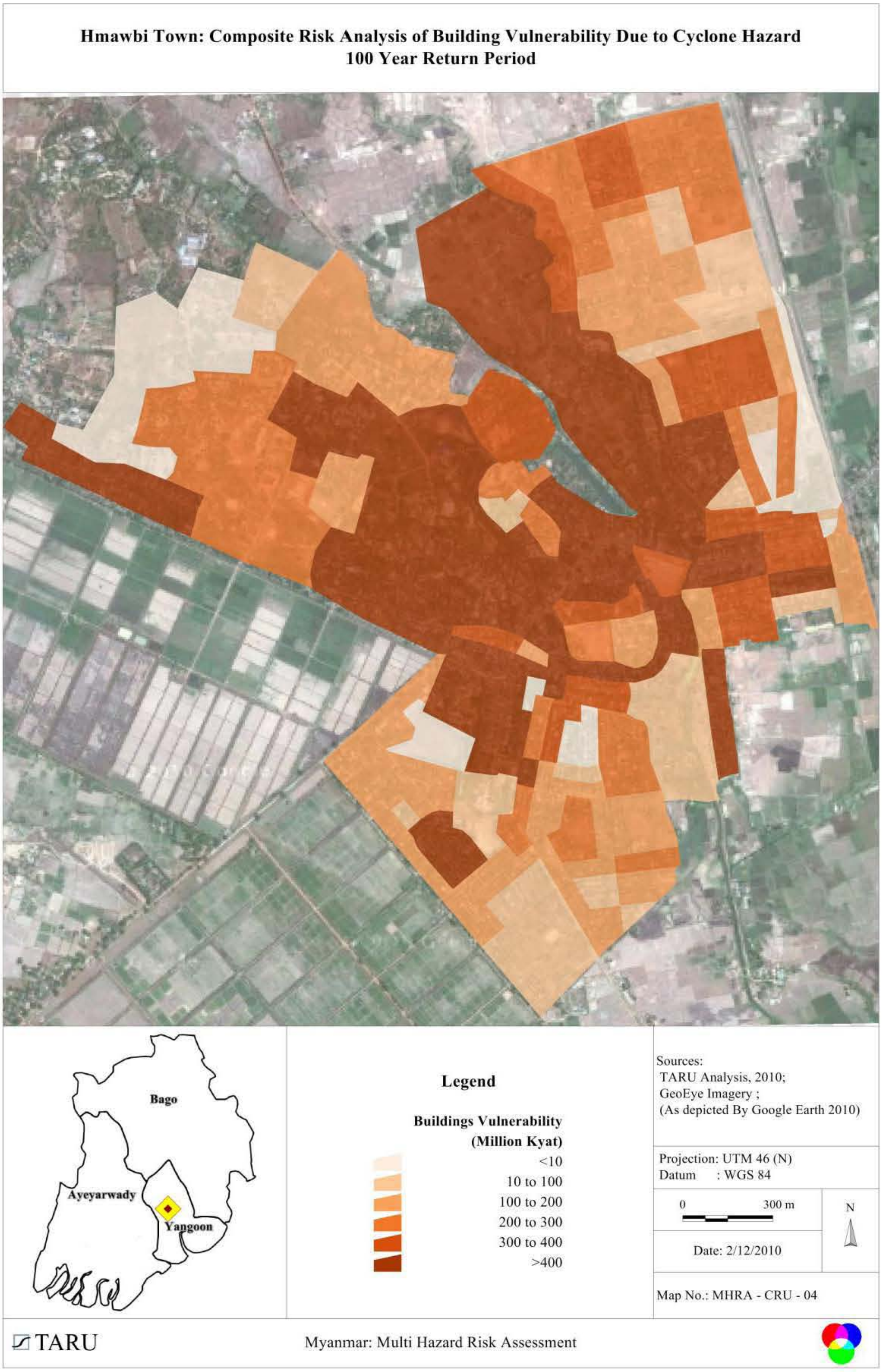


Figure 5-2: Maubin Town: Building Loss Analysis Due to Cyclone

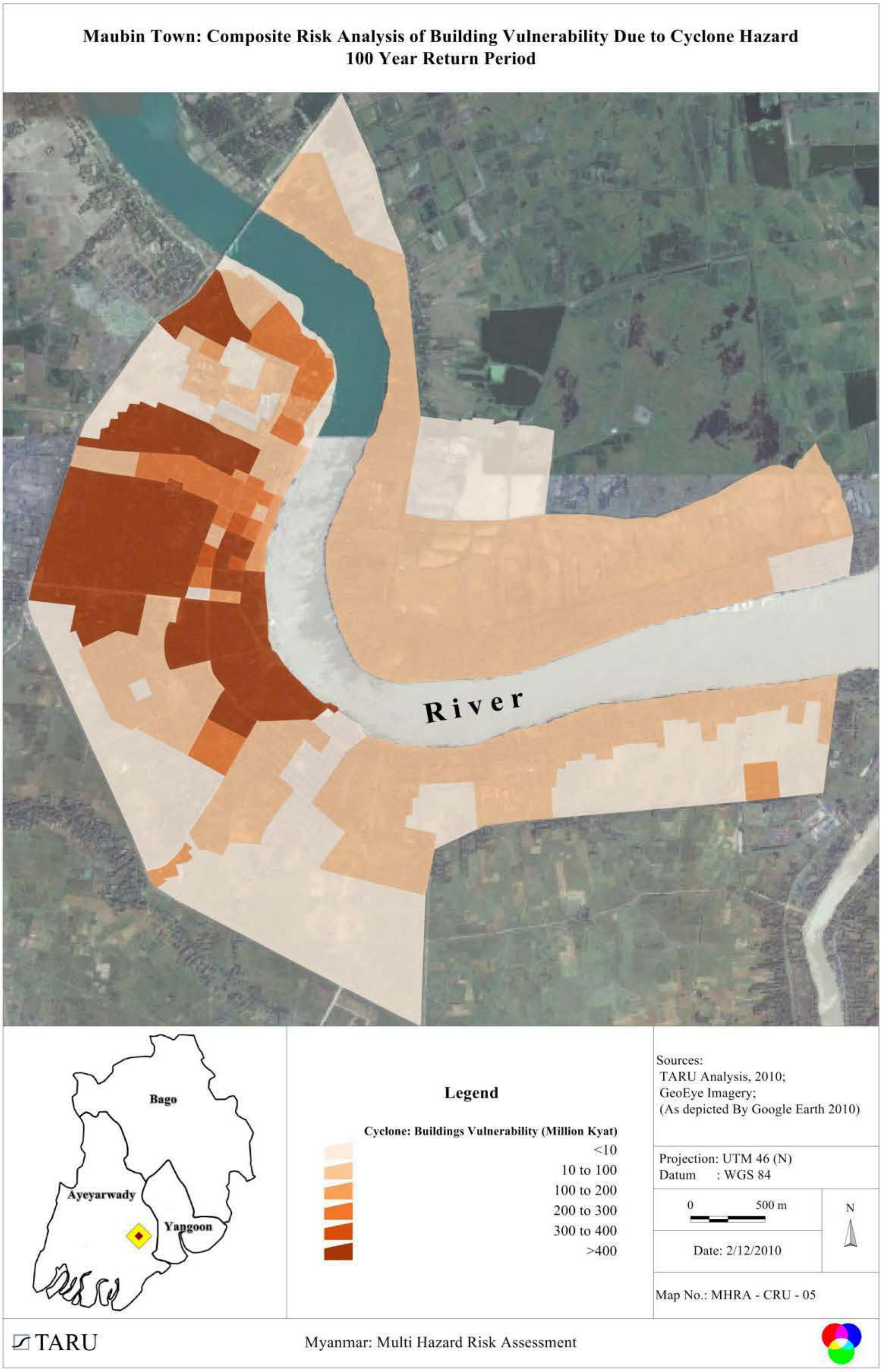


Figure 5-3: Pyapon Town: Building Loss Analysis Due to Cyclone

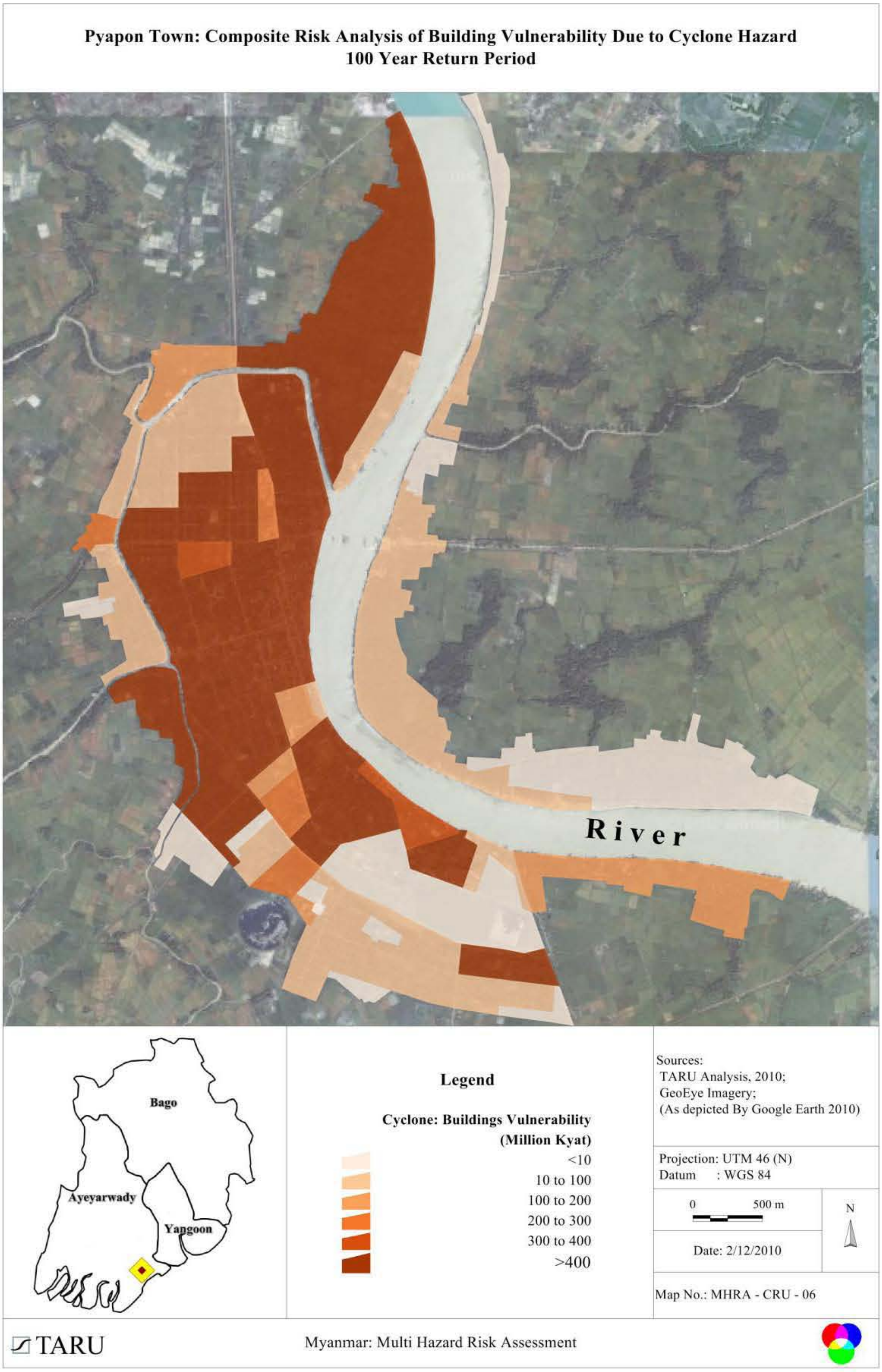


Figure 5-4: Myaungmya Town: Building Loss Analysis Due to Cyclone

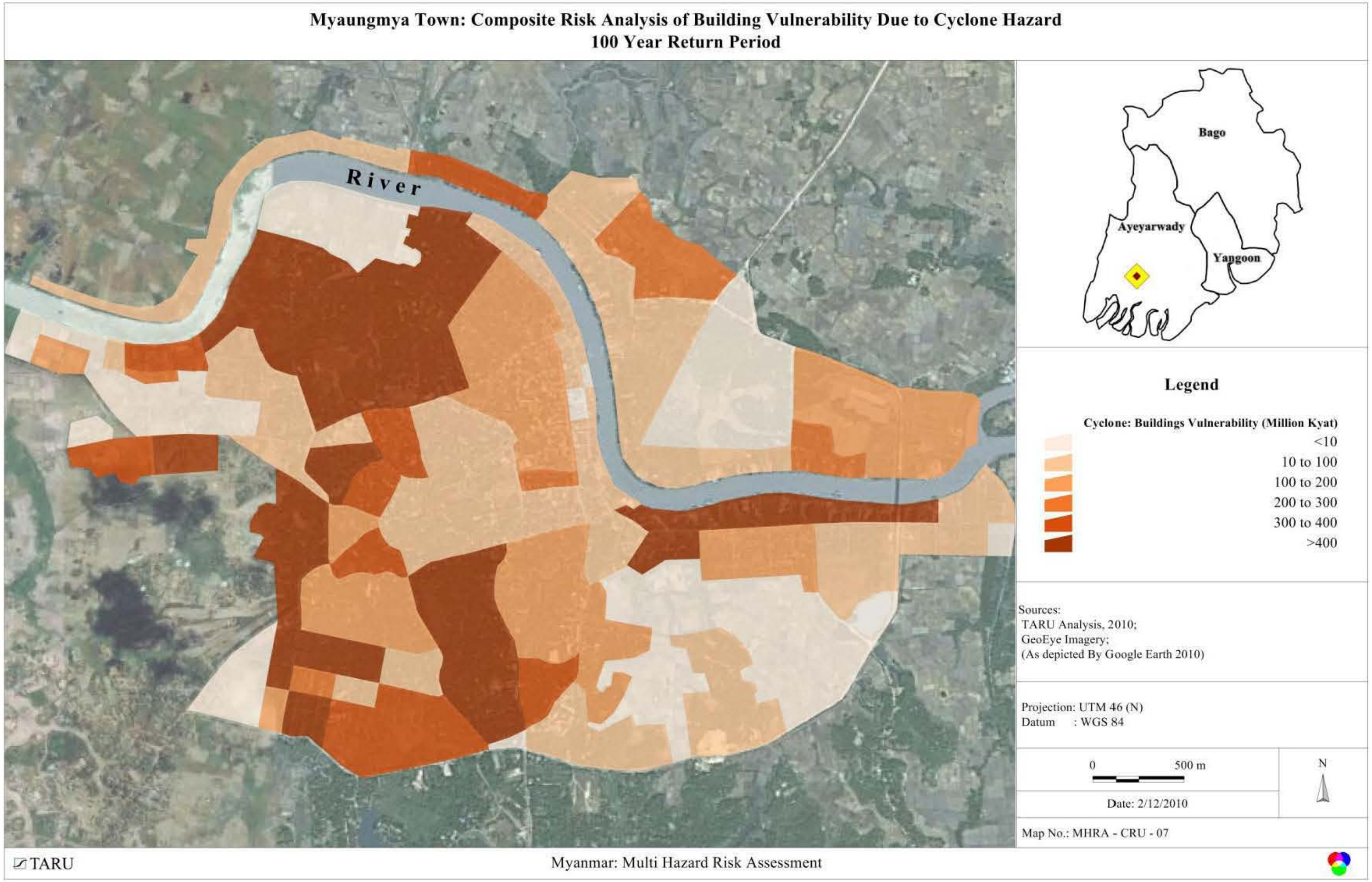
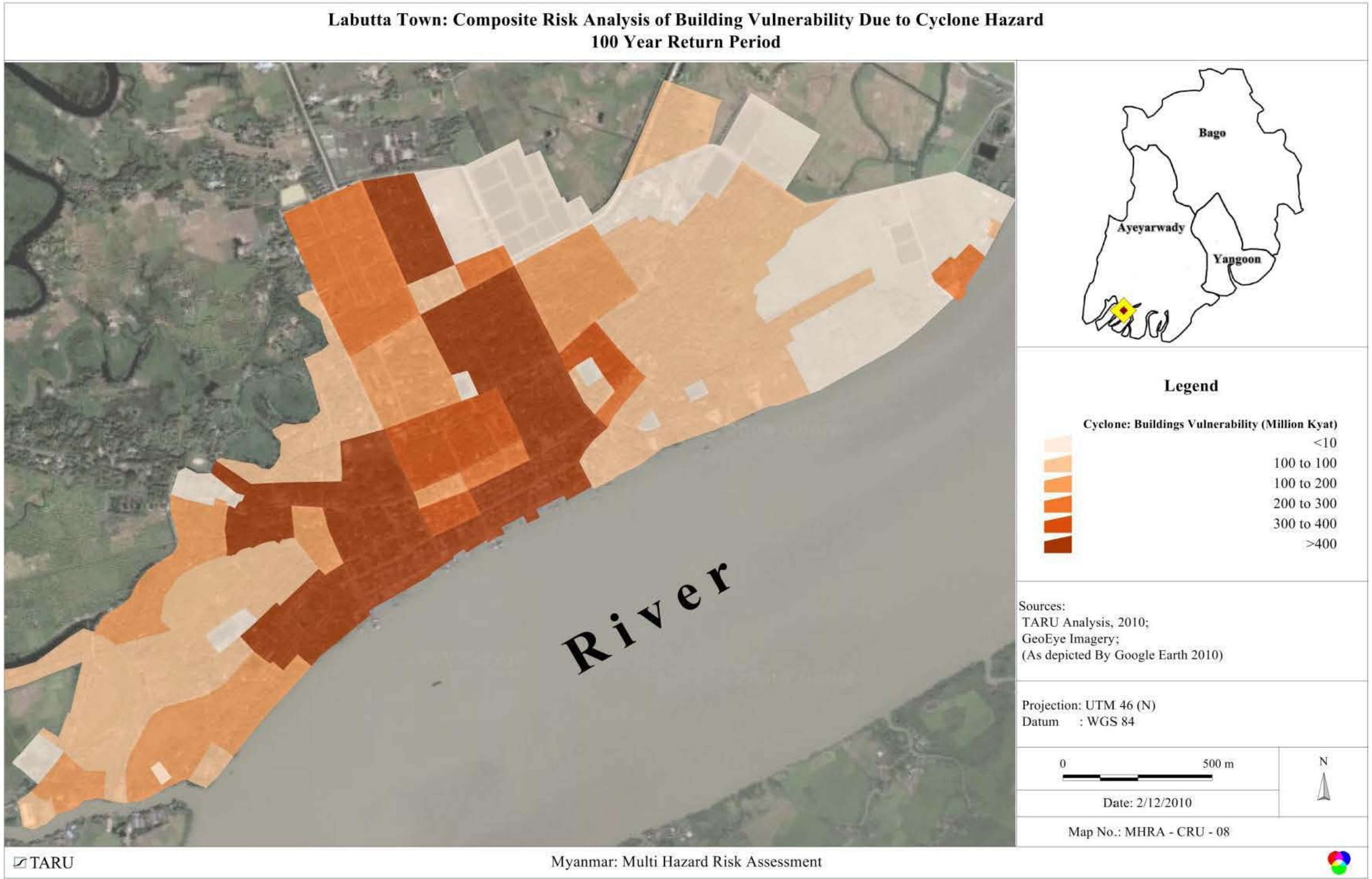


Figure 5-5: Labuta Town: Building Loss Analysis Due to Cyclone



Source: TARU Analysis, 2010

Building losses due to cyclone (100-year return period) account to greater than 118 Billion Kyat. Snapshots of building damages in Cyclone Nargis Event in 2008 are presented in Figure 5-6.

Figure 5-6: Snapshots of Building Damage Due to Cyclone Nargis

Source: TARU/MSR Filed Visit, 2010

Building Loss Due to Earthquake (100 Year Period)

Earthquake usually has little impact on Type III buildings in comparison to Type I and Type II buildings. In this study, the vulnerability of different building categories was estimated based on expert knowledge and experience in assessing the earthquake building damage in similar environments. Further, while assessing the losses, care was also taken to include the percentage of materials that could be salvaged after the event. For example, the roofing materials especially tin sheets and thatch could be salvaged after the hazard. Building loss due to earthquake is presented in Table 5-5. From the table it is evident that Type II building account for the maximum possible loss followed by Type I. The losses from Type III building are low because the numbers of such structures are relatively low within the surveyed towns.

Table 5-5: Building Loss Due to Earthquake (100 Year Period)

Town	Type I	Type II	Type III	Total
	Loss (in Million Kyat)			
Hmawabi	1,114	23,067	28	24,210
Labutta	-	8,867	709	9,571
Maubin	569	11,965	482	13,017
Myaungmya	1,620	10,131	911	12,662
Pyapon	337	15,906	678	16,921
Total	3,641	69,930	2,809	76,381

Source: TARU Analysis, 2010

Figure 5-7: Hmawbi Town: Building Composite Risk Analysis Due to Earthquake

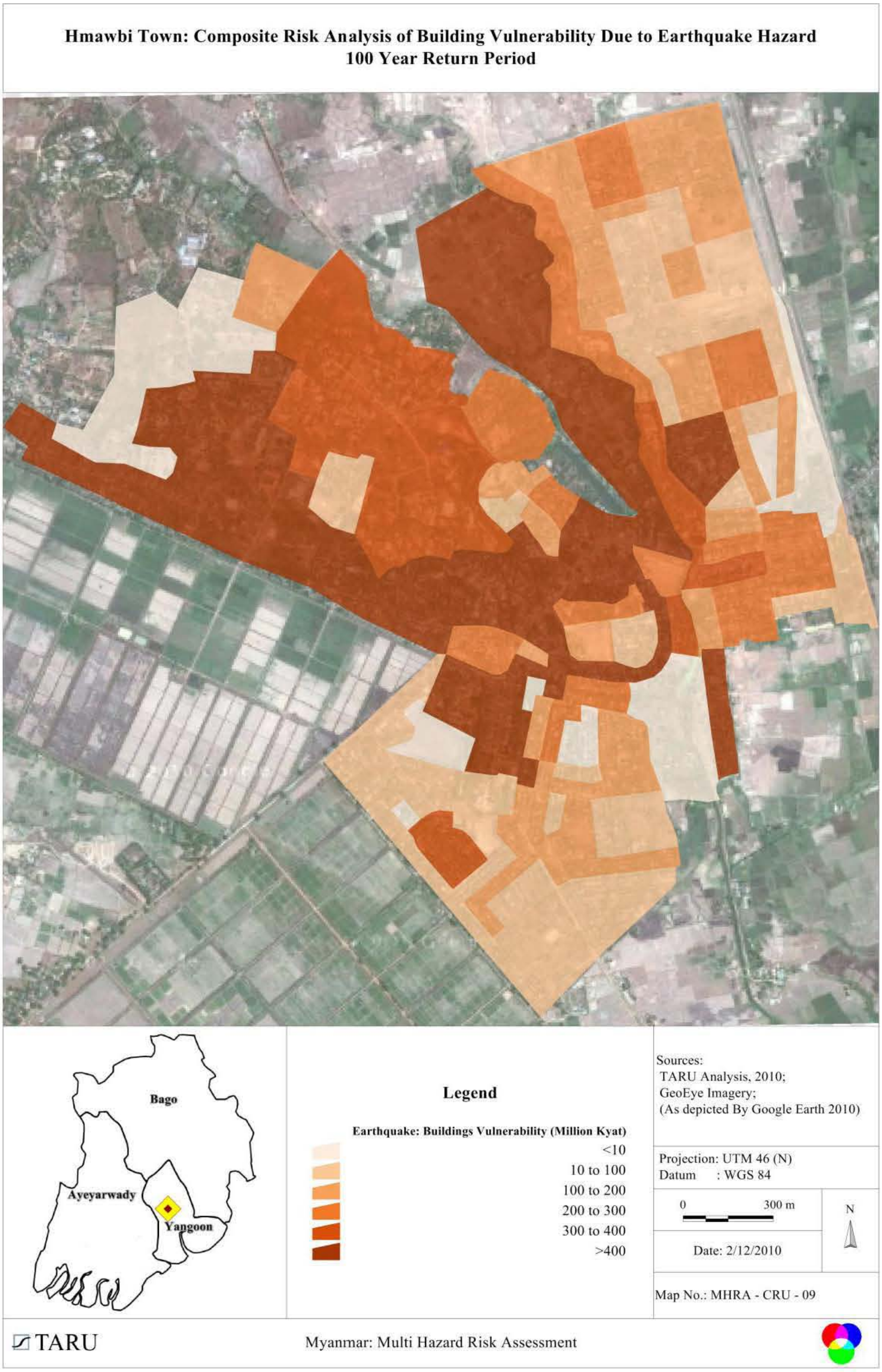


Figure 5-8: Maubin Town: Building Composite Risk Analysis Due to Earthquake

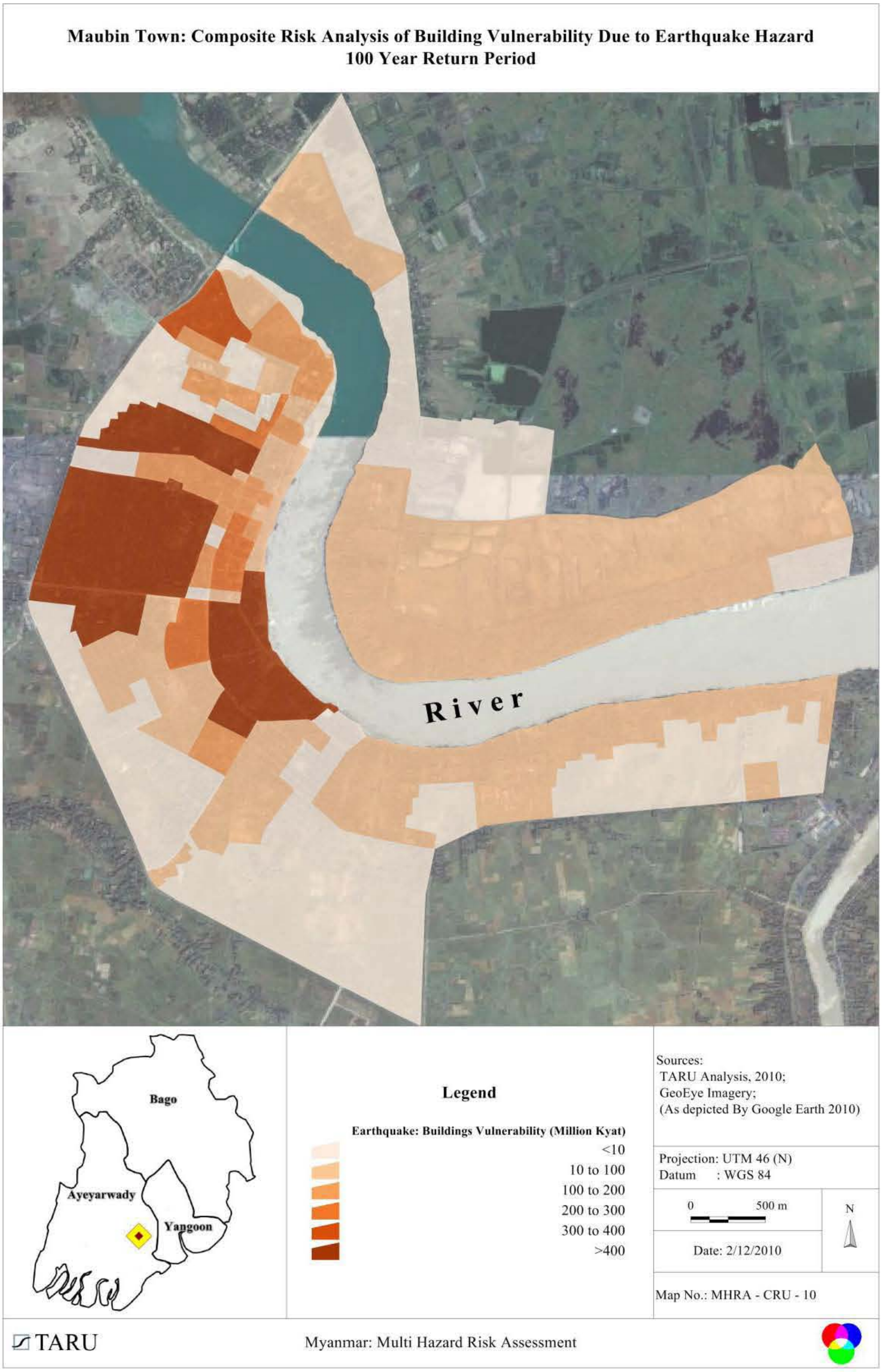


Figure 5-9: Pyapon Town: Building Composite Risk Analysis Due to Earthquake

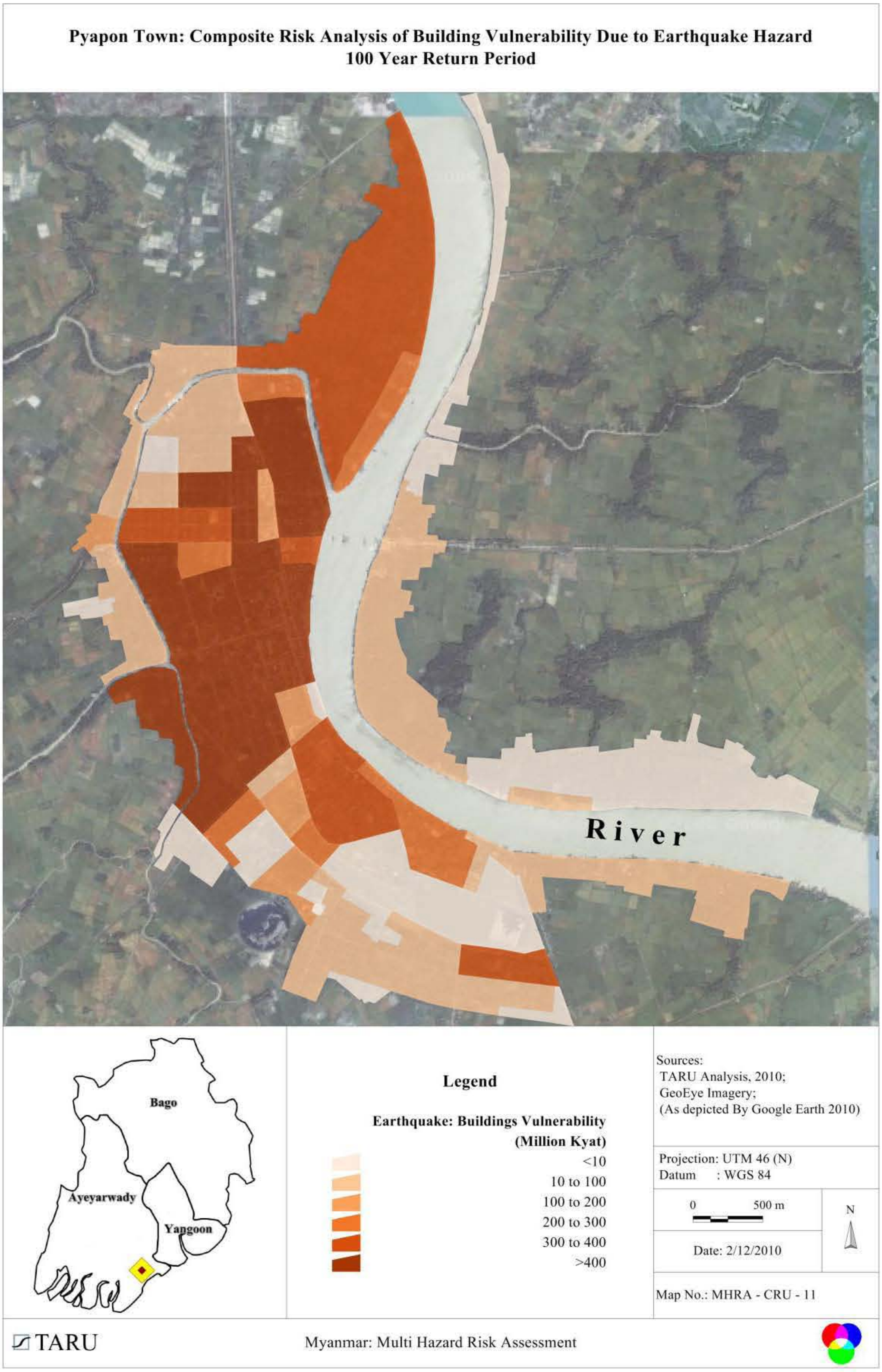


Figure 5-10: Myaungmya Town: Building Composite Risk Analysis Due to Earthquake

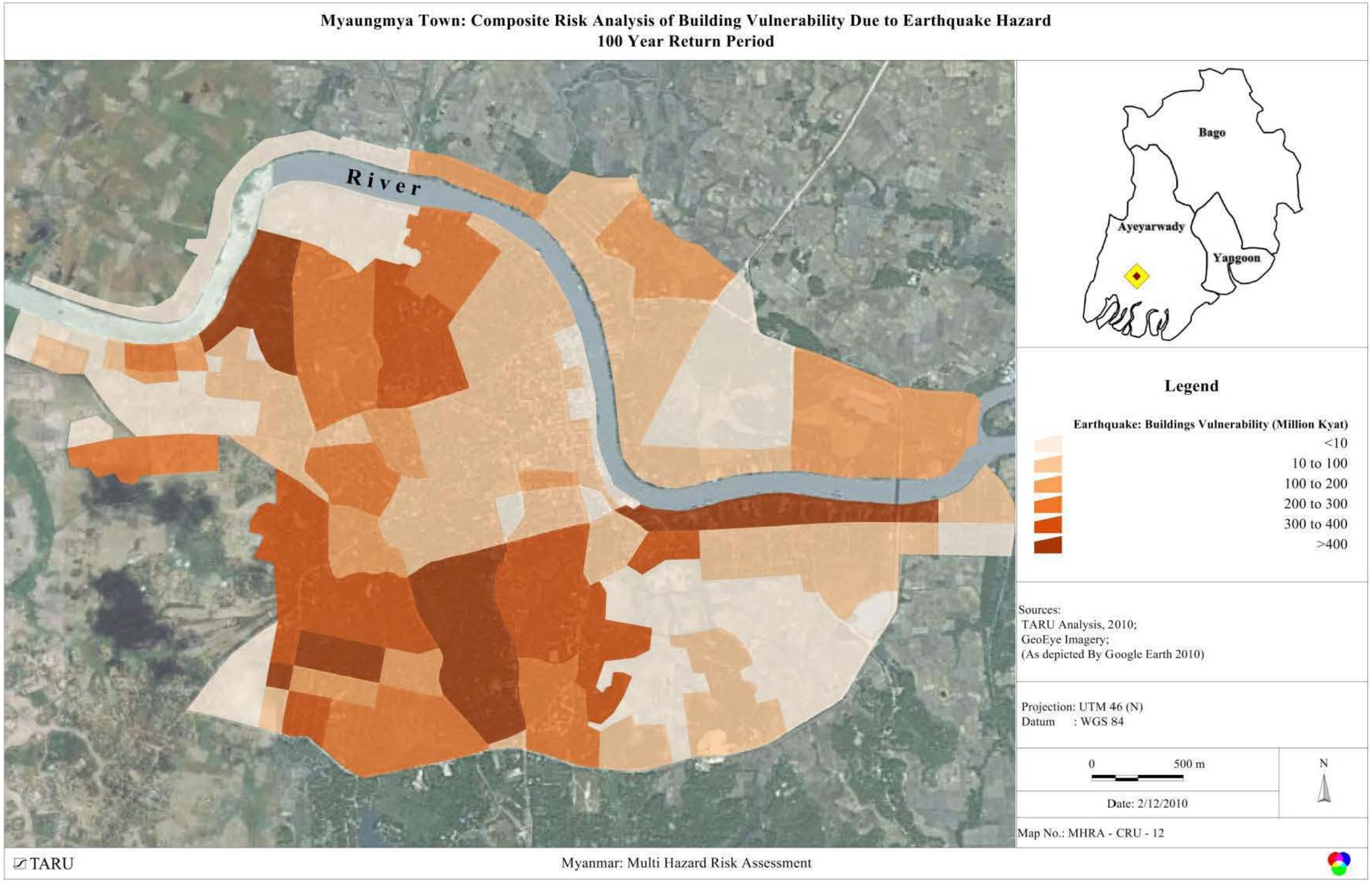
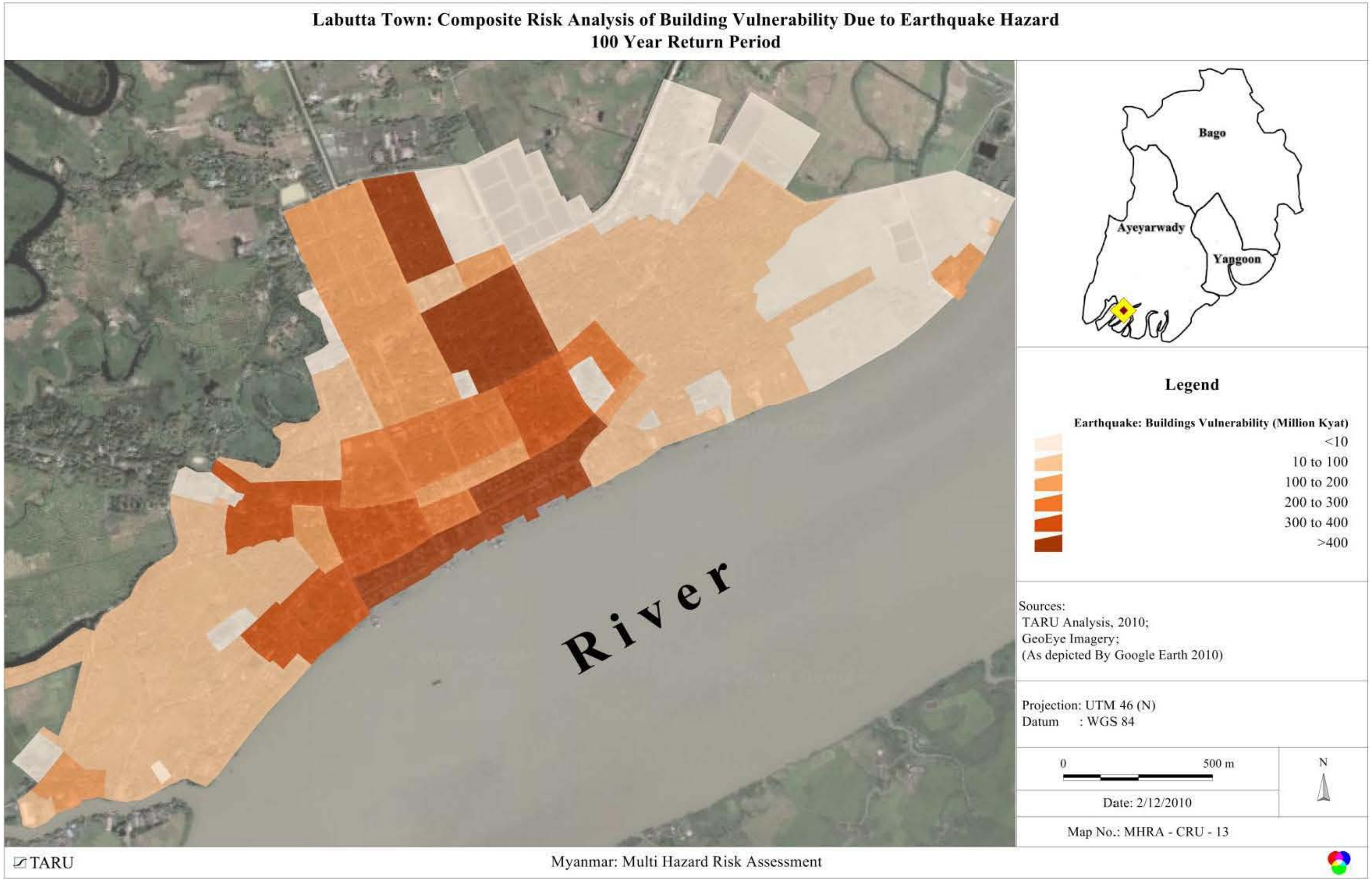


Figure 5-11: Labutta Town: Building Composite Risk Analysis Due to Earthquake



Source: TARU Analysis, 2010

5.1.2 Manufacturing and Industrial Sector

Delta region has number of agro and fishery based industries in addition to cottage industries, pottery and food processing. Industrial development of Delta Region depends on export of commodities such as processed grain (e.g. Rice) and other semi-finished products. The manufacturing and industrial sector in the Delta Region is developing gradually with a number of impediments as indicated below:

- Limited capacity to produce for export,
- Inadequate foreign market information
- Lack of diversification into value-added manufactured products,
- No stringent quality standards,
- Production of export products not matched by market demand,
- Lack of skilled manpower and institutional capacities,
- Lack of technological upgrading and technical skills, and
- Lack of financial and marketing capability.

Entrepreneurial talent and experience is scarce and needs to be nurtured. Likewise the technical, managerial, and marketing skills needed to facilitate operations logistics, including the development of supply and distribution backbones, is in short supply. Over these constraints the frequent occurrence of disasters further impedes its development. The main objective of this component of the study was to assess the vulnerability of manufacturing and industrial sector in the Delta Region of Myanmar to natural hazards based on defined indicators.

Type of Industries Surveyed (Sample Survey Coverage)

To analyze manufacturing and industrial sector vulnerability of Delta Region of Myanmar, primary survey was carried out across the five surveyed towns between the periods of March to April 2010. The survey essentially covered four basic types of industries, which are presented in Table 5-6.

Table 5-6: Industries (Class wise) sample coverage

Town	Household & Cottage	Small Scale	Medium Scale	Large Scale	Grand Total
	(Nos.)				
Hmawbi	2	2	-	-	4
Labutta	-	-	3	1	4
Maubin	-	-	4	-	4
Myaungmya	-	-	4	-	4
Pyapon	-	-	3	1	4
Total	2	2	14	2	20

Source: TARU Analysis, 2010

In each town, four different categories of industries were surveyed. The industrial survey was carried-out based on stratified random sampling. Table 5-7 shows the details of categories and type of industrial sample selected across the five towns.

Table 5-7: Type and Type of industries covered in survey

Type of Industries	Class of Industries			
	Tiny & Cottage	Small (SSI)	Medium	Large
Food Products and Beverages	100%	50%	36%	-
Rice Mill	-	-	14%	50%
Bleach Liquid	-	50%	-	-
Thanaka Mill	-	-	7%	-
Wood and Wood Products	-	-	21%	50%
Ice Production	-	-	7%	-
Salt Pan and Salt Processsing	-	-	15%	-
Total	100%	100%	100%	100%

Source: TARU Analysis, 2010

Figure 5-12: Industries with Different Classes & Type

Pottery Industry

Rice Industry

Food Product Industry

Food Product Industry

Reed/ Bamboo Industry

Reed/ Bamboo Industry

Source: TARU/MSR Field Visit, 2010

Industrial Loss Analysis

Various disasters in the recent past such as Sumatran Tsunami, 2004 and Cyclone Nargis, 2008, did have an impact on the industrial production sites and their networks along the coastal areas of delta region. The disasters affect the industries on two fronts i.e. 1) Direct losses (due to physical damage to assets and buildings) and 2) Indirect losses (production losses).

a) Direct Losses

Direct losses are mainly caused by the partial or total damage of buildings, production equipment as well as service and control installations in any industrial production sites.

b) Indirect Losses

Indirect losses include all losses including losses to raw materials, intermediate and final products stored as well as loss due to lack of production resulting from damage to the infrastructure and labor unavailability post disasters. Production losses are mainly influenced by the duration of the production downtime. Production losses may result from direct damages, supply chain interruptions, outages within critical infrastructure and negative markets. Negative market effects caused by a catastrophic event comprise e.g. the increase in prices of the raw materials in the affected region. In some industrial sectors, the indirect losses can be in the order of three to ten times larger than direct losses. Types of losses in industrial sector are presented in Table 5-8.

Table 5-8: Type of losses in industrial sector

Direct Losses	Indirect Losses
• Physical damage to buildings • Physical damage to production equipment • Physical damage to raw materials • Physical damage to products in stock • Physical damage to semi-finished products • Physical damage to control installations • Physical damage to service installations	• Loss of production due to direct damages • Loss of production due to infrastructure disruptions • Loss of production due to supply chain disruptions • Losses due to unavailability of labor post- disasters

Vulnerability to cyclones is associated with the intensity of the event, location of the element (industry) and its characteristics. Cyclone specific element wise industrial vulnerability was derived from data based on primary survey. The results of the manufacturing sector vulnerability are presented in Table 5-9.

Table 5-9: Manufacturing sector vulnerability due to cyclone

Element	Industry Class			
	Small (SSI)	Tiny & Cottage	Medium	Large
Damage to Building	35%	20%	46%	95%
Damage to Plant and Machinery	0%	3	33%	95%
Damage to Raw Material	0%	0%	49%	70%
Damage to Goods in Process	0%	0%	11%	0%
Damage to Finished Goods	0%	15%	50%	60%
Drop in Turnover	20%	45%	64%	100%
Number of days Production Interruption	16	16	52	68
Production at Reduced Capacity	35%	35%	39%	40%

Source: TARU Analysis, 2010

Loss estimation due to cyclone hazard for the manufacturing sector industry is presented in Table 5-10. Loss estimation was derived from average unit value of different elements presented in Table 5-9. From the Table 5-10 it can be inferred that damage and losses to machinery, raw material, goods in process and finished goods in small-scale industries (SSI) are almost nil, whereas it increases with the size of the industries. One of the possible reasons could be the type of the machinery/raw material used. Medium and large industries using largely electrical equipments may suffer the most even with minor flooding.

Table 5-10: Industrial Loss Estimation Due to Cyclone

Element	Small (SSI)	Tiny & Cottage	Medium	Large
	Loss (in Million Kyat)			
Damage to Building	1.75	1.30	6.80	98.80
Damage to Plant and Machinery	-	2.50	8.74	99.75
Damage to Raw Material	-	-	66.66	315.00
Damage to Goods in Process	-	-	22.38	-
Damage to Finished Goods	-	2.47	104.46	354.00
Drop in Turnover	1.16	7.42	134.30	590.00
Production Interruption (Number of days production stops)	0.25	0.72	30.00	109.10
Total (Kyat) Loss/Unit	3.16	14.42	373.38	1566.65

Source: TARU Analysis, 2010

In the absence of the reliable universe data regarding industries, information regarding the industries was obtained from Food and Agricultural Organization's (FAO), Atlas of Myanmar. Due to lack of detailed industrial information, only agricultural based industries were taken into consideration for loss estimation. Number of industries and their types are presented in Table 5-11.

Table 5-11: Number of industries in different classes

Division Name	Small (SSI)	Medium	Large
Ayeyarwady	473	42	13
Bago (E)	279	68	22
Bago (W)	290	254	39
Yangon	145	96	106

**Only Wheat, Oil, Bean. Rice and associated industries*

Source: FAO Agricultural Atlas

Total industrial losses were derived using the number of industries and their possible estimated loss. Industrial losses due to cyclones in different division of delta region are presented in following Table 5-12. Total building losses due to cyclonic winds in delta region may account to over 457 Billion Kyat. Within this, the loss that may be experienced by large-scale industries account the most (166 Billion Kyat), followed by medium scale industries (35 Billion Kyat). These estimates could be further improved on the availability of detailed information regarding the type and number of the industries within the delta.

Table 5-12: Total Industrial Loss

Division Name	SSI	Medium	Large
	Loss (in Million Kyat)		
Ayeyarwady	1,497	15,682	20,367
Bago (East)	883	25,390	34,467
Bago (West)	918	94,839	61,100
Yangon	459	35,845	166,066

Source: TARU Analysis, 2010 and FAO Agricultural Atlas

Along with the loss estimation, attempt was made to estimate the number of workers especially unskilled and semiskilled who may be affected due to disasters. This analysis was carried out taking into consideration the number of workers estimated from the primary survey and extrapolating it to the three divisions based on the industrial data from FAO. Due to the lack of data, the analysis was restricted to only food processing units within these regions.

Total number of food processing industrial workers who are vulnerable (income instability) to the cyclonic hazards are presented in Table 5-13. Even though the above analysis was limited to one type of industry, such analysis could be carried out for other industries on the availability of detailed information. Such kind of analysis will throw light on issues of vulnerable population at large.

Table 5-13: Total Number of Industrial Workers

Division Name	SSI	Medium	Large
	No. of workers		
Ayeyarwady	1892	678	501
Bago (E)	1116	1098	847
Bago (W)	1160	4100	1502
Yangon	580	1550	4081

Source: TARU Analysis, 2010 and FAO Agricultural Atlas

This information is based on the number of industries according to FAO statistics and average number of workers obtained from the primary survey. This may be an underestimate, since workers involved in support activities like transport etc are not taken in to account and also the FAO estimates are likely to be outdated.

5.1.3 Summary

The urban composite risk assessment was undertaken for two main hazards namely cyclone and earthquake. Analysis was carried out for key elements at risk namely buildings and industries within the surveyed towns (5 nos). Flood hazard was not included. Vulnerability of the buildings is quite low with respect to floods because the model simulated levels of inundation was less than a meter in surveyed towns. Moreover, most buildings in the Delta have been designed to take care of floods, i.e. the structures have either a higher plinth or are rested on struts (elevated over a meter). However, considering the location of these buildings and the standard of construction and severe precipitation events may cause damage.

While assessing the building losses for earthquake hazard risk, care was taken to discount the possible salvageable amount from the total damage. Expert knowledge and experience in assessing the earthquake building damage in similar environments were used while assessing the vulnerability of different building types. Further, earthquake usually has less impact on Type III buildings in comparison to Type I and Type II buildings. Building losses due to Earthquake (100-year return period) account to greater than 76 Billion Kyat, where maximum loss was observed within Type II buildings (69.93 Billion Kyat). Estimated loss that may be experienced by Hmawbi town is highest in all surveyed towns are nearly 32% followed by Pyapon (21%) and Maubin (17%) by earthquake hazard.

Building losses due to cyclone (100-year return period) account to greater than 118 Billion Kyat. Cyclone damage losses to Type II buildings have greater losses, even though the numbers of building of Type III are higher. Whereas Type I includes builds composed of reinforced cement concrete (RCC) on brick and RCC on RCC observed less damage losses in cyclone hazard compare to two other classes. Even though the numbers of building of Type III are higher, the Cyclone damage to Type II buildings was found to be greater. It was found that Type I and Type II accounted for majority of the loss. Estimated loss due to cyclone may be experienced by Hmawbi town is highest in all surveyed towns are nearly 30 % followed by Pyapon (17.09%) and Maubin (16.19%).

Industrial loss estimation was carried out for cyclone with 100-year return period. The industrial productivity and damage estimations were based on the results of primary survey which did indicate that that vulnerability of industrial sector is reported to be negligible to low intensity cyclonic storms. Due to the lack of information, only agricultural based industries mentioned within Food and Agricultural Organization's (FAO), Atlas of Myanmar were taken into consideration for loss estimation.

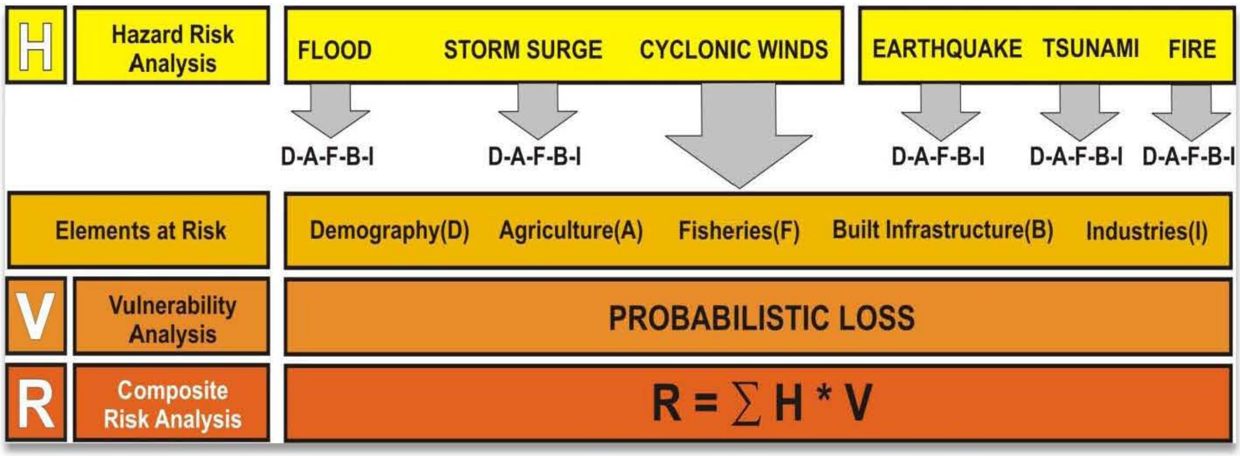
It is evident from results that damage and losses to machinery, raw material, goods in process and finished goods in small-scale industries (SSI) are negligible in comparison with MSI and LSI. One of the possible reasons could be the type of the machinery/raw material used. Total losses due to cyclonic winds in delta region may account to over 457 Billion Kyat. Estimated loss that may be experienced by LSI and MSI are around to 30% and 9% respectively.

5.2 RURAL COMPOSITE RISK ASSESSMENT

Myanmar is prone to multiple natural hazards. As per the data of relief and resettlement department, from 1998 to 2007, floods (10%), storms (11%) and others (8%) including earthquakes, Tsunami and landslides were the percentage of reported disasters in Myanmar. The Cyclone Nargis (2008) was one of the worst natural disasters in recent history of Myanmar, which severely affected the Irrawaddy delta region.

The hazard risks of the delta have been analyzed and presented in the Chapter-2. This section elucidates the results of composite risk analysis of the Myanmar delta region. The composite risk assessment was carried out based on the hazard risk (Cyclone, Flood and Earthquake) and vulnerability (population and building behavior) profile and presented in terms of economic loss in Kyat. The risks in the present exercise were calculated by considering the elements at risk as a main function. Important elements including building types and agricultural practices were considered for the analysis of the delta region Figure 5-13 depicts the composite risk assessment/analysis approach, which begins with analyzing the risk of individual hazard (Flood, Cyclone etc.) and involving the elements at risk (Demography, Agriculture etc.).

Figure 5-13: Analysis Framework



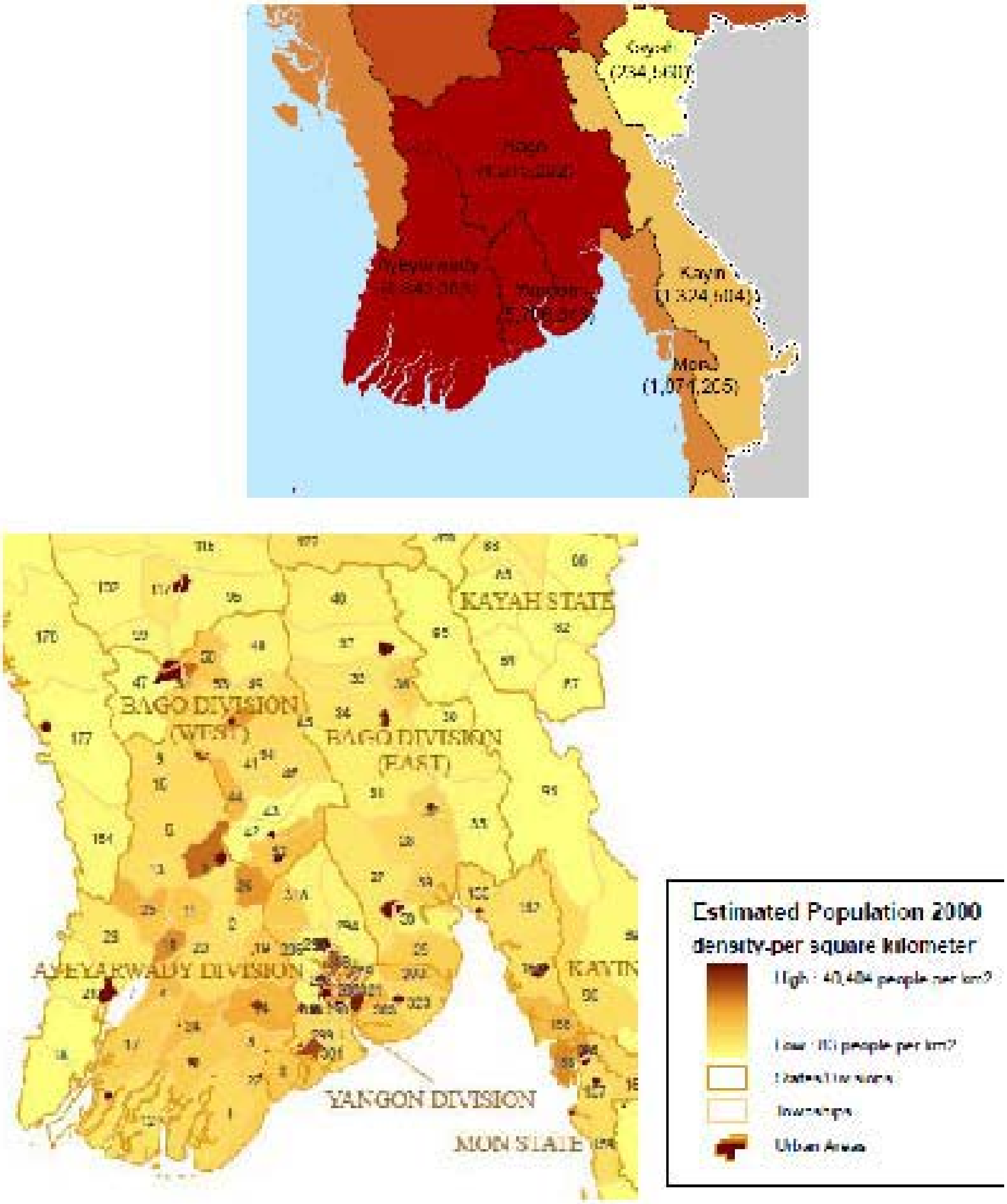
Myanmar delta region profile:

The loss due to hazard based on certain vulnerability profile will be much useful for decision makers in prioritizing their planning, adaptation and mitigation initiatives. For the present exercise, it was felt that the elements like population, building typology and agriculture practice of the Myanmar delta region becomes important to understand and to better evaluate the composite risk. In this regard the elements mentioned herein provide an insight as well as the process undertaken in the present study.

5.2.1 Population

The delta region is a home to more than 16 million people, distributed over various physical segments of the delta. Along with human population, the livestock is also an important element at risk with any hazard. This livestock is used as a critical support to the human population in agricultural practices, as well as meat. The details pertaining to habitat layer are described and have been presented in vulnerability assessment (Chapter 3). Population and livestock remain as key element in the determination of the risk assessment of the delta region. Population though not directly presented in the form of composite risk maps, they have been considered in the building typology analysis. Figure 5-14 shown below are to indicate the population in the delta region (division wise as well as township wise, source: MIMU).

Figure 5-14: A Glance at Population Distribution in the Delta Region: Myanmar



Source : MIMU

5.2.2 Building Typology

The field surveys helped in classifying the buildings within the rural areas of the delta into three types. This classification was based on the roof and wall types. The results indicate that most of the built residential structures are either semi-engineered or non-engineered. The construction material used is mainly comprises of Bo-mass which includes materials such as bamboo, thatch, earthen material etc. followed by tiles (burnt clay tiles, tin roof, sheet roofs, etc.). Apart from the above two types of building materials there are also presence of brick and concrete structures. Following Table 5-14 represent the percentage distribution of different building categories observed in the Myanmar delta region as per the survey conducted.

Table 5-14: Building Typology Distribution in Delta Region

Building Category	Percentage households
Biomass on Biomass	59
Tiles on Biomass	28
Tiles on Brick and concrete	13

Figure 5-15: Representatives of Building Typology in Rural Myanmar Delta Region

Bio-mass on bio-mass type of building category in the delta region

Tiles on bio-mass type of building category in the delta region

Tiles on brick and concrete type of building category in the delta region

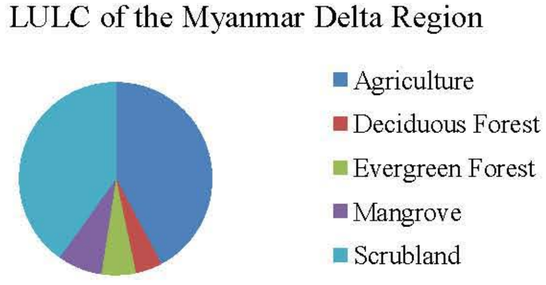
Housing density in the peri-urban area indicating the vulnerability of the building to natural hazards.

Source: TARU/MSR Field survey, 2010

5.2.3 Land Use Land Cover (LULC)

Figure 5-16 shows the distribution of the LULC of the delta regions of Yangon, Ayeyrawady and Bago divisions.

Figure 5-16: Diagram Showing the Lulc Distribution in the Study Area



Source: UNEP

Figure 5-17: Land Use Land Cover (Lulc) Distribution in the Delta Region.

Paddy field showing Agriculture

Mangrove: Showing water marks of high tides

Source: TARU/MSR Field survey, 2010

Based on the pie-diagram, it is evident that the agriculture and scrubland emerge out to be major LULC classes in the delta region. Mangrove is another important land cover class in the delta region, which although covering limited area, can be considered as an important land use class as it has its own importance in the bio-diversity and economy of the region. In the present exercise of composite risk the agriculture class was used to observe the extent of damage occurring to agriculture due to hazards mainly floods. This is mainly for the pluvial floods caused by extreme seasonal rainfall or extreme precipitation due to cyclonic storms. Figure 5-17 is showing LULC representatives of the delta region.

Myanmar is predominantly an agricultural country. Most of the rural households within the core delta region are involved in agriculture. Primarily paddy is widely grown in the delta region and thus it contributes to the majority of the rice production within the state. Along with the paddy, other crops grown in the delta region include groundnuts/oilseeds, cotton, pulses, vegetables in addition to few coconut and areca plantations. Apart from contributing to the basic food requirement of the state, the delta also contributes significantly to the economy of Myanmar.

Main objectives of the Composite Risk Assessment:

The main objectives include:

1. To assess the composite risk along the delta for three major hazards
2. To estimate the probabilistic loss occurring in the delta region with respect to specific hazard
3. Preparation of risk assessment maps displaying information of multi hazard risk across varying geographical units

Data:

Table 5-15: Data Source for Composite Risk Assessment

Element Used in Composite Risk Assessment	Data Source
Population	Central Statistical Organization, Myanmar, Statistical Year Book (2008)
Agriculture	FAO, MIMU, UNEP
Building Typology	MSR Field survey
Vulnerability Curves	TARU Analysis

To carry out the composite risk analysis and to subsequently prepare the composite risk maps; both non-spatial (primary survey information) and spatial data (secondary datasets) were utilized. Primarily, building typology & agricultural data sets were utilized for the risk assessment along with limited demographical details. For estimating buildings under various categories, the data surveyed by Myanmar Survey and Research were used. Similarly, the input from the MSR on the agricultural practices of the region which includes the cropping pattern, seasonal agricultural activity, crop economy was used. This gave insights on agricultural practices of the region and was utilized in the preparation of composite risk maps for the delta region.

The spatial datasets from the FAO and MIMU sources and the primary information from surveys were used for geo-spatial analysis. FAO and MIMU datasets were useful especially to derive the crop production and agriculture sown area at district level. As a part of the composite risk assessment to compute the agricultural risk; the information related to the agricultural area was used at village tract level and later on aggregated to the township level in the analysis. This agricultural area was derived from the Land Use Land Cover (LULC) data of UNEP, after carrying out necessary spatial analysis, especially transferring them at the desired unit level (township, village) for the further usage. The population data of the study area was primarily derived from the MIMU and central statistic organization, Myanmar (statistical year book 2008).

Limitations:

The limitations in carrying out the composite risk analysis were in accessing the following data sets:

1. The flooding simulations were carried out using baseline climate data sets for the period of 1970 to 2000 supported by the results from the primary survey. The availability of the weather information (time series station data) as well as actual inundation data during this period could have improved the modeling results.

2. The population and agricultural patterns analyzed within this study were carried out using the FAO data sets which were collected during the period 1998 to 2002. This is the pre-Nargis situation. The post-Nargis agricultural situation may be different and the availability of Post-Nargis Agricultural data could have improved the loss estimations.
3. The current basin level analysis was carried out considering the existing infrastructure (data that were made available to us during 2010 February to 2010 July period). Construction of infrastructure including dams, weirs and bridges may alter the future fluvial flooding scenarios. Also the summer flows in the rivers may alter the saline/mixed/freshwater boundaries.
4. The administrative maps were obtained from MIMU and FAO. Change in these maps or availability of detailed maps can further improve the results presented within this study.

5.2.4 Composite Risk Assessments: Methodology

Composite Risk (CR) is the expected total loss in a region due to effects of expected hazard risks of the region. Computation of composite risk carried out for present study area is expressed mathematically as:

Composite Risk (CR) = ∑ Elements at Risk (E) x Specific Risk (Currency, MMK)

= ∑ Elements at Risk (E) x Hazard Risk (HR) x Vulnerability (V)

The present assessments of CR for the delta region was carried out at village tract level and aggregated to the township level. The primary data from the field survey pertaining to the agricultural practices of the study area, seasonal activity and building typology of the study area were used for the analysis.

The secondary datasets used in the CR assessment pertaining to demographic details, agricultural details were obtained mainly from MIMU and FAO. The results from the hazard risk analysis detailed out in Chapter 2 were also used. Further, vulnerability curves developed by TARU based on its previous experience in similar housing conditions were used to study the impact of a hazard on particular building type.

Figure 5-18: Element at Risk

Elements at Risk in delta region of Myanmar			
			
Population	Buildings	Agriculture	Livestock

Extensive geo-spatial analysis has been carried out by using the datasets mentioned earlier to derive the GIS based maps. The 'Composite Risk Maps' have been prepared to represent in Myanmar Kyat for the elements at risk.

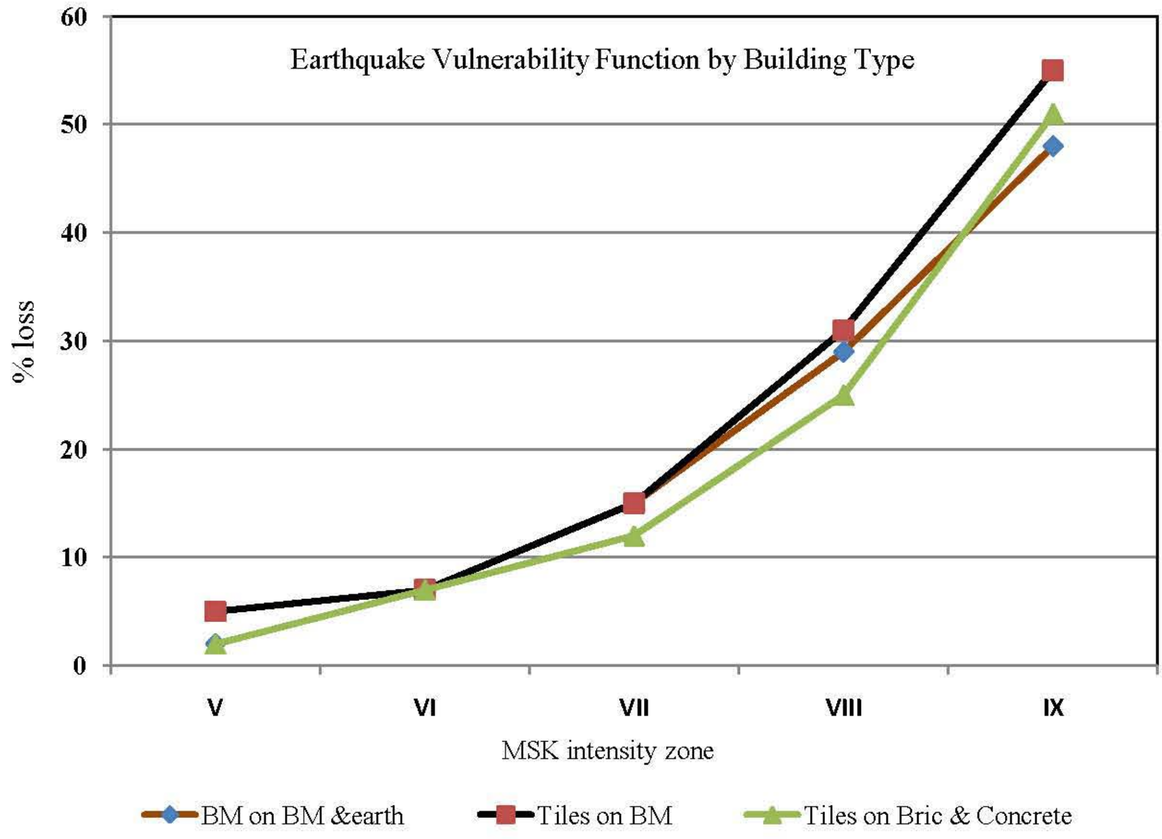
5.2.5 Determination of Losses:

To determine the vulnerability of different rural dwellings (buildings) of the region, lessons and information from primary survey and past assessments of similar nature was taken into consideration. For example, the extent of the damage caused by Cyclone Nargis (2008) in the delta region was used to understand the vulnerability of the building types to cyclonic winds. Similar approach was adopted for flood and earthquake vulnerability assessment. In the absence of detailed and validated information (related to vulnerability of the buildings due to a hazard) from the primary survey, data pertaining to damage from past experiences (TARU, 2005 & peer reviewed publications) were used.

Vulnerability of the buildings was analyzed with respect to the possible return period or the possible maximum damage likely to be caused by the individual hazard. In case of cyclone hazard, the wind speeds obtained from the deterministic model were used as the benchmark for composite risk analysis. Results from 100 year return period were used for estimating the maximum possible damage for the study area.

The exposures of building to these hazards were considered as percentage losses in the present study. Similarly the ground acceleration (in PGA)/ earthquake intensity zones in earthquakes hazard (100 year return period) and the intensity of the floods (50% and 100% increase from normal) i.e. low, medium and high in case of flood hazard were considered in combination with the number of buildings and their respective cost in Kyat to prepare the composite risk maps. Figure 5-19 illustrates the example of the percentage loss of the buildings (building typology as present in the study area) due to Earthquake.

Figure 5-19: Loss due to earthquake hazard to various building types



5.2.6 Approach towards Composite Risk Assessment

The details on hazards of the delta region are presented in "Hazard Risk Analysis" (Chapter 2). The study indicates that there are two frequent hazards (cyclones, floods) which occur in the delta region. Apart from these two, the hazard which may have an impact on the delta region is the earthquake. Present chapter of composite risk assessment includes the estimation of loss to the elements at risk based on the Cyclone, Floods and Earthquake hazard risk assessment.

The assessment of the risk due to cyclone, flood and earthquake becomes important. The data presented in the Chapter 2 provides an overview of the severity of these hazards which have occurred in the delta region in the past and also indicates the possibilities of their recurrence. Their impacts not only affect the population and their dwellings but can also severely affect the agricultural sector which is the economic backbone of the region.

Table 5-16: Hazard Wise Element at Risk

Hazard	Primary elements at risk in delta region	Risk
Cyclone	Population, Building Types	Life and buildings
Flood	Population, Building Types, Agricultural practices, livestock	Life, building types and agricultural practices
Earthquake	Population, livestock	Life

5.2.7 Elements at Risk

Buildings

The Ayeyrawady delta is complex networks of creeks and rivulets. The two important rivers i.e. Irrawaddy and Sittaung flow from the delta region. The geographical setting and physiographic setup of the delta has great influence on the type of dwellings in the region and agricultural practices. Due to easy accessibility of the basic construction material like bamboo and thatch (bio-resources); majority of the dwellings in the delta region are non-engineered in nature. The results from the preliminary survey (rural) conducted in this study indicates that roofs and wall of about 60% of the dwellings within the study area are of Bio-mass types. This increases their vulnerability to Cyclone and Flood hazard.

Agricultural practices

The agriculture in the delta region cater to the basic food requirements of the population as well as its regional economy. Agriculture is widely practiced in the flat land in the delta region as seen in Figure 5-20. The delta region is rich in terms of agricultural practices especially rice cultivation.

Along with rice; groundnut/oil seeds, cotton, maize are some of the other important crops which are grown in the delta region mainly after monsoon. The average flooding conditions as well as maximum flooding conditions above normal (cyclonic or extreme rainfall) can impact the agricultural production of the region. The inundation due to flooding might partially or completely impact upon the crops grown in the region.

The photographs taken during field visits represent the level of inundation with normal tidal conditions in the delta region.

Figure 5-20: Image Showing Agricultural Fields Near River and Creek Face Danger From Inundation

Trees partially submerged due to normal inundation

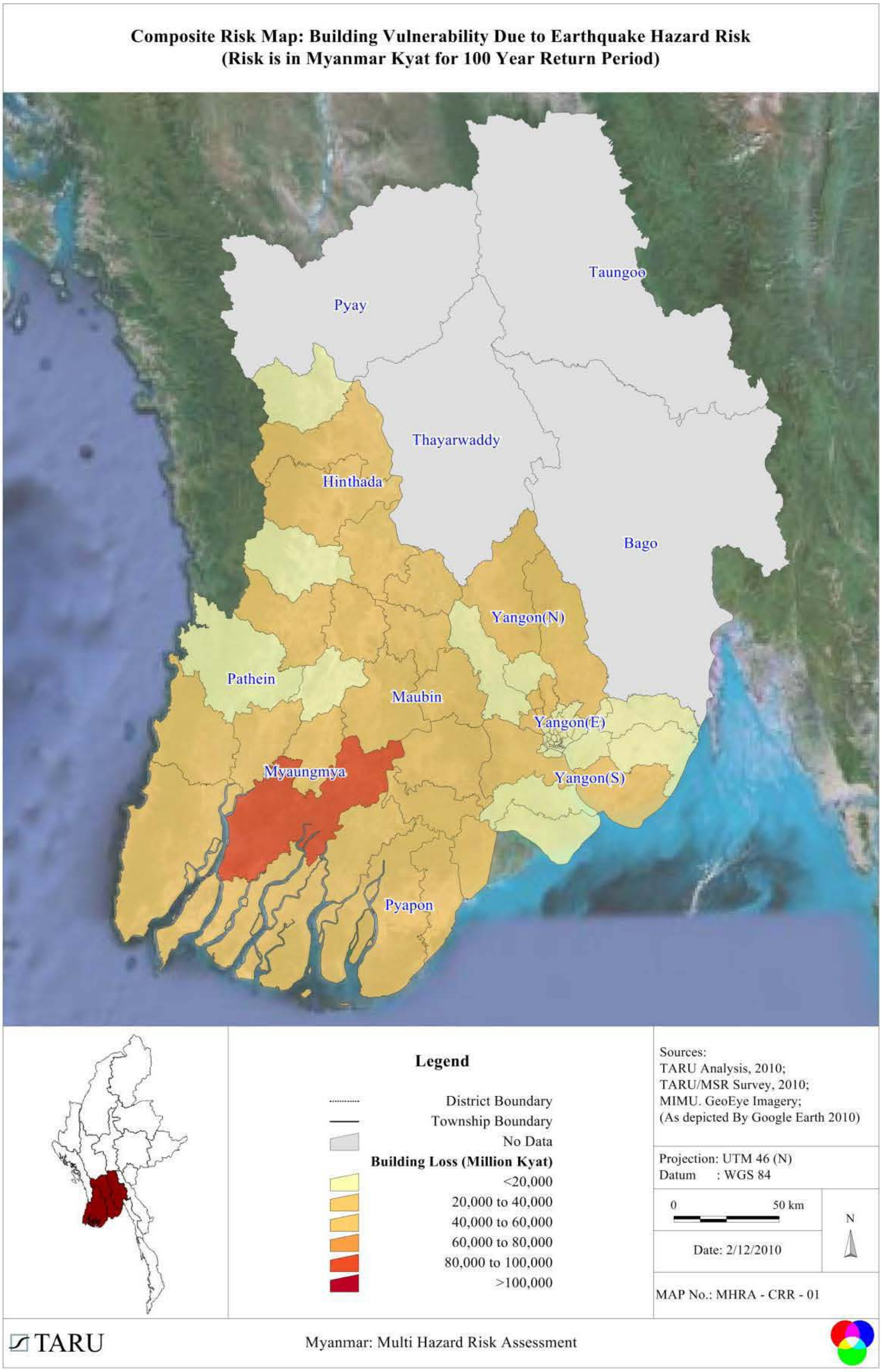
Trees showing water marks of level of tides

5.2.8 Rural Composite Risk Assessment: Earthquake

Buildings within the delta are exposed to major hazards and their typology contributes to their vulnerability. Figure 5-21 represents the composite risk map for three building typologies namely Bio-Mass on Bio-Mass, Tiles on Bio-Mass and Tiles on Brick and Concrete.

The losses were derived from vulnerability function. In case of earthquake the vulnerability function was fine tuned to take into consideration the extent of materials that could be salvaged after the disaster. Based on this possible economic losses (Kyat) from different building types were calculated. The results are presented in the Figure 5-21

Figure 5-21: Composite risk: Earthquake



It is evident from the analysis, the Southern delta region particularly Ayeyarwady division will account to maximum losses due to earthquakes hazard compared to the Western delta region. Nevertheless, the high population density and building typology of Yangon region makes it more vulnerable (loss per sq.Km). Moreover, the active faults like Sagaing fault (active) are also responsible for the increased hazard risk situation. The results obtained in the present analysis are shown in following table.

Table 5-17: Building Loss due to Earthquake

Division	District	Building Loss (Million Kyat)
Ayeyarwaddy	Hinthada	23,897
	Maubin	28,998
	Myaungmya	24,653
	Pathein	19,085
	Pyapon	28,200
Ayeyarwaddy Total		**124,836**
Yangon	Yangon(E)	-
	Yangon(N)	89,382
	Yangon(S)	62,264
	Yangon(W)	-
Yangon Total		**151,646**
Grand Total		**315,003**

The percentage contribution of Ayeyrawady and Yangon division to the total losses are 40% and 48% respectively. The higher estimation of losses within the Ayeyrawady division is mainly due to the sheer size of the division which encompasses around 33,300 sq. km in comparison to Yangon which covers 10,250 sq.km.

Figure 5-22 shows an example of building type of the rural delta region. The photographs show buildings and engineering structure at risk due to an earthquake hazard. It is indicative that the construction material used and the density of the building can cause severe damage in case of high magnitude earthquake, the collapse of such buildings might also lead to severe loss of life.

On the other hand, where the construction material is bio-mass, the severity of the damage remains less as the cost for reconstruction of such structure is not much as well as the chances of the recovery of the material remains high. This is reflected in the maps illustrating the composite risk from earthquake on the bio-mass on bio-mass category of the buildings. On the other hand, the damages to life and livestock from bio-mass dwellings/structures may be relatively minimal. But, such considerations were not included within the economic loss estimation.

Further, most of the delta region is covered with alluvial soil and the subcategories of it. The foundations of engineering structure like bridge seen in the photograph can be at higher risk due to collateral damages caused by liquefaction hazard as the groundwater of the region seems also to be near surface.

Figure 5-22: Rural Street & Bridge at Risk Due to Earthquake Hazard

Source: TARU/MSR Field survey, 2010

5.2.9 Rural Composite Risk Assessment: Cyclone

Cyclone risk to building categories were carried out following the methodology similar to that of earthquake. In addition, this composite risk analysis also includes the possible impact of cyclonic winds on rice cultivation. The building types which mainly comprise of bio-mass on bio-mass and tin on bio-mass are at relatively high risk along with the population residing. On contrary to the earthquake analysis, the Type III building which were less susceptible to earthquakes are highly vulnerable to the cyclone hazard risk.

Figure 5-23 shows examples building type in the rural delta region. The photograph shows that the roofs of the dwellings are covered by tin sheets. In case of cyclonic event, the sheets can fly due to high wind speed. This can bring economic loss to the building as well as life.

Figure 5-23: Vulnerable Houses in Delta Region

The loss to rural buildings due to cyclone will be as high as 1.2 Trillion Kyat (Table 5-18). The building losses distribution over Ayeyrawady and Yangon division are 70% and 30% respectively. Risk to buildings due to cyclone is much higher than compared with earthquake hazard. This suggests that the delta region is more vulnerable to Cyclonic losses (20 times) than an earthquake.

Similar to buildings, cyclonic losses were analyzed for rice; a dominant crop cultivated in the delta region. In this study a worst case scenario was taken into consideration for the calculation of the losses. The scenario is such that a cyclone occurring over the region during the middle cropping periods i.e. September to November. The estimation of these losses does consider the full crop loss which may not be the case in situations similar to Nargis where the event occurred during/before the land preparation. Nevertheless, the land if affected by storm surge, especially within the saline regions may lead to crop losses for not only that year but also for the following year thereby increasing the loss. Due to such complexities, in this study, the maximum loss for the worst case scenario was taken into consideration.

The analysis indicates that Myaungmya district of Ayeyrawady division show highest risk to rice crop loss in the case of a cyclonic event. The estimated losses account to 399 Billion Kyat (Table 5-18). On an average within each district the losses are above 100 Billion Kyat except for Yangon (E) and Yangon (W) for which no information was available (or not much cultivation is practiced due to urbanization).

Table 5-18: Loss to Rural Buildings & Rice Crop Due to Cyclone (million Kyat)

Division Name	District	Buildings	Rice
Ayeyarwaddy	Hinthada	174,027	210,577
	Maubin	122,002	137,994
	Myaungmya	220,863	399,073
	Pathein	173,366	300,636
	Pyapon	145,012	286,547
Ayeyarwaddy Total		835,272	1,334,830
Yangon	Yangon(E)	0	0
	Yangon(N)	160,416	158,792
	Yangon(S)	139,555	296,755
	Yangon(W)	0	0
Yangon Total		299,972	455,548
Grand Total		**1,135,245**	**1,790,379**

Source: TARU Analysis, 2010

The composite risk estimation for the cyclone hazard was carried out using collective loss information of building and rice crop. Figure 5-24 represents the composite risk map due to cyclone hazard. From the two division study i.e. Ayeyarwady & Yangon (no building/household information of Bago division was available) it can be inferred, that Myaungmya accounts for the maximum loss account to over 21% of the total loss. The distribution of losses within Ayeyarwady and Yagon are 74% and 26% respectively.

Composite risk map for the building types in the delta region is presented in the Figure 5-24.

Figure 5-24: Composite Risk: Cyclone (Building Types)

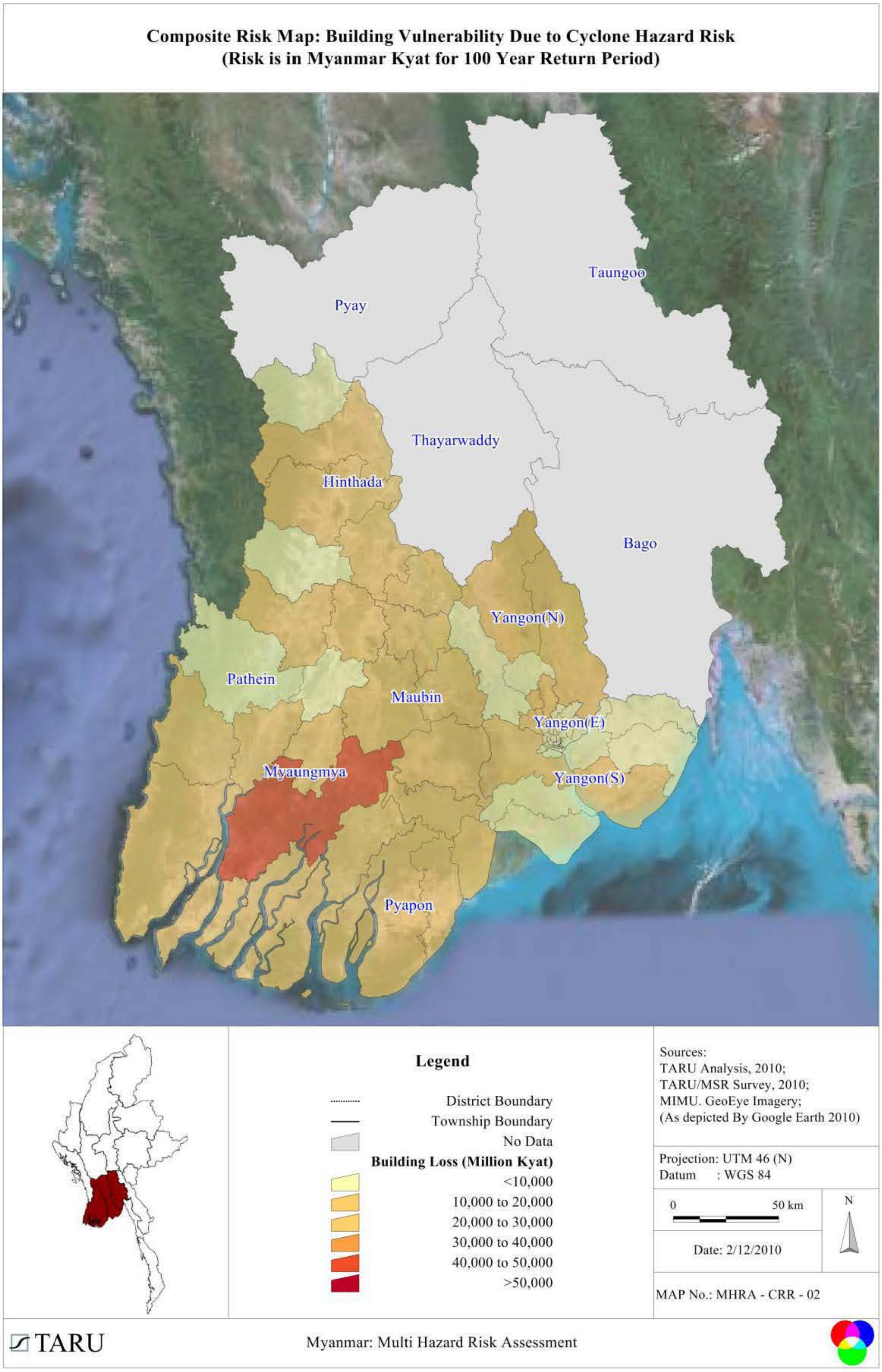


Figure 5-25: Composite Risk: Cyclone (Rice)

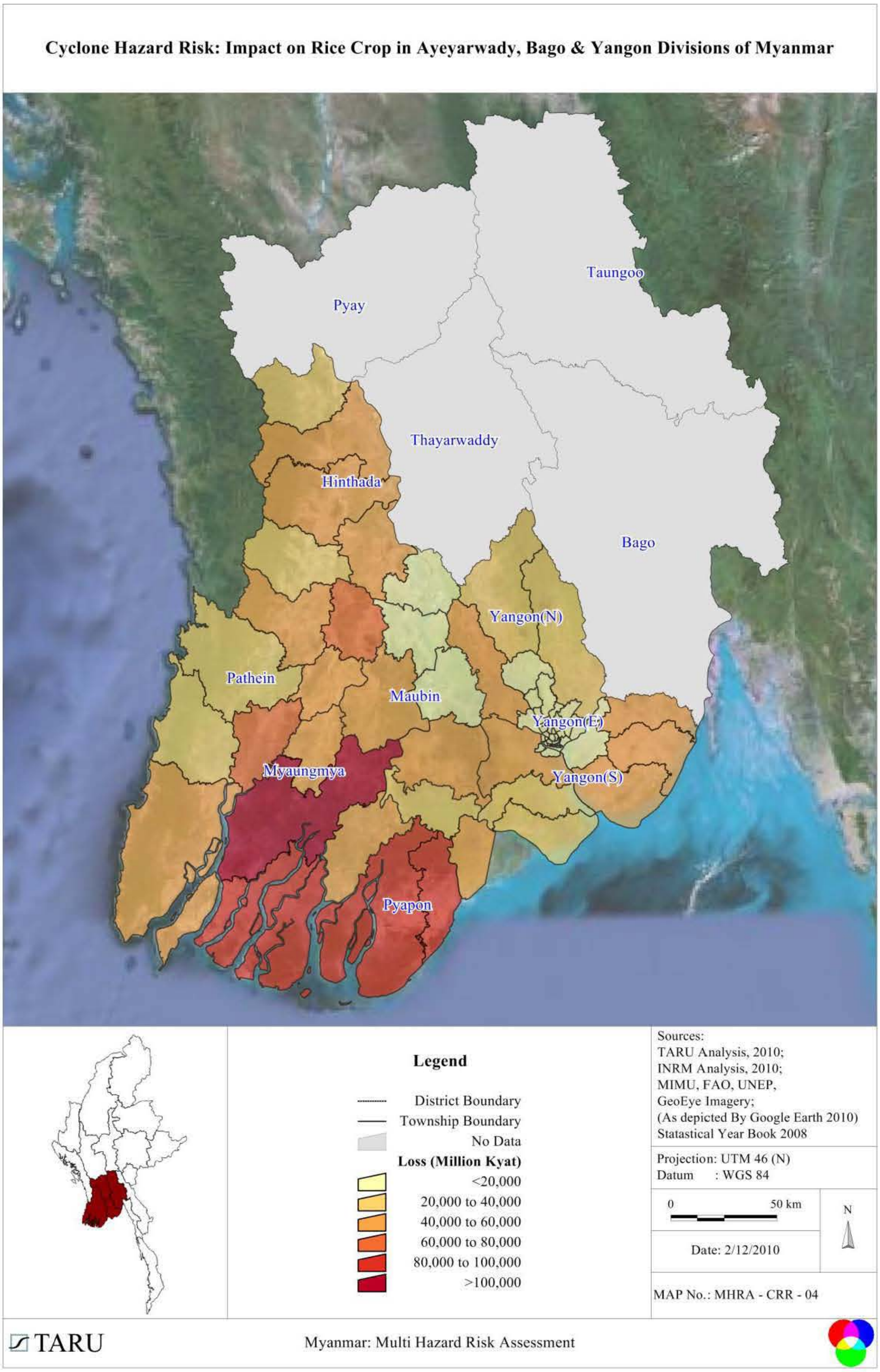
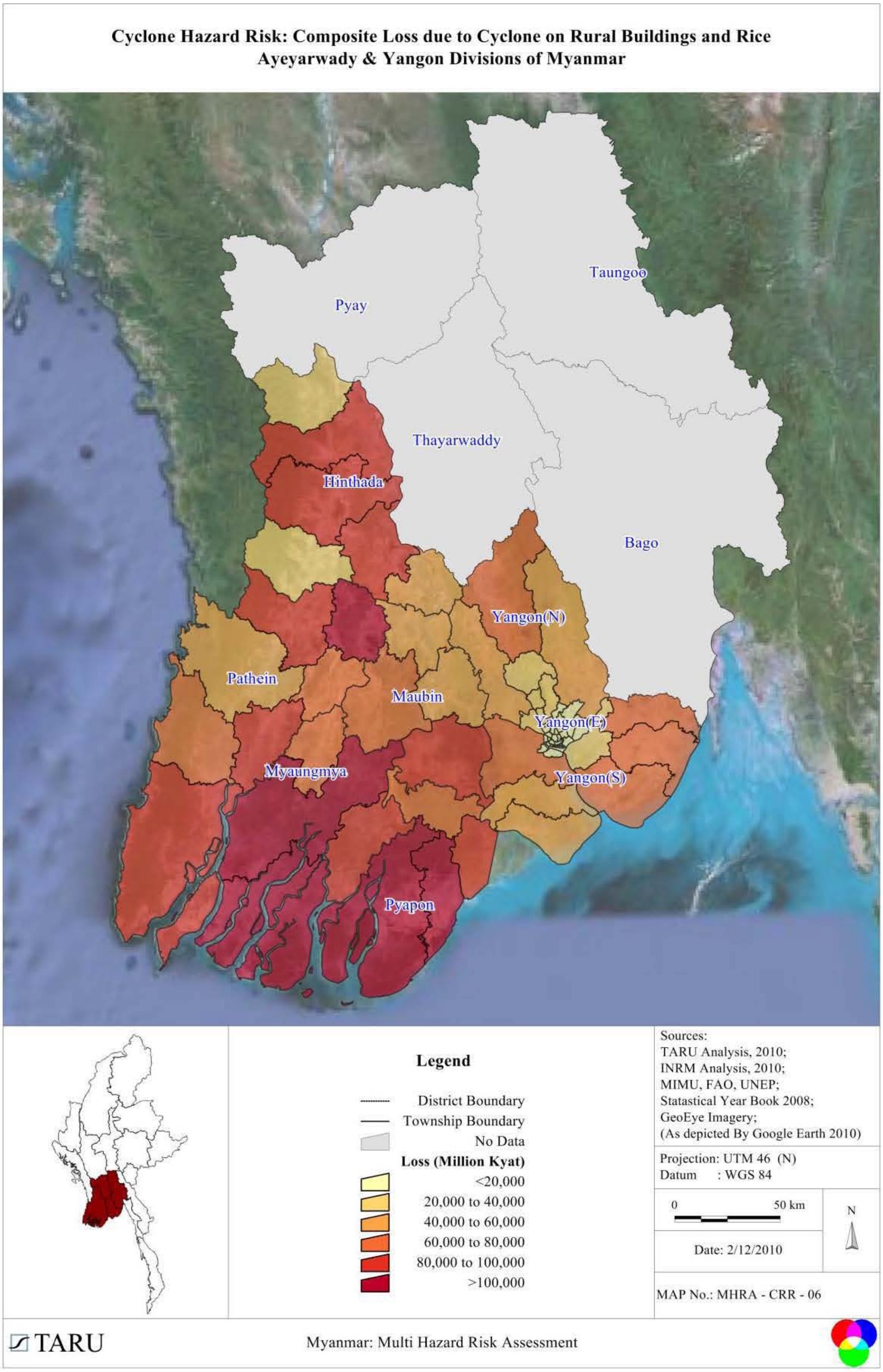


Figure 5-26: Composite Risk: Cyclone (Building + Rice)



5.2.10 Rural Composite Risk Assessment: Flood Losses

Most of the rural dwelling and agricultural practice in the delta region is along the floodplains. The delta is low lying and is prone to inundation due to both fluvial and pluvial floods. As explained in Chapter 2 the results obtained in Flood Hazard Risk modeling were used for this composite risk assessment.

Southern and Central Ayeyrawady delta regions are more prone to losses from floods. The photographs shown here with stilted house as high as about 5 feet further supports the fact that the region is facing the frequent flooding conditions. Flood risk loss estimations for the buildings are 403 Billion Kyat and 464 Billion Kyat for pluvial and fluvial floods. Most of the townships of Myaungmya and Pyapon district exhibit high losses. Similar loss is also exhibited by central Pathein and Southern township of Maubin districts.

Table 5-19: Loss Due to Pluvial and Fluvial Flood (Million Kyat)

Divison	District	Pluvial Flood (100%)	Fluvial Flood
Ayeyarwady	Hinthada	213,709	84,004
	Labutta	0	34,013
	Maubin	0	58,285
	Myaungmya	0	91,789
	Pathein	56,043	92,055
	Pyapon	0	59,210
Ayeyarwady Total		**269,752**	**419,358**
Yangon	Yangon (East)	0	0
	Yangon (North)	134,074	42,202
	Yangon (South)	0	3,198
	Yangon (West)	0	0
Yangon Total		**134,074**	**45,400**
Grand Total		**403,826**	**464,759**

Agricultural losses due to floods depend on the type of crops grown (flood tolerance), the stages of growth of the crops or inundation of storage spaces, if the floods occur after the harvest. Only generic loss estimation can be done since the exact period of flooding is uncertain. In this exercise, April- to June and September to November periods, which are cyclone periods, were used for analysis. In most parts of the study region, Paddy is the main crop, accounting for nearly 99% of the monsoon cropped area in the delta. Therefore agricultural loss due to floods considers worst case scenario of floods during middle and late cropping season.

Due to paucity of data on agricultural equipments, only crop production losses were considered. The analysis carried out indicated loss of about 795 Billion Kyat due to flooding condition in the delta region wherein, distribution of the losses is 48% and 2% for Ayeyrawady and Yangon divisions respectively.

Table 5-20: Rice Crop Loss

Division	District	Rice Loss (Million Kyat)
Ayeyarwaddy	Hinthada	16,398
	Maubin	49,931
	Myaungmya	160,386
	Pathein	88,634
	Pyapon	63,324
Ayeyarwaddy Total		**378,675**
Yangon	Yangon(E)	-
	Yangon(N)	11,726
	Yangon(S)	7,260
	Yangon(W)	-
Yangon Total		**18,987**
Grand Total		**795,326**

Source: TARU Analysis, 2010

Pathein, Myaungmya, Maubin, Pyapon and Western Yangon districts appears to be at high flood risk (maximum flooding). The composite risk for the rice crop was analyzed in conjunction to the building loss. The results (Figure 5-27: Composite Risk Map: Flood (Building types)) indicates that the Central delta region of Ayeyrawady particularly Myaungmya district appears to be at high risk. This might be due to the higher rainfall from the catchment areas in the region as observed in the flood modeling.

Stilted house indicating preparedness against flooding
(height of person for scale)

Water mark on vegetation
Indicating tidal inundation and idea
of later spread of water in floods

Figure 5-27: Composite Risk Map: Flood (Building types)

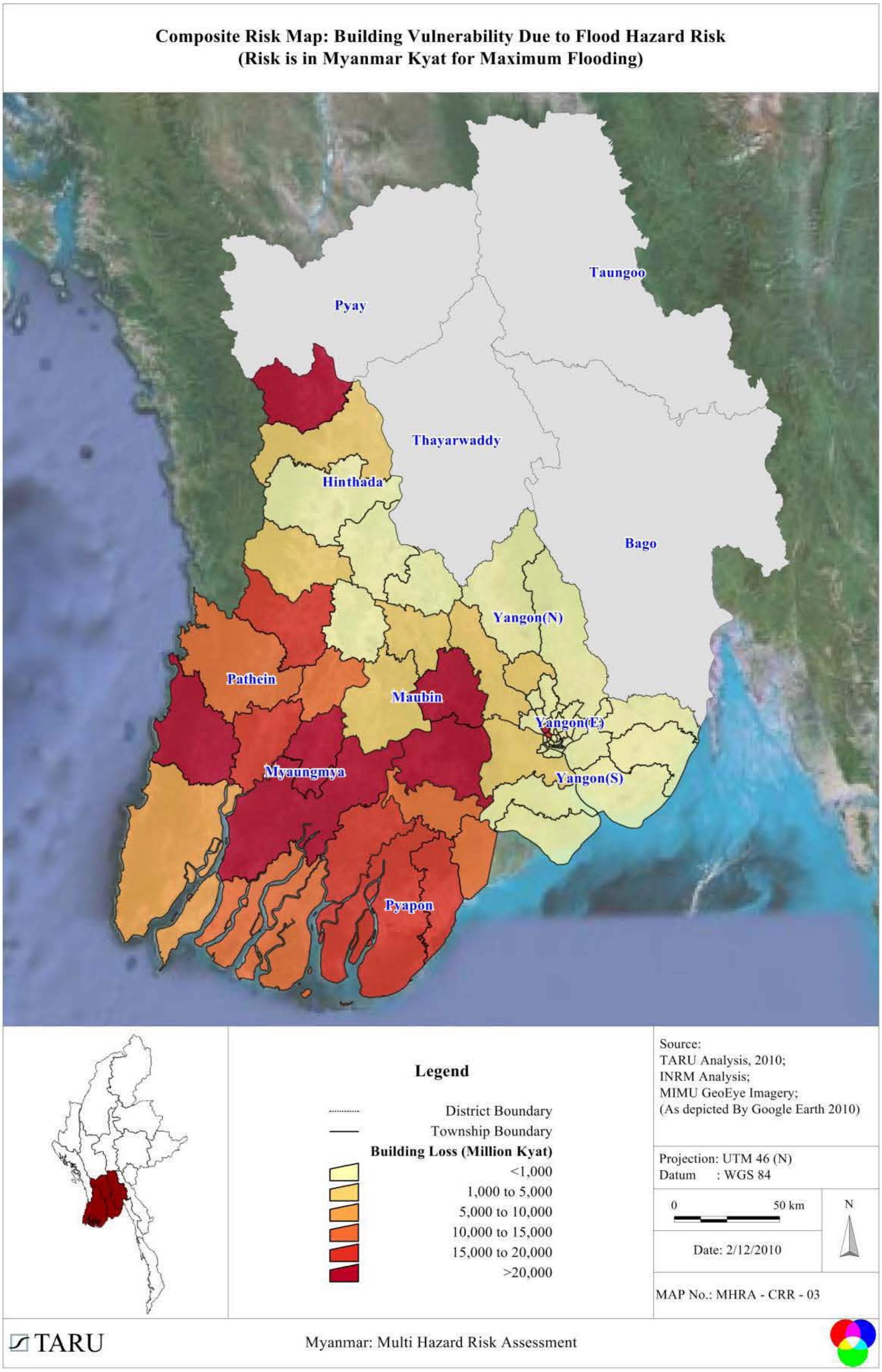


Figure 5-28: Composite Risk Map: Flood (Rice)

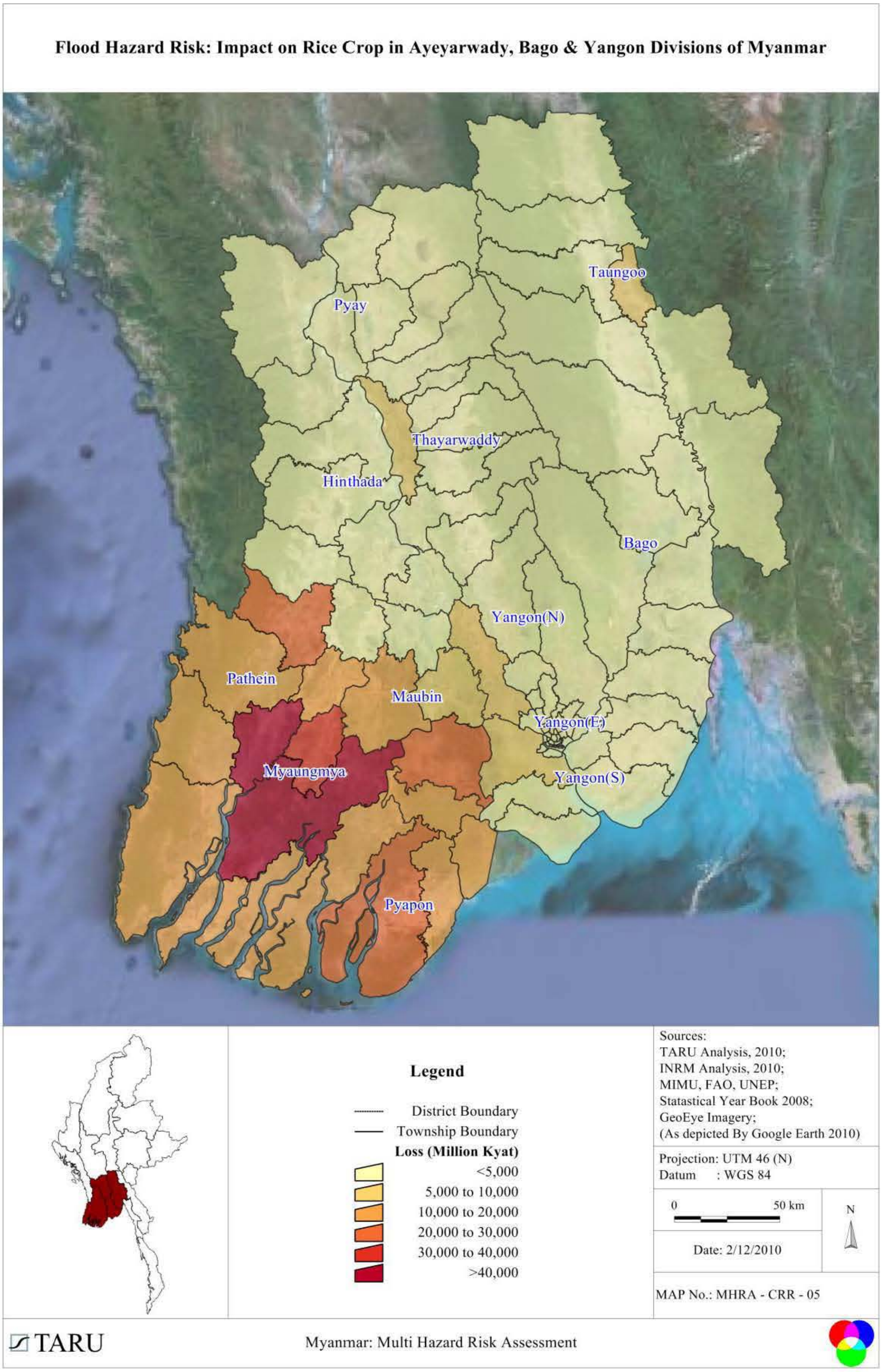
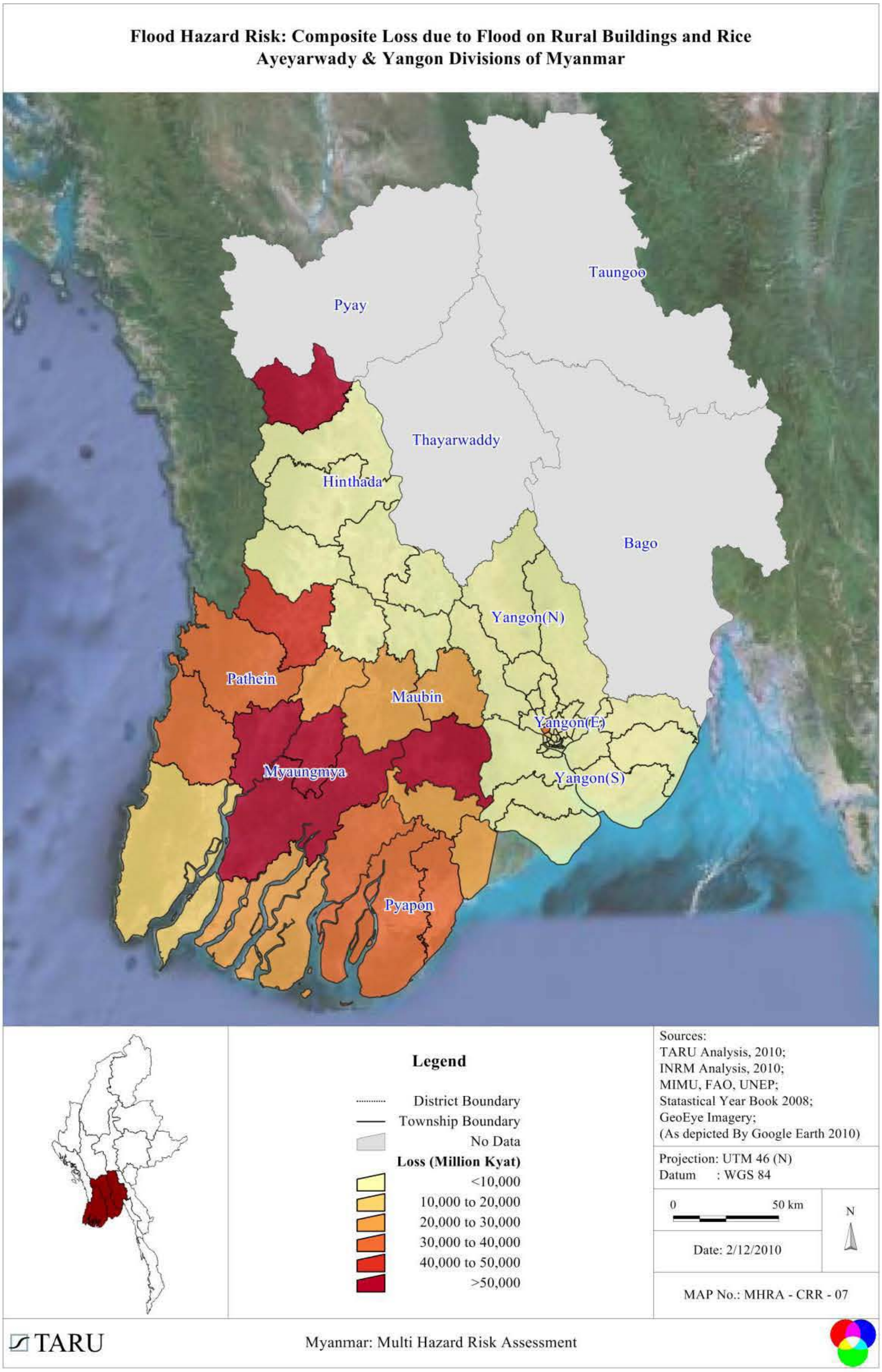


Figure 5-29: Composite Risk Map: Flood (Building + Rice)



5.2.11 Summary

The rural composite risk assessment of the Myanmar delta region was carried out for three main hazards (Cyclone, Flood and Earthquake). Most of the delta region is covered by the semi-engineered or non-engineered type of the building. Based on the survey conducted in the delta region, three main categories were recognized viz. Bio-mass on Bio-mass, Tiles on Bio-Mass and Tiles on Brick and Concrete. Out of these Bio-mass on Bio-mass covers about 60% in the present study area of delta region. To determine the vulnerability of different rural dwellings (buildings) of the region, lessons and information from primary survey and past assessments of similar nature was taken into consideration. For example, the extent of the damage caused by Cyclone Nargis (2008) in the delta region was used to understand the vulnerability of the building types to cyclonic winds. Similar approach was adopted for assessing flood and earthquake hazard risk. In the absence of detailed information to validate data pertaining to damage from past experiences were used.

The delta region is rich in terms of agriculture especially rice cultivation. Along with rice; groundnut/oil seeds, cotton, maize are some of the other important crops which are grown in the delta region. This agriculture practices not only caters the basic food requirements of the delta region; but is also an important part for the overall economy of the Myanmar. Rice being the most important crop grown in the Southern delta region, it was considered for the composite risk assessment. Further, rice is the predominant crop within the delta for which the cultivation begins in the month of April (early monsoons) and continues well into the winter. The early and late monsoon periods are also prone to cyclone and flood hazards. Losses estimation was therefore conducted for this crop in detail.

The results from Earthquake hazard risk indicate that the Southern delta region, particularly Ayeyarwady division account to maximum losses compared to the Western delta region. Nevertheless, the high population density and building typology of Yangon region makes it more vulnerable (loss per Sq. Km). Moreover, the tectonic element like Sagaing fault is also responsible for the increased hazard risk situation. The results obtained in the present analysis are shown in following table. The percentage contribution of Ayeyrawady and Yangon division to the total losses are 40% and 48% respectively. The higher estimation of losses within the Ayeyrawady division is mainly due to the sheer size of the division which encompasses around 33,300 sq. km in comparison to Yangon which covers 10,250 sq.km.

In the case of cyclone, composite loss estimation included buildings as well as crop loss. On contrary to the earthquake analysis, the Type III building which were less susceptible to earthquakes are highly vulnerable to the cyclone hazard risk. The building losses distribution over Ayeyrawady and Yangon division are 70% and 30% respectively. Risk to buildings due to cyclone is much higher than compared with earthquake hazard. This suggests that the delta region is more vulnerable to Cyclonic losses (20 times) than an earthquake. The analysis indicates that Myaungmya and Pyapon districts of Ayeyrawady division show highest risk to rice crop loss in the case of a cyclonic event. The composite risk estimation for the cyclone hazard was carried out using collective loss information of building and rice crop. The distribution of losses within Ayeyarwady and Yagon are 74% and 26% respectively.

From the overall analysis it is also evident that cyclone accounts for the maximum possible damage in comparison with Earthquake. The building loss due to cyclone and earthquake account to 1.1 and 0.4 Trillion Kyat respectively. One should also understand the probability of a cyclone passing through the entire delta is less likely in comparison to an earthquake which may have an impact on the entire delta region. Further, the amount of materials that can be salvaged after an earthquake will be far greater than a cyclonic event.

The delta is low lying and is prone to inundation due to both fluvial and pluvial floods. Based on the present indicative studies it was observed that most of the townships of Myaungmya and Pyapon district exhibit high losses. Similar loss is also exhibited by central Pathein and Southern township of Maubin districts. In this exercise, April to June and September to November periods, which are cyclone periods, were used for analysis of composite risk for crops due to flood hazard. Based on the analysis it was observed that distribution of the losses is 48% and 2% for Ayeyrawady and Yangon divisions respectively. Pathein, Myaungmya, Maubin, Pyapon and Western Yangon districts appears to be at high flood risk (maximum flooding). The composite risk for the rice crop was analyzed in conjunction to the building loss. Central delta region of Ayeyrawady particularly Myaungmya district appears to be at high risk for the composite risk which includes building losses and with rice cultivation.

Chapter 6: A BRIEF REVIEW OF SECTOR RECOVERY PROGRAMMES

Background

The cyclone Nargis struck the Ayeyarwady Delta on the 2nd and 3rd of May 2008 and caused an unprecedented scale of destruction in Myanmar. Cyclonic winds up to 200 kilometres per hour speed and a tidal storm surge of 3.6 metres high caused different types of damage. It affected more than 7 million people out of which 2.4 million people were severely affected and more than 140,000 people were reported killed or missing (TCG, 2010). About 37 townships were significantly affected by the cyclone in Ayeyarwady and Yangon Divisions. The cyclone-affected area of the Ayeyarwady Delta covers about 23,500 square kilometres (TCG 2008a). The widespread destruction affected the livelihoods of the people living in the delta - the 'rice bowl' of the country. The Nargis Cyclone underlined the vulnerability of settlements, people, buildings, basic infrastructure (especially water supply and transport) as well as livelihood base in the delta region.

Cyclone Nargis submerged about 63% (783,000 ha) of paddy land in 19 townships, damaging standing paddy crop equivalent to about 80,000 tonnes of grain, destroying 707,500 tonnes of stored paddy and milled rice as well as 85% of seed stocks, and killing many draft animals, including 50% of buffaloes. Almost 28,000 fishermen died or remain missing. Half of approximately 200,000 inland multi-purpose boats,2 and about 70% of all fishing gear were lost, and 15,000 ha of fish and shrimp ponds were badly damaged (TCG, 2008b).

The disaster also caused widespread destruction to homes and critical infrastructure, including roads, jetties, water and sanitation systems, fuel supplies and electricity. A large number of water supplies were contaminated and food stocks damaged or destroyed. The winds tore down trees and power lines, while the accompanying storm surge submerged countless villages.

While the huge human losses were the main issue in the early post Cyclone phase, drinking water, food and shelter issues emerged as major issues soon after the event (MSR 2008). While most of the rural houses were extensively damaged due to cyclonic winds, storm surge and pluvial flooding contaminated the water sources in villages as well as towns. A significant proportion of rural houses(mostly biomass based) were fully damaged by cyclonic winds, while the tin as well tiled roofs (mainly in urban areas) also got extensively damaged. The rain damage on roof less buildings damaged household assets, stored grains etc. Most of the stored grains were lost both in houses as well as rice industries located along the river banks.

Since the cyclone occurred in the pre/early part of the Monsoon paddy season, some of the interior villages and those located in the fresh water zone without storm surge impacts could have started the farming operations, even though with the considerable delay and constrained by death of draught cattle. Most of the human and livestock deaths were ascribed to storm surge and flooding.

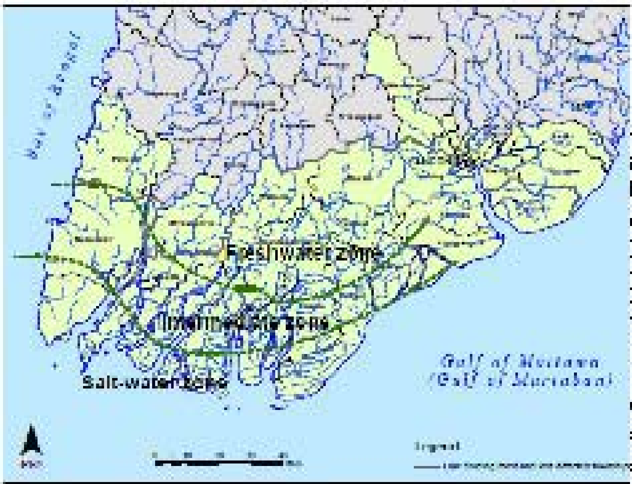
6.1 GEOPHYSICAL AND LIVELIHOOD CONTEXTS

The delta is an under developed region despite being the rice bowl of Myanmar due to lack of reliable safe water supply, limited communication infrastructure, almost total reliance boats for transport and near total reliance on agriculture, fisheries and salt pans for livelihoods. Migration is another source of cash income, mainly for rural households.

The terrain is flat and intersected by a myriad network of distributaries, making this region complex in terms of risks and also constrains the road building. The soils are mostly clayey with pockets of sands. The water table is shallow and often saline near the coastal areas. Deeper aquifers are mostly saline in most parts of the lower delta. The river water in the lower ends of the distributaries is saline or brackish during January to May period. Mangrove patches and wild growth is common at the river banks. A type of palm leaves commonly found along the river banks is used as roofing material, while locally grown bamboo is used for structural members of rural houses. Wood is another common building material.

The whole delta can be divided in to saline, intermediate and fresh water zones. Especially in the middle and upper parts of delta, there are several perennial water bodies used for aquaculture. Single crop paddy (monsoon), fisheries and salt making are most common livelihoods in saline zone, while two crop agriculture, inland fisheries, pottery and trade are more common livelihoods in the intermediate and fresh water zones. Several weirs and canal systems provide irrigation to fresh water and intermediate zones. Compared to the freshwater zone, poverty is more in saline water zones.

Figure 6-1: Agriculture Zones in the Delta, Potential Impacts and Typical Characteristics

Map Showing Different Agricultural Zones in the Delta	Potential Impacts	Typical Characteristics
 *Source : Adapted from PR4 Report based on FAO, ERCU et.al (2009)*	All Zone may get pushed further north due to (a) Destroyed Mangrove Barrier, (b) Sea level rise. This will cause additional area from double crop to single crop	In Fresh water zone farming dominates with **double cropping** of monsoon and summer paddy. **Vegetable cropping** and small and medium livestock holdings
		The intermediate zone faces dry season salt water intrusion. Economic activity includes **single crop** - monsoon paddy, followed by pulse in few areas. Also **river fishing** and small live stock rearing
		In Salt water zone **fishing** dominates with other activities including commercial **shrimp farming**, **salt making** and monsoon paddy (with low yields)

Traditional agriculture is mostly practiced in Delta region and it is highly dependent on draught animals. The agriculture practices are traditional and use of power tillers and tractors as well as improved seeds, fertilisers and pesticides is very low. The land holding pattern information shows that about one third or more of the rural agriculture dependent households are land less and among the rest, large proportions are subsistence farmers. Also poverty Headcount Index is higher than one fourth of the population in Ayeyarwady delta region except for Yangon District with 17% of the population. About half or more of the working population is engaged in agriculture. (MNPED & UNDP 2007). Opportunity costs of human labour are very low except during farming season and only option for landless and subsistence farmers to supplement their income is manual labour in nearby towns, seasonal fishing, boat building and house construction related activities, pottery, rice mills or migration. Even though the list of activities look large enough, the livelihood portfolio of the individual households are restricted to two or three activities only. Cash incomes are quite low as reflected by the very few shops found in rural areas and the range of merchandise in the small towns.

Industrial sector is underdeveloped. Income levels are low and the delta exports significant amount of rice, fish, salt and pulses, which is the main source of cash. Under these livelihood contexts, reviving agriculture and fisheries are essential for rehabilitation.

In contrast to the livelihoods and lifeline infrastructure, Delta region fairs well with adult literacy rate of 89.8% in 2005 (ibid) in Ayeyarwady Division and satisfactory coverage of households with sanitation unlike the neighboring countries of South Asia. The households with access to safe drinking water was reportedly about 36% in Ayeyarwady delta region and access to improved sanitation was reported at 74.8% in 2005 (GoUM &UNDP [11]). Access to health facilities is limited with few basic health centers covering a group of villages.

Village level institutions are in early stage of evolution and the religious organizations play an important role in the village life. The CBDRM activities need to be embedded within the community level organizations to ensure sustainability.

6.2 DISASTER RESPONSE

The government as well as the people were shocked by the enormity of the Cyclone disaster and it took nearly a week to initiate full scale relief efforts, mainly due to nearly complete breakdown of critical infrastructure including communication and transport system. Exposure generated by the absence/unavailability of goods and services also increased the vulnerability. Though there have been initial challenges to majority of aid agencies to participate in relief operations, it changed with Government decision on allowing aid agencies to work in the delta region. The Tripartite Core Group (TCG) consisting of the Association of South East Asian Nations (ASEAN), the Government of Myanmar and the United Nation was formed on 31 May 2008 in response to the needs of people affected by Cyclone Nargis (TCG 2008a). Soon, already operational and new INGOs also started providing relief as well as initiated rehabilitation interventions.

TCG launched a three year recovery framework called the Post-Nargis Response and Preparedness Plan (PONREPP) covering the period from January 2009 through December 2011(TCG2008b). This provided a platform for the transition from emergency relief and early recovery towards medium-term recovery in the eight operational sectors including Livelihoods; Shelter; Education; Health; Water Sanitation and Hygiene; Protection of vulnerable groups; Environment and Disaster Risk Reduction (DRR). These also initiated the focus to shift from relief and rehabilitation to mitigation and preparedness.

The disaster risk reduction was treated as a standalone sector as well as a cross cutting theme to be integrated into sectoral interventions for the long term sustainability. Five broad outcomes anticipated i.e.

a. community base disaster preparedness and enhanced risk awareness;

b. end-to-end multi hazard early warning systems with standard operating procedures;

c. hazard risk mitigation to sustain developmental gains;
d. integrating disaster risk reduction in the recovery and reconstruction process; and
e. strengthening policy frameworks and institutional mechanisms for disaster risk management.

These had been identified to be achieved through adopting multi-hazard framework. The TCG also initiated a two complementary monitoring process of the sectoral programs, the Social Impacts Monitoring (SIM) survey and Periodic Review (PR) series of assessment on six monthly basis to provide data and information on the achievements of the response and mid-course corrections. The Periodic Review IV (PR IV) is the fourth in a series (released in July 2010) of periodic assessments that provides the status and needs at the household level through quantitative estimates, while Social Impact monitoring III (SIM III) the third in the series (released in July 2010) provides the qualitative information on impacts.

This report analyses sectoral findings of PR IV and SIM III, along with primary surveys and field visits and other data to provide input to future recommendations on sectoral priorities in Disaster Risk Reduction (DRR) and Community Based Disaster Risk Management (CBDRM) initiatives. The filed visits were done in 2010, nearly two year after the event, therefore some of the traces of extent of damage and early rehabilitation information could be interpreted through secondary data only. The filed observations indicate that most of the traces of observable damages have been wiped out by the peoples own efforts and interventions. The visiting team could not find any trace of temporary shelters. This indicates the resilience of the system, especially rural housing and livelihoods.

6.2.1 The Early Response

During the initial weeks, response was initiated by the national government and local agencies including the Government Departments of Myanmar, the Myanmar Red Cross Society, the private sector, a combination of religious groups, NGOs and CBOs (both existing and newly formed), spontaneously-formed civic groups. Some of these local organisations had neither direct working experience in the delta themselves, nor of emergency response work. They had to face major challenges of transformations in scale and scope. Their systems were weak and did not always conform to the scale of the emergency and sometime lacked depth of engagement. This was further accentuated by very real logistical difficulties of working in the affected areas, most of which were un-accessible or accessible only by air or boat and a limited availability of boats (with most of them destroyed or damaged).

With limited road access, most boats stock damaged, some of the villages could be reached only after a fortnight or more. This also constrained the regional damage assessment as well as prioritization of action across the affected areas. It was acknowledged by many agencies, that the early response was not so efficient, organized or coordinated. Some of the INGOs also mentioned the duplication of activities and felt the need of better coordination.

It took several weeks after Nargis struck, for the Myanmar's authorities to provide access to new international agencies offering relief. The initial phase of the response was predominantly driven by national operators, who had little exposure to the modalities of disaster response practiced by international organizations. With the government formalities taking time, water transport systems damaged, there was considerable delay in the initial response by the pre-existing agencies. However, those organizations which were already working in the country were less risk-averse and were less constrained by issues of access as well as mandatory permissions required from the government. INGOs such as ActionAid, Care International and few others who had their presence in Myanmar- though not necessarily in the delta region- pooled their local resources and personnel from other parts of Myanmar in their early response phase. Though they also faced with challenges of scaling up operations as before Nargis they were handling small and low budget programme largely run by an expatriate members of staff plus few support interns. In nut shell, following main common issues were faced by most of the agencies involved in the early response phase:

1. Breakdown of transport system amplified by delays in getting permission
2. Insufficient existing institutional infrastructure in the delta areas.
3. Mismatch between needs/priorities of the affected and resources made available
4. Lack of sufficient trained staff to handle large scale emergency
5. Limited budgets available to manage the scale of tasks necessary
6. Coordination of efforts between multiple agencies.

According to SIM-I conducted in November 2008, aid providers rarely considered needs and priorities as identified by the village committees or individual villagers. It highlights "Aid providers tended to come with pre-identified assistance and pre-identified targeting mechanisms, rather than giving villagers real decision-making power in what assistance was provided and how it was targeted" On the upstream end, "providers did not consult them during the planning process and as a result assistance had not focused adequately on the most marginalized and poorest households" (TCG 2009).

Most of the interventions in early phase which can broadly be referred to the first six months of operation i.e. during May 2008 to December 2008, were focused on providing immediate relief. This mostly included provision of food, drinking water, cleaning of wells and ponds and provision of temporary shelters. The overall focus during this period was on protecting lives especially to vulnerable (including children), ensuring availability of food, prevention of outbreak of water borne diseases via provision of safe drinking water and cleaning water ponds, safe living through provision of materials for temporary shelters, and other basic items such as cloths, kitchen utensils and storage vessels.

This was also the phase which provided initial joint assessments and formed TCG and developed next three years plan for a coherent approach by various agencies. This provided a platform for the transition from emergency relief and early recovery towards medium-term recovery. These also initiated the focus to shift from relief and rehabilitation to recovery, mitigation and preparedness. One of the positive outcomes of this phase was the initiation of the involvement of many international agencies, which paved the way for further action in the subsequent phases.

Lessons learnt and possible options:

1. Communication: There is urgent to protect the communication infrastructure by creating sufficient redundancies, especially in emergency communication modes through use of human communication links through informal methods and technology dependent systems (mobile telephony, wherever coverage is available). This is important since the travelling time between nearest towns and most distant village by boats can be 6 hours or more.
2. Transport: Transport infrastructure, especially sufficient number of boats should be available for use immediately after the disaster. Using the respite time[12] of nearly 12 to

[12] Respite time is the period between receiving the information about the possible event and actual event. Depending on the advance warning time and the message reaching the last mile, it can vary between days to 0,

24 hours, boats maybe withdrawn from water (beaching) and stored and tied to firm objects away from the water. Also boat engines may be stored in high places, where the surge/flood in unlikely to reach. The places can include religious places, schools and other safe buildings which are located on high ground. Sufficient fuel, lubricants and spares should also be stored safely, so that the transport system can function for at least one week after the disaster. Formal training on maintenance/emergency repairs can be included as part of the CBDRM activities.

3. Drinking water: Safe drinking water is a major issue during and after floods. Destruction of houses and toilets result in use of pit and floating toilets, which can contaminate the river and shallow groundwater. It is suggested that at least one week's need for chlorine tablets for water purification and bleaching powder for disinfecting water sources for the whole village may be kept ready at each village in safe place within or near the village. The safe water sources like tube wells may be protected by withdrawing pumps and closing them with water proof caps to protect them from floods and storm surges.
4. It may be difficult to protect all food grains in case of cyclones and storm surges, given the housing types prevalent in the Delta region, especially in rural areas.. However, provision of food grains soon after the disaster should be given a high priority, which would need storage of grains in safe locations sufficient for at least one week of supply as well as protecting the transport links, especially boats.
5. Health & Hygiene: The emergency medical kits and training of volunteers can be extended and this system may be internalized within each village. The CBDRM activities have already included these in their training programmes, but its sustainability should be ensured by anchoring these within the village level institutions. A list of vulnerable may be made with sufficient emergency/routine medicines stored well in advance (pregnant women/children, old age people etc).
6. Immediate livelihood recovery: One of the biggest losses to the farmer is the loss of draught animals that has to be addressed within weeks, especially during the early cropping seasons. While the saline zone agriculture is likely to take at least a monsoon season to recover from the salinity caused by the storm surges, in the un-inundated parts of Intermediate and fresh water zones, farming can be started within a month with late sowing. Replacement of draught animals or provision of power tillers within a month can help in reducing agricultural losses. The power-tillers and tractors as well as late season crop seeds and catch crop based farming methods can help in early rehabilitation of agricultural livelihoods. This is especially relevant in case of pre-monsoon cyclones.
7. Fisheries and water transport sector are two other sectors that require plans for early recovery. Plans for storing boats and engines as well as the service sector supporting them need to be disaster proofed with detailed plans for protecting the productive assets. Similarly, the artisan and trade sector should also be disaster proofed, especially for cyclones, floods and earthquakes.
8. There is need for establishing strong horizontal and vertical linkages in preparedness at various levels starting from Village level to township level as well as with higher levels of administration.

depending on the type of event. For example, the cyclones can provide a respite time of nearly a day in the age of satellite weather monitoring systems and wireless telephony. In case of earthquakes, respite time is usually 0 (zero) or few minutes (if the source is far off). Mexico city has set up an advance warning system which gives a respite time of few minutes in case of western coastal earthquakes.

6.2.2 Rehabilitation Phase

The second phase of activities largely relate to the rehabilitation efforts carried out by all agencies including Government and UN agencies. This can broadly be referred to most part of 2009 beginning from January 2009 and continued for a year or little more for most of the agencies. This witnessed for most INGOs and UN agencies in scaling up of the operations, starting operations in new geographical areas and organizing funding for rehab and recovery.

The broad set of intervention saw most agencies moving out from food distribution to investing in livelihoods interventions e.g. provision of boats and fishing gear, assistance in cleaning and developing agricultural lands, provision of seed and other agricultural inputs, agricultural equipments, livestock, permanent shelter, drinking water and sanitation infrastructure and basic village infrastructure. This also accounted for bulk of the money spent by most of the agencies.

Unlike the early response phase, majority of the interventions made during this phase was informed by the local needs as identified in the joint assessment (PONJA) and further articulated in Post-Nargis Recovery and Preparedness Plan (PONREP) or various assessments conducted by INGOs themselves. On the whole, majority of the interventions provided was the need of that hour.

6.3 THE KEY SECTORAL INTERVENTIONS

6.3.1 Shelter

In the initial rehabilitation phase different organizations built houses for the most vulnerable in many villages across the region. The house types, spaces and the types of materials used show significant diversity. Some of the organizations focused on rebuilding houses of the type similar to old houses without any major cyclone protective measures.

Finding land for construction for the most vulnerable also became an issue in some villages as the field observations indicate. At later stages, some amount of standardization was done and still later UNHABITAT developed guidelines for incorporating earthquake, flood and cyclone resistant features focused on vernacular rural buildings and also plans to streamline disaster resilient features in urban construction practices.

One of the most interesting innovation was usage of concrete stilts, which was adopted by many informal and semiformal prefabricated cement production units (manufacturing mainly cement vases, well rings and pots earlier) across the delta. This has prevented the decay of wooden and bamboo support elements in biomass based houses popular in this region. It indicates the autonomous adoption and replication potential of appropriate technologies in the given context by the local population.

Figure 6-2: House in Flood Prone Area & House Built by IOM

Example of location of new house in flood prone area. Pyapon Township	One of the good quality houses built by IOM, but without any toilet facility. Pyapon Township

6.3.2 Livelihoods

a. Agricultural interventions:

Although the Ayeyarwady Delta is known as the "rice bowl of Myanmar", rice yields have not improved significantly over the last decade, averaging around 3.1 to 3.3 tons per hectare. In the early 1990s, the main increase in rice production was due to the expansion of land under cultivation, which increased by about 25 percent between 1990 and 1994 (UNEP,2009). The stagnation of yields increases the vulnerability of farmers, especially the subsistence farmers, who are unable to invest on agriculture as well as on safer houses and other protective assets. Recovery of yields to Pre-Nargis levels and improving beyond those levels are necessary for reducing the socio-economic vulnerability of the rural communities. Low yields also result in near total reliance on draught animals and inability to invest on fertilizers.

The agricultural inputs and provision of the draught animals as well as power tillers helped in rehabilitation of agriculture, wherever these inputs were provided. Other main outcomes of these interventions are introduction of technologies and practices and their dissemination across the region. Improved seeds and farming practices are likely to increase rice yields in the near future. The agricultural interventions also helped in reducing the distress periods after the Nargis cyclone and it should be always one of the major interventions in this rural farming dependent communities. It is too early to draw conclusively about the acceptance and affordability of these inputs since a significant proportion of farms are yet to recover fully to pre-Nargis level yields. With the government also showing interest in improving farming practices and use of fertilizers and better seeds, there is a good possibility of the delta area being able to overcome yield stagnation issues pointed out earlier.

b. Fisheries and aquaculture:

Fisheries are another major source of livelihood, especially in the lower delta and also in some parts of central delta with natural and man-made water bodies. Destruction/damage to boats and fishing gear was one of the major issues and it was reported that the fisheries and aquaculture has not fully recovered even now. While provision of boats and fishing gear has significantly rehabilitated the fishing dependent livelihoods, the SIM III report indicates that the fishery sector has not yet recovered fully. The field observations indicated that inland aquaculture sector has mostly recovered as indicated by the increasing demand for fingerlings.

Protection of boats, fishing gear and boat engines from cyclone and storm surge damage is an important activity that should be included under the CBDRM. It can include pulling the boats from the rivers and storing the engines and fishing gear well in advance of incoming storms. This would require at least a day of respite time and also coordinated efforts at village level.

c. Artisans and construction workers

Pottery (Figure 6-3) and carpentry are two major skilled activities in this region. Many of the pottery kilns were damaged by the Cyclone. The interventions included support to the potters by orders for water storage pots as well as related activities. During the field visit, the team observed two water filter production units supported by one of the INGOs. While one was found to be operating, with sufficient quality control system, another one was shut down- apparently due to poor quality products. This opportunity created has rehabilitated most of the pottery in the region.

Figure 6-3: Pottery Business

Hydraulic Clay moulding machine: for making water filters

Improved Pottery baking kiln

House construction activity was reportedly picked up soon after the disaster and training as well as tools were provided to the carpenters by UNHABITAT as well as some of the INGOs. The new standards also are being adopted even in the rural areas as evidenced by use of improved materials like concrete stilts, better carpentry of newly constructed houses. Context specific innovations to reduce hose construction costs and use of local materials with improved cyclone resistant features will be useful for adoption of these technologies and practices by the local communities. Some of the houses built recently have adopted most of these features, but these interventions will require continued support through training and capacity building to be internalized by the continued. It is suggested that a survey covering local material availability (especially bamboo, wood and roofing grass), their comparative costs extent of adoption of the guidelines and skill availability can provide insights in to additional inputs to rural housing sector.

6.3.3 Drinking water and sanitation

The UNEP 2009 report (ibid) has pointed out emerging problem of the contamination of groundwater sources (e.g. ponds and wells) during the dry season. Due to the salinisation of groundwater, which is an important source of drinking water, villages in the Delta are reportedly resorting to importing fresh water from other villages. Limited access to drinking water is reportedly common problem in many of the coastal villages of Labutta and Bogale townships, especially during the dry season (from November to May). Given limited household incomes for purchasing potable water, this can add pressure to generate cash which can only be sourced by further eroding the natural resource base. It is also reported that some of the coastal farms are also getting increasingly affected by soil salinisation.

This highlights drinking water crisis even during normal years and disasters further worsens the situation. The climate change induced sea level rise is expected to worsen the situation in saline zones. Drinking water sector interventions need to be analyzed in this context.

Figure 6-4: Drinking Water and Sanitation Facility

Brick lined Dug well with roofing (ECHO) — Improved toilet

The interventions in drinking water sector included provision of water tanks (plastic and clay pots), household level water filters, cleaning and protection of water bodies and treadle pumps to prevent contamination of open water bodies, wells and hand pumps. Different organizations adopted different approaches and technologies, many of them were found to be used by communities. This has reduced the possibility of contamination of many drinking sources across the district.

The cleaning and fencing of surface water bodies as well as installation of treadle pumps is an important innovation relevant especially in the saline water zones. These water bodies can create lenses of shallow fresh water in the aquifers, which can be tapped even if the water body dries up in summer. This intervention has to be strengthened by creating local mechanisms for annual cleaning of wild growth and periodic desilting of the water bodies so that the percolation is sufficient to maintain shallow fresh water lenses.

Use of rainwater was found to be common in many villages during the rainy season and clay urns/vases were commonly used by households in both rural as well as town areas in the delta region. Increasing the storage capacity at household levels can significantly reduce the distress periods in the normal summers also.

Figure 6-5: Rainwater Storage Pots and Water Filter

Transport of rainwater storage earthen pots used for from Delta through boat

Improved baked clay water filter introduced in the Delta

While visible improvement is drinking water sector was observed in field studies, there are also concerns regarding the quality of drinking water sources developed. Periodic maintenance of these assets as well as the maintenance of quality of filters manufactured need attention. Out of two baked clay water filter plants set up by one of the agencies, one factory has closed down due to poor quality of the filter. This technology would require external inputs in quality control as well as equipment servicing facilities.

Regular disinfection of water sources using cheap techniques like chlorination may be necessary (especially during monsoon months) in this shallow ground water conditions and crowded villages and towns. These practices are being introduced in flood prone regions of neighboring countries by UNICEF and other organizations (e.g. North Bihar flood prone regions, India). Introduction and internalization of these practices may be necessary at community levels to reduce post-disaster situations.

The field observations indicated that there is scope for improvement of these interventions as well as need for fine-tuning the technologies given the technical capacities and hydro-geological context. It was felt that a field guide of choice of cost effective drinking water technologies suitable for different hydro-geological and community contexts can help in focusing as well as internalizing these interventions by the communities.

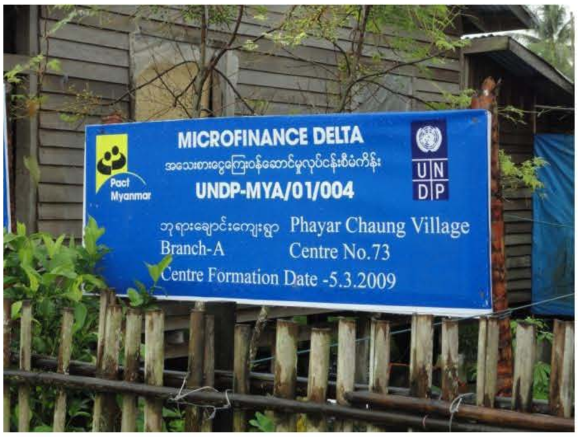
Use of toilets is quite high in all of the villages surveyed and observed in field visits. Open defecation is not prevalent. However the conditions of toilets are often poor, especially in rural areas. Sometimes the faeces is directly disposed thorough a long pipe on to ground nearby or to the river, which is not a safe disposal practice and can contaminate the drinking water sources nearby.

Since the ground water is shallow, most of the areas are unsuited for septic tanks; the interventions were mostly limited to provision of toilet basins and pipes without any major modifications in design. Contamination of ground water is possible with the use of current sets of technologies. Hand washing after defecation is commonly practiced by almost all the communities in the region. There are significant improvements possible in sanitation sector including introduction of Ecosan toilets and prevention of contamination of ground water.

6.3.4 Micro finance

With many of the rural and urban livelihoods affected by the cyclone, the loans of households, especially the poor increased significantly. The UNDP initiated microfinance activities in some of the poverty pockets of the affected region. This provided early recovery of livelihoods in many urban pockets. The loan recovery is reportedly high, but these groups may require longer periods of support to ensure sustainability.

Figure 6-6: Microfinance Group Setup by UNDP



Source: TARU/MSR Field Study, 2010

6.4 MAIN POSITIVE OUTCOMES

The government accepted the role of INGOs after initial delay, which allowed larger scale of interventions necessary to address the scale of damage caused by the disaster. This also empowered the government agencies with information and knowledge and several policy level interventions advocated by various INGOs and external institutions. Without these agencies, the recovery would have been much slower.

The operations of INGOs also provided exposure to local agencies as well as created a large pool of trained local staff and strengthened the local institutions. Supporting them sufficiently may be necessary for some time until they are able to become fully self-sufficient and sustain the pace of their activities on ground.

The entry of the INGOs and expansion of the activities of UN agencies brought several technologies and practices unknown earlier in this region. These included better housing, improved cropping practices and equipment, and drinking water related technologies.

The policy and institutional landscape to support DRM has developed significantly with the government accepting the MAPDRR as well as including several activities within their scope. This would have taken much longer time, without the advocacy efforts by the UN agencies and other international Organizations.

The rehabilitation of rural livelihoods would have taken much longer time without the support of international agencies. The pace of recovery as analyzed by SIM 4 shows that a significant proportion of households have increased their livestock as well as reported increase of agricultural yields to pre Nargis or better levels.

6.5 CHALLENGES

A majority of the agencies faced challenges in their own management capacity in scaling up operations and also partnering with local NGOs, or forming CBOs at village and town level through whom the overall delivery were planned. Often these were isolated efforts without horizontal(across communities) as well as vertical linkages(community to township and higher administrative units and government) and not seen in the perspective of DRR.

Some interventions, such as shelter, made a breakthrough in developing a clear guideline to assist various by implementing agencies for provision of risk resistant vernacular houses in the delta region. This was largely anchored by the UNHABITAT, which also lead training to around 5,000 masons/ carpenters on these guidelines. However, not all the agencies followed the same and a mix of houses could be seen in the delta region. Some of these houses were built prior to the UNHABITAT guidelines were published and distributed. Unfortunately, sustainability of these efforts is an issue with weak institutional environment as well as technology base at the village level.

Also there was duplication of efforts in some sectors. For example the UN agencies and Action Aid conducted independent studies and Participatory Poverty Assessments. Different agencies prioritized their action early and by the time coordinated efforts could be started, most of the agencies had their funds tied up to their activities. This limited opportunities for coordinated action on ground.

Most agencies brought expatriate experts and also worked out independent and often uncoordinated strategies. Many of the experts had limited experience in the local geophysical, socio economic and political context. For example, several cyclone shelters were built based on technologies and materials that were not common in the areas where they were built, nor affordable by the communities/ local governments, thereby limiting their replication in the near future. In other cases, like clay water filters required more stringent quality control over pottery technology and equipment which were not locally available or could be repaired.

Though government allowed most of the interventions, overall institutional and infrastructure environment was too poor to operationalize and sustain some of the interventions. In many areas, it meant starting from beginning without conducive environment.

6.6 RECOVERY PHASE (CBDRM*)*

The recovery or transition phase broadly refers to last quarter of 2009 and 2010 period. The recovery phase largely saw the focus on concluding the ongoing rehabilitation phase activities with many agencies finishing their commitment and closing/ reducing their operations with the utilization of available funds. It also registered a clear shift in focus from provisioning to DRR and community based disaster risk management (CBDRM). Disaster Risk Reduction (DRR) became a common intervention among many of the donor agencies and it also began as a reference framework for most of the ongoing activities. This included focus on:

- Awareness building and training to Community and Disaster Management Committee
- Conduct Community based Vulnerability & Capacity Assessment
- Initiating Early Warning System at village level by establishing protocols and through provision of basic equipment and training
- Provide IEC Materials on DRR and CBDRM
- Provide Pre-positioning Kit (community and Household level) in some cases
- Public Infrastructure (e.g. Cyclone Shelter, Cyclone Resistant School, Rural Health Center, Safe evacuation routes, minor bridges and river embankments) being planned and implemented.

The consolidated data from TCG[13] suggests that, there were more than 18 agencies (among the 40 odd agencies active during the relief and rehabilitation phase) had taken up DRR activities in the Delta region. The effort of these agencies covered 1,410 villages and urban wards (as against a total of 2,097 villages and wards in which they had been working), spread over 489 village tract in 12 townships of the Ayeyarwady Delta region. This lead to formation of 1,410 Village Disaster Management Committee (VDMC). Out of these about 855 of these committees formed the village preparedness plans and 649 only mapped the hazards. This indicates that only partial success in setting up of CBDRM action on ground. Fund and contraction of staff strength seems to be the main issues facing these agencies.

The SIM III suggests that the decline in the overall level of aid has been accompanied by the significant change in the priorities of aid providers. It also cites that the aid has continued to decline and by way of comparison, total humanitarian assistance to Ayeyarwady Division was US$596 million (in 2008), US$77 million (in 2009), and US$25 million (in 2010)[14].

At the community level, the DRR activities were initiated by most agencies through establishing Village Disaster Management Committees (VDMCs) to lead development of disaster preparedness plans and implementation; establishing communication and response protocols; specialized in basic search and rescue, first-aid and early warning communication; development of IEC materials, manuals and guidelines on DRR measures for public awareness and for use in DRR preparedness trainings; training of carpenters and artisans to promote locally applicable disaster-resistant buildings; and construction of various physical mitigation infrastructure; and construction of cyclone shelters.

In addition to physical structures such as cyclone shelters and restoration of community infrastructure, DRR activities also include provision of equipment for individuals and villages for early warning system (EWS). Common types of equipment include loud speakers and flags to give signal of a cyclone's intensity, watertight floating bags in which villagers could keep their important documents and identification, and radios.

The structural mitigation measures as part of the DRR activities spread over provision of Community emergency shelters, transportation infrastructure i.e. road, small bridges and jetties, education and health infrastructure, communication infrastructure drinking water, sanitation and other social infrastructure. The sustainability of new created/upgraded infrastructure will largely depend on usage during normal periods (as schools/community buildings) as well as community taking ownership, as experiences from the neighboring countries indicate (India and Bangladesh). The experience also shows that the emergency shelters to accommodate the whole village may be overkill, since such large structures would require large funds to maintain. Increasing the respite time and possibility of evacuation of a significant proportion of the population to safer areas (towns, with sufficient public building spaces) should be explored before deciding on the capacity of such shelters. Experience elsewhere suggests that these buildings should be designed as schools or other education uses and the capacity to serve these uses is often sufficient to accommodate the most of the population in standing/cramped sitting position for 6-8 hours of main event.

Main positive outcomes at this phase are:

1. CBDRM has taken root in many villages with communities prepared to face cyclone events better.
2. Formal emergency shelters being built in many areas with some support infrastructure

[13] As on June 2010
[14] Source: SIM III and OCHA (as of 23 June 2010)

like bridges, jetties etc for evacuation

3. Acceptance of the process by the government agencies
4. Involvement of a variety of local stakeholders including local NGOS and professional bodies.
5. Early warning systems in place that can potentially increase the respite time and linked with the community level institutions.

Key challenges and issues during this phase can be summarized as follows:

1. The concept of DRR and CBDRM was less known in Myanmar – both Govt and locals – worked were receptive to these issues but do not have capacity to implement and sustain the activities and infrastructure. Limitation of village level organized institutions, which can take forward the CBDRM as a continuing process.
2. Most agencies developed their own CBOs and made them responsible for CBDRM activities, without analyzing their standing in the community or institutional sustainability. Most of these were the initial CBOs set up to undertake the rehabilitation work.
3. A significant proportion of the international agencies finished their funds much before this phase started and had also wound up - with initial notional allocation of areas where they were working, and then left on their own as new agencies had to start building new alliances.
4. A DRR intervention in the delta region has not been informed by hazard risk and vulnerability studies/composite risk assessment, and sectoral interdependencies.

Other issues that need attention include:

1. CBDRM and DRR measures need to be contextualized further in order to minimize the losses and maintain minimal services soon after the event. CBDRM needs to incorporate issues like loss reduction, protection of lifeline infrastructure/maintain the flow of goods and services in adverse situations, especially transport/communication and drinking water. This would need developing more detailed CBDRM measures as elicited earlier.
2. Significant contextual research may be required to develop design briefs for emergency shelters and other DRR infrastructure. Some of the relevant issues include: Exploring possibility of evacuation; optimal size of emergency shelters taking in to account normal as well as emergency use; source of funds and institutional mechanisms for regular maintenance of these buildings; community level capacity to manage these buildings.
3. Increasing the respite time of the events as well as last mile coverage of warning by a mix of human and technology based systems.
4. The DRR may further contextualize and detail out not only risk reduction measures but include measures to rehabilitate and recover the livelihoods in minimal possible time (say couple of months) by protecting or recouping productive assets like cattle, equipment, and factories. For example, protection of the lifeline infrastructure and services as well as livelihoods can decease the human losses and pain and suffering after each disaster. If basic provisions of food water and medicine can be provided in time through minimal loss to transport infrastructure, disaster losses can be considerably reduced. While it may not be feasible to provide drinking water to all the

villages, during post disaster situation, it is easier and practical to provide chlorine tablets and purification kits and utilize the local water sources if they are protected before the event.

5. Horizontal linkages between CBDRM of neighboring communities including nearest towns communities and Vertical linkages with administration and NGOs. Sufficient storage facilities for essential items like food, creation of asset banks, water purification kits spread across the delta region will be necessary vertical link that can significantly reduce the post-disaster human losses.
6. Departmental Standard operating procedures for flood/cyclone and other hazards preparation may be put in place. This can include drills, checking of emergency transport and rescue equipment and relief material storage at strategic locations and preparedness of administrative and NGO resources. Systems can be studied and contextualized for Delta region.
7. Continuous emphasis on capacity building of institutions and communities at risk. Engage in partnership development and demonstrate actions that focus on prevention and mitigation measures
8. Exposure to international experience is necessary and can enrich the experience of administration in DRR. This can include visits to risk-prone regions of neighboring countries, facing similar challenges.

6.7 CONCLUSIONS

The responses to the cyclone disaster was initially delayed, but picked up with the involvement of multiple local and international organizations. The international agencies faced several challenges including lack of understanding of the delta context, delay in getting permissions as well as limited availability of skilled local resource persons.

Considering these limitations, significant progress was achieved within two years, with almost all the affected population getting back to their normal life patterns. This is a great achievement made possible by concerted effort of multiple stakeholders in a challenging environment.

Interventions were not initially coordinated, but at the later stages the coordination system was developed with some degree of success. The sectoral interventions by various organizations provided rich experience to the communities as well as introduction of new techniques and practices. While most of them were able to improve the quality of life was well as improve the livelihoods, much more needs to be done considering the resource conditions and political and socio-economic context.

The Myanmar Action Plan on Disaster Risk Reduction (MAPDRR) 2009-2015(MSWRRRD 2009), is a remarkable achievement and leap ahead from the time of little acceptance within Government on DRR. Though MAPDRR provides an overall framework for DRR and institutional design in undertaking them, it is too early to comment on its implementation. A brief discussion with Relief and Resettlement Department at Ministry of Social Welfare, and, Planning Department under the Ministry of National Planning and Economic Development suggest that they are incorporating the findings in their planning and implementation process. However it is not clear if there is clearly allocated funds for implementing and sustaining these efforts.

The delta region is predominantly rural and dependent mostly on natural resource based livelihoods and has high incidence of poverty, while this region has a fairly high literacy as well as good coverage of sanitation, compared to many other perpetually risk prone regions in the neighboring countries. With narrow livelihood base, the communities will require support in expanding the livelihood base in this developing country challenged by political and economic environment. While the higher literacy and higher awareness about sanitation provide opportunities to improve quality of life, low income and surplus are major challenges that needs to be addressed. Vulnerability is high due to risk to the natural resource base, but housing and other infrastructure is not well developed, but costs of replacement is also low, due to extensive use of local materials.

Some of the interventions and technology introduction e.g. concrete stilts have autonomously replicated, some others may not be replicated. The Emergency shelters also need to be carefully designed taking in to account the local context, maintenance mechanisms and future sustainability issues.

Starting from virtually no operational disaster risk reduction system, significant achievements were witnessed as evidenced by a more responsive government, formation of CBOs and strengthening of local NGOs. This change was possible largely due to advocacy as well as intervention support by the INGOs as well as increasing responsiveness of the government to these issues. While a lot of improvement is still necessary, the process has reached beyond critical stage and sustainability of some of the interventions can be assured.

Slow processes like sea level rise and increase in temperature or rainfall can severely erode the natural resource base of the Delta region. Such changes should inform design of DRR activities.

6.8 WAYS FORWARD

1. Food, Water, clothing and shelter are three areas that would require continued attention for any efficient disaster management. These have to be ensured at the earliest after any disaster event. To ensure these several steps will be necessary. They include:
    a. **Food storage**: Minimal damage to stored food grains and grain banks at village level in safe places, wherever possible. At least a week's supply of grains(based on population and per capita minimum calorie needs for survival) need to be stored at town level in safe godowns or arrangements for rapid transport from outside areas need to be undertaken. These godowns can be located on high grounds.
    b. **Context specific water technology toolkit:** The water supply interventions need to be informed by the local ground and surface water conditions. A tool kit providing possible options for local water supply technologies and decontamination after the floods can be developed. This tool kit should include;
        i. Exploration and analysis of surface water and ground water situation in saline, intermediate and fresh water zones;
        ii. Estimation of water requirements
        iii. Technologies suitable for various geophysical conditions
        iv. Protection of water sources before disasters
        v. Decontamination of polluted sources
    c. Sanitation systems to ensure minimal pollution after disasters to avoid open

defecation as well as pollution of local water resources.

d. Minimal clothing requirements to be met after disasters for the affected population, especially women. A vendor list as well as local procurement system can be set up to ensure this.

e. **Safe housing technology options toolkit**: The biomass based housing is likely remain the dominant house type in rural areas, but making them safer with limited external materials can be done to improve building safety under cyclones and floods. "Building safer" should be the motto for each disaster rehabilitation action. Local material based safe building guidelines were made available after cyclone Nargis. There is a need for developing a tool kit providing options for local material based disaster resistant houses suitable for different townships, their indicative per unit/per area costs. The options can be created which can suit different income categories as well as family sizes and needs. This tool kit can be made for each zone and predominant risk type and should be informed by the local level consultations. This tool kit can be developed as a part of DRR at township/district level. This would provide a ready reckoner for fund providers so that safer houses can be built after each event.

2. **Rehabilitation of traditional livelihoods**: The ready availability of catch crop seeds, tools and techniques may be ensured to recover the agricultural and fishery sector as has been done Post-Nargis. While it may not be possible to deal all needs through INGO interventions, suitable mechanisms for subsidized credit for recovery and involvement of banking sector may be useful and has to be explored. Careful monitoring of rural indebtedness after each disaster needs to be further strengthened by institutionalizing such action research.

3. **Creating options for new livelihoods:** Myanmar is expected to undergo a rapid economic transformation, after relatively stagnant past. This is evidenced by the pace of changes happening in the cities and towns. The Myanmar rural as well as urban livelihood portfolio is expected to change rapidly and the disasters provide windows of opportunity to build new skill sets, use tools and techniques for improving their livelihood portfolio. While planning for livelihood recovery, this factor should be taken in to account and it is suggested that innovative and practical new livelihood options should be given due importance instead of focusing on traditional livelihoods alone. Further research in this aspect is necessary and it is suggested that such options are explored, field tested and kept ready.

4. **CBDRM**: The CBDRM plans have been developed, but the sustainability of these has to be ensured by continued engagement between government, NGOs& CBOs and communities. Maintenance and Replacement costs of different kits provided after few years will be a major issue. There is a need for developing village level funds to take up routine maintenance and replacement of these kits as well as annual drills etc. The village level micro-finance and credit activities can generate funds to maintain the CBDRM action. Involvement of existing village level institutions will be critical for sustainability of CBDRM activities.

   CBDRM should also include an action plan for protecting lifeline infrastructure/productive assets including boats, power tillers etc. as well as measures to rapid rehabilitation of livelihoods.

5. **Township/District level DRR Action Plan**: Horizontal as well as vertical linkages are necessary for strong DRR. Each township may take up an **Action plan for DRR**. The government has already been planning to start this on a pilot scale in Bogale. The guidelines for preparing these plans need to be developed as well as community consultations to test these on ground are necessary. Each of these Plans should detail out the predominant hazards, composite risk assessment, CBDRM activities as well as setting up village to village and village to town linkages to build synergy. The current HRVA document provides a framework for such analysis to initiate dialogues with various stakeholders. These action plans need to be informed by risks, resources and resilience of the communities as well as the current constraints at various levels.
6. **Composite Risk Assessment:** This study on risk assessment is the first of its kind in the country. Key select risk prone regions/priority regions must be taken up on a priority basis as part of scaling the current effort. A national level initiative can help establish risk level benchmark and investments necessary to bring down the risk to 'as low as reasonably practicable'. Key pockets/sectors in Ayeyarwady Delta can deepen the engagement ofn risk assessment to outline priority investments for DRR.
7. **Infrastructure maintenance:** Maintenance of Cyclone shelters and other community level infrastructure should be given due importance. While most of them are being planned for regular use (e.g. Schools) a maintenance plan should be prepared to ensure that the infrastructure is kept in working condition during the next disaster. Institutionalsing these processes would be necessary with active involvement of CBOs as well as government agencies.
8. **Early Warning System:** The current early warning system depends significantly on TV as well as human chain of communication, especially in villages. The Mobile telephony coverage is likely to improve in the near future. The current costs of mobile call charges are not affordable by poor. In the peri-urban areas and neighboring villages, sms based warning systems may be possible and such options may be explored.

Increasing the respite time to the communities at least two days in case of cyclones and floods is possible with the available satellite remote sensing. However, reaching the last mile is a challenge now. Measures to ensure at least two days respite time can significantly reduce the losses. While the CBDRM will be able to reduce the response time, the respite time increase through context specific options need to be developed, as a part of the Township level Action Plans.

Chapter 7: CONCLUSIONS

7.1 HAZARD SUMMARY

7.1.1 Earthquake

Tectonic set up of Myanmar delta region indicate high seismic risk. Seismotectonic processes of the region are very complex. The subductive nature of Indian plate, active spreading zone in south and an Sagaing an active fault in east of Yangon makes delta region vulnerable to high seismic risk. Historically also about five major destructive earthquakes have occurred in the Myanmar. This demands proper investigations pertaining to seismic hazard assessment of the Myanmar as a whole and also region specific.

In present study an attempt is made to determine the seismic hazard for Ayeyarwady, Yangon and Bago Divisions of Myanmar. Based on the extensive literature study and available data suitable earthquake catalogue was derived with several assumptions. Probabilistic Seismic Hazard Assessment (PSHA) approach was adopted for the current study. Based on the results of simulation and the limitations within some of the earthquake attenuation model to include the bed rock conditions the PGA as proposed by Si & Midorikawa (2000) was used. The results obtained during the analysis have been used to evaluate the seismic hazard based on the PGA values for 25, 50, 100 and 200 year return period. The PGA value for the study region varies between 0 to 0.5. The Spatial analysis indicates that the seismic risk is high for the Eastern delta region of Southern Myanmar compared to Western delta region. This may be attributed to Sagaing fault which is an active fault along with the active spreading zone in the offshore of Southern Myanmar.

7.1.2 Tsunami

Tsunami caused by Sumatra earthquake reached up to the coastal areas of the Southern Myanmar coastal areas. The dynamic tectonic setup in off shore Myanmar indicates the possibilities of the tsunami for the coastal areas of Southern Myanmar. Based on the previous experience of Sumatra tsunami, model prepared by ECW/DMH for hypothetical tsunami, present tidal conditions of the delta region; two possibilities were envisaged for tsunami and accordingly inundations maps were prepared for the delta region.

Time Stage relationships for the tidal conditions were developed by accommodating storm heights observed during cyclone Nargis. Two scenarios i.e. maximum tsunami heights and average tidal conditions and maximum tsunami heights with maximum tidal heights were used for the simulation. Based on the analysis, it was observed that the hazard risk due to tsunami is very low with the average tide level but considerable during the high tide levels. The maximum high tide for the study area is usually around the months of July to August. Occurrence of tsunamigenic earthquakes during this time period will increase the risk of the delta region with such event. The results obtained with the analysis of the tidal data and the spatial analysis indicate that the maximum number of villages i.e. 333 out of 335 (maximum tsunami heights and average Tide condition) in Ayeyarwady division is at more risk compared to Yangon division. In the case of maximum tsunami heights and maximum tides, 586 out of 634 villages fall within the Ayeyrawaddy division while the remaining 48 are within the Yangon division.

7.1.3 Cyclone

There are two prominent cyclone seasons for the country i.e. between April to May and October to December. Historical data points indicate that on an average, every ten years a major cyclone makes a landfall in Myanmar. For the present study probabilistic cyclone and wind hazard assessment for Myanmar delta region was carried out. Estimation of exceedence peak gust wind speed probabilities for 25, 50, 100 and 200 year recurrence intervals were calculated based on the combination of the widely referred Holland / Jelesniask wind field model based on its robustness in various goodness of fit test. The results obtained with the analysis were observed in light of two classification systems i.e. widely referred Saffir-Simpson (1971) scale and other one followed for the Indian ocean basin BIS Code: 875 (Part III), 1987. Results indicate that the wind speeds for 25, 40, 100 and 200 return period are mostly higher in the western delta provinces and it progressively diminishes across the eastern parts.

7.1.4 Storm Surge

Inundation/flooding in the coastal area can occur due to cyclonic condition which may result in storm surges. The present study area experiences diurnal tides in six hour time period. About 15 tidal gauge stations are falling in the present study area. The tidal heights observed in the eastern side of the study area are higher than the western side of the study area i.e. Ayeyrawaddy delta region. This can be attributed to the coastal configuration in the eastern region i.e. Yangon region which might be amplifying the tidal heights. The average storm surge heights observations related to the Nargis cyclone was about 3.17m. Based on the time stage relationship of about 6 hours for the cyclonic conditions storm surge map was generated for the delta region. The results obtained from the simulation were viewed in context of vulnerable populations. Worst case scenario of the storm surge conditions was considered for further analysis and therefore there are chances of over estimations. The results indicate that Myaungmya, Pyanpon and Yangon along with Pathein districts shows higher possibilities of inundation due to storm surge conditions affecting large number of population.

7.1.5 Flood

Flood analysis for the present study area aimed at modelling the impacts of fluvial flooding from Irrawaddy and Sittaung rivers flowing within the study area and pluvial flooding due to extreme rainfall and possible storm surges. Hydrological model was used to generate the flow series for the entire catchment of Irrawaddy and Sittaung river basins to analyze the implication of a flood along the river stretches and its neighborhood. The outcome of the modeling indicates maximum flooding near the downstream end of the river where it spreads into a fan shape in the lagoon area. It was evident from the results that the combined spread and depth of inundation as modeled was similar to the flooding of Nargis cyclone. Due to non- availability of actual observed rainfall in the study area, sensitivity analysis was carried out by increasing the rainfall by 50% and 100% on the rainfall pattern extracted from TRMM girded rainfall for the Nargis cyclone period. The depth of inundation is more than 1.5 m in some places and in general the inundation is below 0.75 m due to pluvial flooding conditions for the selected study area.

7.1.6 Climate Change

The goal of this exercise was to analyze the possible changes in precipitation and temperature within Myanmar Ayeyrawaddy delta under future climate change scenarios. Due to intricate nature of the climate and its complex relationship with environmental parameters, the task of analyzing the inter-relationship between events that are occurring sporadically over space and time is difficult. The method for climate analysis within this study follows three step approaches which included a) Analysis of downscaled climate data and normalization of the same with respect to the historical (1990-2007) climate data, b) Selection of appropriate GCM based on correlation analysis and c) Analysis of selected models for evidence of future changes in temperature and precipitation.

Out of the 15 models only one model i.e. GFDL did exhibit satisfactory correlation index for present study area. Overall there is not much variation within the precipitation profiles across the divisions but the model indicates a possible change in the future temperatures which may range from 0.5 C to 2 C from current averages.

7.2 URBAN VULNERABILITY

The urban vulnerability assessment was carried out to address the different facets of risks and quantify the components of vulnerability across the different surveyed towns to inform adaptation framework. The assessment attempted in addressing the vulnerability and capacity issues in the surveyed towns of delta region of Myanmar. While analyzing the urban vulnerability it was taken into consideration that towns are part of the process transition of the Delta region's economy from the primary to the secondary and tertiary sectors with its accompanying shift of employment. Much of current growth of towns in Delta region is increasing due to people move to cities in search of better livelihood opportunities.

Social aspects of vulnerability in town are very unlike from villages. Networks and reciprocity are usually more fragile and unpredictable due to high fragmentation and heterogeneity of the town population. The capability of individuals or households was assessed based on advanced warning mechanism used in previous hazards, such as human chain.

However, population in towns are highly benefitted by different types of educational intuitions and people who have not had basic education are very low in number and constitute just 5% of population. The results indicate that more than 23% members have education upto 5 years, followed by 50% of people having had 6 to 12 years of education. 21% of the Town dwellers are graduates while postgraduate-professional constitute only about 2%.

Occupations in towns are highly diversified and it was observed that members of household are engaged in different type of occupations and their stability. Nearly 66% are engaged in stable occupation. However, they are very much dependent on contractors, suppliers, employers to find work owing to their lack of marketable skills as well as exposure to frequent hazard events. Subsequently, around 25% are engaged in unstable occupations. Unstable employment usually absorbs household members of low-income settlements. An increase in the level of unstable employment may lead to problems during times of economic downturns including the ones caused by hazards. Highly stable worker are very less constituting to about 9%of the population.

It is very clear from above discussion that social and economic vulnerability/capacity are closely linked to the education, income and occupational diversity that a particular household is able to activate, in terms of both number of household members in the workforce, as well as educational background, skills acquired, health status, age and gender of the household members.

Buildings in urban areas are certainly the most important physical asset that a household can possess. More than 60% of the buildings are constructed using type III materials and therefore it was taken into consideration as physical vulnerability in towns. It is evident from results that building vulnerability is high in Hmawbi and Maubin followed by Myaungmya, Pyapon and Labutta in the similar order.

7.3 RURAL VULNERABILITY

The rural vulnerability analysis was based on indicators addressing the Sustainable Livelihood Framework (SLF) of DFID. The indicators selected include five capitals which control the livelihoods of poor namely physical, human, financial, social and natural capitals.

The rural settlements in the Delta Region are highly vulnerable due to the physical locations. Majority of area is in low elevation flat terrain with many interweaving distributaries of Irrawaddy River. The coastal and river side settlements are at higher risk to floods and storm surges. The results show that nearly 60% of the population in the delta region is vulnerable to flood and storm surge risks. Another major challenge of physical vulnerability assessment in the Delta Region is the overwhelming proportion of non-engineered or partially engineered buildings. Majority of the buildings are made of Biomass walls/roofs (Biomass, Tin, ACC Sheets), therefore they are highly vulnerable to wind speed over 33 m/s.

Accessibility is critical for evacuation before the hazard, and for providing timely relief after disaster. Accessibility through roads in Delta Region is a major issue because most of the mud roads in delta are only accessible during fair weather. Due to insufficient bridges and culverts, most roads do get inundated during rainy seasons. Water ways are the only source of transportation which is highly relied upon by people within the delta. In spite of its functionality during fair weather similar to roads, the use of waterways during the occurrence of a severe weather event will be an issue of concern.

Within the Delta, the land holding distribution is highly skewed. The results indicate that 50% to 80% of the households in surveyed villages are landless and therefore have to rely on agriculture (as farm hand) or fisheries or other non-steady source of employment including working in salt pans for their sustainability. Paddy cultivation and fisheries are the main sources of livelihoods for the people within the rural regions of the delta. High out migration (movement from rural to urban areas) is evident within the delta and the migratory population contributes to about 15% of the economy (within households).

Secondary and tertiary sectors are weak and contribute to less than 10% of people's livelihood. Therefore, any damage to agriculture or fisheries may affect more than 90% of the households in the Detla region. Analysis results also indicate that single crop based agriculture in saline areas, are relatively more vulnerable due to their lack of income diversity, security and savings.

Nevertheless, rural settlements in the Delta region are highly benefited from proximity of natural resource (including river or forest). This provides a source of livelihood to majority of population. The analysis indicates highest natural resource accessibility (85%) in Hinthada district, which has the advantage of having low population density and being located within fresh water zone.

Rural settlements in delta are fairly well knit, with large Buddhists population. The social cohesion is very high within the societies, which establishes good social networks. Local monasteries provide variety of services to the communities especially in improving the basic education. Apart from the education provided by the monasteries, the government run institutions also cater to the basic education. Therefore, primary education is accessible to the majority of the population within delta region. Unfortunately, due to lack of infrastructure (accessibility) higher education is inaccessible to the majority of the villagers. The results indicate that illiterates are less than 14% and around 48% having primary education. People with secondary education including high school account for 35% of the population but only 3% are graduates. This shows that it would be easy for agencies in conducting awareness programs.

7.4 COMPOSITE RISK

The composite risk analysis was classified into two broad categories names urban and rural. The urban loss estimation focused on six towns that were surveyed where the rural loss estimation focused on all villages within the Ayeyarwady and Yangon divisions.

The urban composite risk assessment was undertaken for two main hazards namely cyclone and earthquake. Analysis was carried out for key elements at risk namely buildings and industries within the surveyed towns (5 nos). Flood hazard was not included. Vulnerability of the buildings is quite low with respect to floods because the model simulated levels of inundation was less than a meter in surveyed towns.

Building losses due to Earthquake (100-year return period) account to greater than 76 Billion Kyat, where maximum loss was observed within tiles on biomass buildings (69.93 Billion Kyat). Estimated loss that may be experienced by Hmawbi town is highest in all surveyed towns are nearly 32% followed by Pyapon (21%) and Maubin (17%) by earthquake hazard.

Building losses due to cyclone (100-year return period) account to greater than 118 Billion Kyat. Even though the numbers of building of bio mass on bio mass are higher, the Cyclone damage to tiles on biomass buildings was found to be greater. It was found that RCC and tiles on bio-mass accounted for majority of the loss. Estimated loss due to cyclone may be experienced by Hmawbi town is highest in all surveyed towns are nearly 30 % followed by Pyapon (17.09%) and Maubin (16.19%).

Industrial loss estimation was carried out for cyclone with 100-year return period. The industrial productivity and damage estimations were based on the results of primary survey which did indicate that that vulnerability of industrial sector is reported to be negligible to low intensity cyclonic storms. Due to the lack of information, only agricultural based industries mentioned within Food and Agricultural Organization's (FAO), Atlas of Myanmar were taken into consideration for loss estimation.

It is evident from results that damage and losses to machinery, raw material, goods in process and finished goods in small-scale industries (SSI) are negligible in comparison with MSI and LSI. One of the possible reasons could be the type of the machinery/raw material used. Total losses due to cyclonic winds in delta region may account to over 457 Billion Kyat. Estimated loss that may be experienced by LSI and MSI are around to 30% and 9% respectively.

The rural composite risk assessment of the Myanmar delta region was carried out for three main hazards (Cyclone, Flood and Earthquake). Most of the delta region is covered by the semi-engineered or non-engineered type of the building. The delta region is rich in terms of agricultural practices especially rice cultivation. Along with rice; groundnut/oil seeds, cotton, maize are some of the other important crops which are grown in the delta region. This agriculture practices not only caters the basic food requirements of the delta region; but is also an important part for the overall economy of the Myanmar. Rice being the most important crop grown in the Southern delta region, it was considered for the composite risk assessment. Further, rice is the predominant crop within the delta for which the cultivation begins in the month of April (early monsoons) and continues well into the winter. The early and late monsoon periods are also prone to cyclone and flood hazards. Losses estimation was therefore conducted for this crop in detail.

Table 7-1: Town Level Hazard Risk Analysis

Division Name	Town Name	Area (SqKm)	Total Population	Cyclone Maximum Wind Speed (m/s)				Earthquake Maximum PGA (g)				Pluvial Flood Average Inundation (in m)		Fluvial Flood Average Inundation (in m)
				25 yr	50 yr	100 yr	200 yr	25 yr	50 yr	100 yr	200 yr	50 Percent Change	100 Percent Change	Fluvial Flood
Ayeyarwady	Bogale	2,607.43	423,202	18.00	23.00	30.00	37.00	0.01	0.04	0.12	0.16	-	-	2.00
	Dedaye	581.76	239,272	16.00	21.00	29.00	36.00	0.01	0.04	0.15	0.18	-	-	2.00
	Einme	742.76	205,997	18.00	25.00	34.00	41.00	0.01	0.04	0.06	0.12	-	1.00	1.00
	Gwa	2,242.23	61,392	19.00	25.00	33.00	43.00	0.02	0.04	0.06	0.07	1.00	-	-
	Hinthada	981.58	447,852	17.00	23.00	31.00	40.00	0.02	0.05	0.11	0.17	1.00	1.00	2.00
	Ingapu	1,672.52	300,102	18.00	23.00	31.00	41.00	0.03	0.05	0.10	0.13	1.00	1.00	3.00
	Kangyidaung	915.47	225,381	19.00	26.00	34.00	42.00	0.01	0.03	0.05	0.09	1.00	1.00	1.00
	Kyaiklat	725.28	209,792	17.00	23.00	31.00	39.00	0.01	0.04	0.16	0.20	-	1.00	2.00
	Kyangin	1,110.39	128,864	18.00	22.00	29.00	39.00	0.03	0.05	0.07	0.09	1.00	2.00	6.00
	Kyaunggon	683.73	177,914	18.00	24.00	33.00	41.00	0.02	0.04	0.07	0.14	-	1.00	1.00
	Kyonpyaw	826.24	291,632	18.00	24.00	33.00	41.00	0.02	0.05	0.09	0.16	1.00	1.00	1.00
	Labutta	2,263.54	343,068	19.00	25.00	33.00	39.00	0.01	0.02	0.05	0.07	-	-	2.00
	Laymyethnar	1,168.79	143,938	18.00	24.00	32.00	42.00	0.02	0.05	0.08	0.13	1.00	1.00	2.00
	Maubin	1,271.60	362,889	17.00	22.00	31.00	39.00	0.01	0.05	0.17	0.29	-	1.00	1.00
	Mawlamyinegyunn	1,083.27	321,288	18.00	24.00	31.00	39.00	0.01	0.04	0.10	0.14	-	1.00	2.00
	Myanaung	1,545.91	297,493	18.00	22.00	31.00	41.00	0.03	0.06	0.09	0.11	1.00	1.00	3.00
	Myaungmya	1,531.52	388,497	19.00	25.00	34.00	41.00	0.01	0.03	0.05	0.09	-	1.00	2.00

Division Name	Town Name	Area (SqKm)	Total Population	Cyclone Maximum Wind Speed (m/s)				Earthquake Maximum PGA (g)				Pluvial Flood Average Inundation (in m)		Fluvial Flood Average Inundation (in m)
				25 yr	50 yr	100 yr	200 yr	25 yr	50 yr	100 yr	200 yr	50 Percent Change	100 Percent Change	Fluvial Flood
	Ngapudaw	3,210.86	323,741	20.00	27.00	35.00	43.00	0.01	0.02	0.04	0.05	1.00	-	2.00
	Nyaungdon	878.01	235,223	16.00	22.00	31.00	38.00	0.02	0.05	0.16	0.31	1.00	1.00	1.00
	Pantanaw	1,313.95	269,305	18.00	24.00	33.00	40.00	0.02	0.05	0.11	0.22	1.00	1.00	2.00
	Pathein	1,420.64	340,052	20.00	27.00	35.00	44.00	0.01	0.03	0.04	0.06	1.00	1.00	1.00
	Pyapon	858.46	241,303	17.00	22.00	29.00	37.00	0.01	0.04	0.12	0.16	-	-	2.00
	Thabaung	2,015.20	183,177	19.00	26.00	35.00	44.00	0.02	0.04	0.05	0.09	1.00	1.00	2.00
	Thandwe	3,473.56	122,233	18.00	22.00	30.00	40.00	0.03	0.04	0.06	0.07	1.00	-	-
	Wakema	1,177.68	350,779	18.00	24.00	33.00	40.00	0.01	0.04	0.10	0.17	1.00	1.00	2.00
	Yekyi	1,227.20	260,553	19.00	24.00	34.00	43.00	0.02	0.04	0.07	0.12	1.00	1.00	2.00
Yangon	Along	3.19	-	-	-	-	-	-	-	-	-	-	-	-
	Bahan	8.33	-	-	-	-	-	-	-	-	-	-	-	-
	Batahtaung	2.58	-	-	-	-	-	-	-	-	-	-	-	-
	Dagon	4.87	-	-	-	-	-	-	-	-	-	-	-	-
	Dagonmyothit(E)	58.08	-	15.00	20.00	28.00	35.00	0.01	0.05	0.20	0.35	-	-	-
	Dagonmyothit(N)	25.71	-	-	-	-	-	-	-	-	-	-	-	-
	Dagonmyothit(S)	37.84	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Dagonmyothit(Seikkan)	51.67	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Dalla	29.39	82,403	15.00	20.00	28.00	35.00	0.01	0.05	0.18	0.30	-	-	-

Division Name	Town Name	Area (SqKm)	Total Population	Cyclone Maximum Wind Speed (m/s)				Earthquake Maximum PGA (g)				Pluvial Flood Average Inundation (in m)		Fluvial Flood Average Inundation (in m)
				25 yr	50 yr	100 yr	200 yr	25 yr	50 yr	100 yr	200 yr	50 Percent Change	100 Percent Change	Fluvial Flood
	Danubyu	741.32	228,293	17.00	23.00	32.00	39.00	0.02	0.05	0.14	0.25	-	-	1.00
	Dawbon	3.23	-	-	-	-	-	-	-	-	-	-	-	-
	Hlaingbwe	9.97	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Hlegu	1,626.30	179,955	16.00	21.00	28.00	36.00	0.02	0.06	0.22	0.41	1.00	1.00	-
	Hlinethaya	78.55	212,665	15.00	21.00	29.00	36.00	0.01	0.05	0.19	0.33	1.00	1.00	2.00
	Hmawbi	313.82	159,745	16.00	21.00	29.00	36.00	0.01	0.06	0.20	0.38	1.00	1.00	1.00
	Insein	31.48	256,687	15.00	21.00	29.00	36.00	0.01	0.05	0.19	0.36	1.00	1.00	2.00
	Kamayut	6.74	-	-	-	-	-	-	-	-	-	-	-	-
	Kawhmu	680.81	127,906	16.00	21.00	29.00	36.00	0.01	0.05	0.19	0.27	-	1.00	2.00
	Kayan	626.76	190,907	15.00	20.00	27.00	34.00	0.01	0.05	0.20	0.33	1.00	1.00	-
	Kungyangon	734.70	139,671	16.00	21.00	28.00	35.00	0.01	0.04	0.18	0.22	-	-	2.00
	Kyauktada	0.71	-	-	-	-	-	-	-	-	-	-	-	-
	Kyauktan	1,023.09	167,255	15.00	20.00	27.00	35.00	0.01	0.04	0.17	0.27	1.00	-	-
	Kyimyintdaing	6.81	-	-	-	-	-	-	-	-	-	-	-	-
	Lanmadaw	1.35	-	-	-	-	-	-	-	-	-	-	-	-
	Latha	0.60	-	-	-	-	-	-	-	-	-	-	-	-
	Mayangone	26.43	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Mingaladon	129.19	182,521	16.00	21.00	28.00	36.00	0.01	0.06	0.19	0.37	1.00	1.00	-

Division Name	Town Name	Area (SqKm)	Total Population	Cyclone Maximum Wind Speed (m/s)				Earthquake Maximum PGA (g)				Pluvial Flood Average Inundation (in m)		Fluvial Flood Average Inundation (in m)
				25 yr	50 yr	100 yr	200 yr	25 yr	50 yr	100 yr	200 yr	50 Percent Change	100 Percent Change	Fluvial Flood
	Mingalartaungnyunt	5.11	-	-	-	-	-	-	-	-	-	-	-	-
	Myaunkokkalar	27.84	-	15.00	21.00	28.00	35.00	0.01	0.05	0.20	0.36	-	-	-
	Pabedan	0.61	-	-	-	-	-	-	-	-	-	-	-	-
	Pazundaung	1.06	-	-	-	-	-	-	-	-	-	-	-	-
	Sanchaung	2.39	-	-	-	-	-	-	-	-	-	-	-	-
	Seikkan	13.98	-	15.00	20.00	28.00	35.00	0.01	0.05	0.18	0.30	-	-	-
	Seikkyi Khanaungto	12.09	27,289	15.00	21.00	28.00	36.00	0.01	0.05	0.18	0.30	-	-	-
	Shwepyitha	55.16	183,799	15.00	21.00	29.00	36.00	0.01	0.05	0.18	0.36	1.00	1.00	2.00
	Taikkyi	1,538.14	259,143	16.00	22.00	29.00	37.00	0.02	0.06	0.21	0.37	1.00	1.00	1.00
	Tanyin	371.17	171,716	15.00	20.00	27.00	35.00	0.01	0.05	0.20	0.34	1.00	-	-
	Taungokklalar	8.04	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Thakeda	16.94	-	-	-	-	-	-	-	-	-	-	-	-
	Thamwe	4.89	-	-	-	-	-	-	-	-	-	-	-	-
	Thongwa	775.08	183,066	15.00	20.00	27.00	34.00	0.01	0.04	0.18	0.29	1.00	-	-
	Tingankyun	13.06	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Twantay	941.76	264,992	16.00	21.00	29.00	37.00	0.01	0.05	0.18	0.33	-	1.00	1.00
	Yangin	4.76	-	15.00	20.00	28.00	35.00	0.01	0.05	0.19	0.33	-	-	-
	Zalun	741.34	243,934	17.00	22.00	31.00	39.00	0.02	0.05	0.16	0.25	1.00	1.00	3.00

Table 7-2: Town Level Capacity and Vulnerability Analysis

Division Name	Town Name	Area (Sq Km)	Population	Accessibility Vulnerability	Flood & Water Logging Vulnerability	Social Capacity	Income Capacity	Education Capacity	Natural Capacity
Ayeyarwady	Bogale	2,607	423,202	3	8	2	3	3	5
	Dedaye	582	239,272	2	8	2	4	3	7
	Einme	743	205,997	3	4	4	5	3	7
	Gwa	2,242	61,392	-	-	-	-	-	-
	Hinthada	982	447,852	5	3	1	4	3	8
	Ingapu	1,673	300,102	4	3	2	5	3	7
	Kangyidaung	915	225,381	3	3	2	5	3	6
	Kyaiklat	725	209,792	4	7	2	4	3	6
	Kyangin	1,110	128,864	5	1	1	4	3	7
	Kyaunggon	684	177,914	3	7	3	5	3	7
	Kyonpyaw	826	291,632	3	8	3	6	4	7
	Labutta	2,264	343,068	1	7	4	4	3	5
	Laymyethnar	1,169	143,938	4	6	3	5	3	6
	Maubin	1,272	362,889	5	6	2	4	3	6
	Mawlamyinegyunn	1,083	321,288	2	6	3	4	3	5
	Myanaung	1,546	297,493	4	2	2	4	3	7
	Myaungmya	1,532	388,497	1	5	5	5	3	7
	Ngapudaw	3,211	323,741	2	5	5	4	3	4
	Nyaungdon	878	235,223	4	4	2	4	3	4

Division Name	Town Name	Area (Sq Km)	Population	Accessibility Vulnerability	Flood & Water Logging Vulnerability	Social Capacity	Income Capacity	Education Capacity	Natural Capacity
	Pantanaw	1,314	269,305	5	6	2	5	3	7
	Pathein	1,421	340,052	2	1	1	5	3	7
	Pyapon	858	241,303	4	8	3	4	3	5
	Thabaung	2,015	183,177	3	4	2	5	3	6
	Thandwe	3,474	122,233	-	-	-	-	-	-
	Wakema	1,178	350,779	4	6	3	5	3	6
	Yekyi	1,227	260,553	4	7	3	6	3	7
Yangon	Along	3	-	-	-	-	-	-	-
	Bahan	8	-	-	-	-	-	-	-
	Batahtaung	3	-	-	-	-	-	-	-
	Dagon	5	-	-	-	-	-	-	-
	Dagonmyothit (E)	58	-	1	7	3	4	3	3
	Dagonmyothit (N)	26	-	-	-	-	-	-	-
	Dagonmyothit (S)	38	-	-	-	-	-	-	-
	Dagonmyothit (Seikkan)	52	-	-	-	-	-	-	-
	Dalla	29	82,403	6	5	4	5	3	7
	Danubyu	741	228,293	3	3	3	5	3	5
	Dawbon	3	-	-	-	-	-	-	-
	Hlaingbwe	10	-	6	1	2	4	3	3
	Hlegu	1,626	179,955	3	3	3	4	3	2

Division Name	Town Name	Area (Sq Km)	Population	Accessibility Vulnerability	Flood & Water Logging Vulnerability	Social Capacity	Income Capacity	Education Capacity	Natural Capacity
	Hlinethaya	79	212,665	4	2	2	4	3	2
	Hmawbi	314	159,745	3	3	3	4	3	2
	Insein	31	256,687	4	3	2	4	4	2
	Kamayut	7	-	-	-	-	-	-	-
	Kawhmu	681	127,906	4	2	4	4	3	3
	Kayan	627	190,907	5	3	3	5	3	4
	Kungyangon	735	139,671	2	1	5	5	3	3
	Kyauktada	1	-	-	-	-	-	-	-
	Kyauktan	1,023	167,255	4	5	4	4	3	6
	Kyimyintdaing	7	-	6	5	4	5	3	7
	Lanmadaw	1	-	-	-	-	-	-	-
	Latha	1	-	-	-	-	-	-	-
	Mayangone	26	-	-	-	-	-	-	-
	Mingaladon	129	182,521	6	1	2	3	2	3
	Mingalartaungnyunt	5	-	-	-	-	-	-	-
	Myaunkokkalar	28	-	-	-	-	-	-	-
	Pabedan	1	-	-	-	-	-	-	-
	Pazundaung	1	-	-	-	-	-	-	-
	Sanchaung	2	-	-	-	-	-	-	-
	Seikkan	14	-	-	-	-	-	-	-

Division Name	Town Name	Area (Sq Km)	Population	Accessibility Vulnerability	Flood & Water Logging Vulnerability	Social Capacity	Income Capacity	Education Capacity	Natural Capacity
	SeikkyiKhanaungto	12	27,289	6	5	4	5	3	7
	Shwepyitha	55	183,799	4	3	2	4	3	2
	Taikkyi	1,538	259,143	4	1	2	4	3	5
	Tanyin	371	171,716	4	6	4	4	3	6
	Taungokklalar	8	-	-	-	-	-	-	-
	Thakeda	17	-	-	-	-	-	-	-
	Thamwe	5	-	-	-	-	-	-	-
	Thongwa	775	183,066	5	2	4	5	3	5
	Tingankyun	13	-	-	-	-	-	-	-
	Twantay	942	264,992	5	3	3	4	3	4
	Yangin	5	-	-	-	-	-	-	-
	Zalun	741	243,934	5	2	2	5	3	6

The results from Earthquake hazard risk indicate that the Southern delta region, particularly Ayeyarwady division account to maximum losses compared to the Western delta region. Nevertheless, the high population density and building typology of Yangon region makes it more vulnerable (loss per Sq. Km). Moreover, the tectonic element like Sagaing fault (active) is also responsible for the increased hazard risk situation. The results obtained in the present analysis are shown in following table. The percentage contribution of Ayeyrawady and Yangon division to the total losses are 40% and 48% respectively. The higher estimation of losses within the Ayeyrawady division is mainly due to the sheer size of the division which encompasses around 33,300 sq. km in comparison to Yangon which covers 10,250 sq.km.

In the case of cyclone, composite loss estimation included buildings as well as crop loss. On contrary to the earthquake analysis, the Type III building which were less susceptible to earthquakes are highly vulnerable to the cyclone hazard risk. The building losses distribution over Ayeyrawady and Yangon division are 70% and 30% respectively. Risk to buildings due to cyclone is much higher than compared with earthquake hazard. This suggests that the delta region is more vulnerable to Cyclonic losses (20 times) than an earthquake. The analysis indicates that Myaungmya and Pyapon districts of Ayeyrawady division show highest risk to rice crop loss in the case of a cyclonic event. The composite risk estimation for the cyclone hazard was carried out using collective loss information of building and rice crop. The distribution of losses within Ayeyarwady and Yagon are 74% and 26% respectively.

The delta is low lying and is prone to inundation due to both fluvial and pluvial floods. Based on the present indicative studies it was observed that most of the townships of Myaungmya and Pyapon district exhibit high losses. Similar loss is also exhibited by central Pathein and Southern township of Maubin districts. In this exercise, April to June and September to November periods, which are cyclone periods, were used for analysis of composite risk for crops due to flood hazard. Based on the analysis it was observed that distribution of the losses is 48% and 2% for Ayeyrawady and Yangon divisions respectively. Pathein, Myaungmya, Maubin, Pyapon and Western Yangon districts appears to be at high flood risk (maximum flooding). The composite risk for the rice crop was analyzed in conjunction to the building loss. Central delta region of Ayeyrawady particularly Myaungmya district appears to be at high risk for the composite risk which includes building losses and with rice cultivation.

Table 7-1 & Table 7-2 provides an overview of Hazard Risk and vulnerability matrix at township level.

7.5 ANALYSIS OF SECTORAL INTERVENTIONS

The responses to the cyclone disaster was initially delayed, but picked up with the involvement of multiple local and international organizations. The international agencies faced several challenges including lack of understanding of the delta context, delay in getting permissions as well as limited availability of skilled local resource persons. Considering these limitations, significant progress was achieved within two years, with almost all the affected population getting back to their normal life patterns. This is a great achievement made possible by concerted effort of multiple stakeholders in a challenging environment.

The Myanmar Action Plan on Disaster Risk Reduction (MAPDRR) 2009-2015, is a remarkable achievement and leap ahead from the time of having little understanding and acceptance within Government on DRR. Though MAPDRR provides an overall framework for DRR and institutional design in undertaking them, it is too early to comment on its implementation. A brief discussion with Relief and Resettlement Department at Ministry of Social Welfare, and, Planning Department under the Ministry of National Planning and Economic Development suggest that they are incorporating the findings in their planning and implementation process. However it is not clear if there is clearly allocated funds for implementing and sustaining these efforts.

The delta region is predominantly rural and dependent mostly on natural resource based livelihoods and has high incidence of poverty, while this region has a fairly high literacy as well as good coverage of sanitation, compared to many other perpetually risk prone regions in the neighboring countries. With narrow livelihood base, the communities will require support in expanding the livelihood base in this developing country challenged by political and economic environment. While the higher literacy and higher awareness about sanitation provide opportunities to improve quality of life, low income and surplus are major challenges that need to be addressed. Vulnerability is high due to risk to the natural resource base, but housing and other infrastructure is not well developed, but costs of replacement is also low, due to extensive use of local materials.

Interventions were not initially coordinated, but at the later stages the coordination system was developed with some degree of success. The sectoral interventions by various organizations provided rich experience to the communities as well as introduction of new techniques and practices. While most of them were able to improve the quality of life was well as improve the livelihoods, much more needs to be done considering the resource conditions and political and socio-economic context.

Some of the interventions and technology introduction e.g. concrete stilts have autonomously replicated, some others may not be replicated. The Emergency shelters also need to be carefully designed taking in to account the local context, maintenance mechanisms and future sustainability issues.

Starting from virtually no operational disaster risk reduction system, significant achievements were witnessed as evidenced by a more responsive government, formation of CBOs and strengthening of local NGOs. This change was possible largely due to advocacy as well as intervention support by the INGOs as well as increasing responsiveness of the government to these issues. While a lot of improvement is still necessary, the process has reached beyond critical stage and sustainability of some of the interventions can be assured.

Slow processes like sea level rise and increase in temperature or rainfall can severely erode the natural resource base of the Delta region. Such changes should inform design of DRR activities.

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GLOSSARY & DEFINITIONS

Adaptation:

Adjustments of natural or human systems to new/ changing environment. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation

Anthropogenic:

Made by people or resulting from human activities.

Composite Risk (CR):

The expected total loss in a particular area due to the effect of expected hazard risks. Computation of composite risk is expressed mathematically as:

Composite Risk (CR) = $\sum$ Elements at Risk (E) x Specific Risk (Rs.)

= $\sum$ Elements at Risk (E) x Hazard Risk (HR) x Vulnerability (V)

Central pressure:

The surface pressure at the centre of the tropical cyclone as measured or estimated. The pressure at the center of a hurricane measured in milibars. The lower the pressure, the higher the wind speeds.

Climate Change:

Climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer).

Climate Model:

A quantitative way of representing the interactions of the atmosphere, oceans, land surface, and ice. Models can range from relatively simple to quite comprehensive

Climate Sensitivity:

In IPCC Reports, equilibrium climate sensitivity refers to the equilibrium change in global mean surface temperature following a doubling of the atmospheric (equivalent) CO_2 concentration. More generally, equilibrium climate sensitivity refers to the equilibrium change in surface air temperature following a unit change in radiative forcing (degrees Celsius, per watts per square meter, °C/Wm-2). In practice, the evaluation of the equilibrium climate sensitivity requires very long simulations with Coupled General Circulation Models (Climate model). The effective climate sensitivity is a related measure that circumvents this requirement. It is evaluated from model output for evolving non-equilibrium conditions. It is a measure of the strengths of the feedbacks at a particular time and may vary with forcing history and climate state

Climate System (or Earth System):

The five physical components (atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere) that is responsible for the climate and its variations.

Cyclone centre:

The centre of the cloud eye or, if not discernible, of the wind pressure centre.

Cyclone Track:

The path traveled by a cyclone’s center over the days from the time they were classified as a cyclone until they "die" out.

Cyclonic storm:

A cyclonic disturbance in which the maximum average surface wind speed is in the range of 62 to 88 km/h.

Depression:

A cyclonic disturbance in which the maximum sustained surface wind speed is between 31 and 61 km/h. If the maximum sustained wind speed lies in the range 52 km/h to 61 km/h the system may be called a "deep depression

Direction of movement:

The direction towards which the centre of the tropical cyclone is moving.

Ecosystem:

Any natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchange of materials.

Elements at Risk (E):

The population, housing, critical buildings, lifeline infrastructure and utilities and productive activities at risk in a given area.

El Niño - Southern Oscillation (ENSO):

El Niño, is warm water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. This oceanic event is associated with a fluctuation of the inter-tropical surface pressure pattern and circulation in the Indian and Pacific Oceans, called the Southern Oscillation. This coupled atmosphere-ocean phenomenon is collectively known as El Niño-Southern Oscillation. During an El Niño event, the prevailing trade winds weaken and the equatorial countercurrent strengthens, causing warm surface waters in the Indonesian area to flow eastward to overlie the cold waters of the Peru Current. This event has great impact on the wind, sea surface temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world. The opposite of an El Niño event is called La Niña

Epicenter:

The geographical point on the surface of earth vertically above the focus of the earthquake.

Estimated Time of Arrival (ETA):

Time of Tsunami arrival at fixed location, as estimated from modeling the speed and refraction of the Tsunami waves as they travel from the source. ETA is estimated with very good precision if the bathymetry and source are well known (less than a couple of minutes). The first wave is not necessarily the largest, but it is usually one of the first five waves.

Eye of the tropical cyclone:

The relatively clear and calm area inside the circular wall of convective clouds, the geometric centre of which is the centre of the tropical cyclone.

Eye Wall:

The cylindrical center of a cyclone with relatively calm winds where wind is funneled upwards from the ocean surface. Winds outside the eye wall rotate horizontally around the center.

Filling:

Progressive decay in the intensity of a cyclonic storm after landfall

Forward Speed:

The speed by which cyclones advance. In addition to the forward speed, the wind rotates around the cyclone's center at much higher speeds depending on the central pressure. Forward speeds are in the order of 8-50 kmph.

General Circulation Model (GCM):

The Global three-dimensional computer model of the climate system which can be used to simulate human induced climate change.

Gradient Wind Speed:

Wind speeds measured at high altitudes unaffected by local terrain conditions usually measured over 10-minute duration. Any given location, wind speed increases with height in what is known as the boundary layer, up till a certain point, beyond which wind speed does not increase. The minimum height for measuring the gradient wind speed is the thickness of that boundary layer, usually in the order of 1 kilometer

Greenhouse Gas (GHG):

Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Gust:

Instantaneous peak value of surface wind speed recorded or expected.

Hazard Risk (HR):

The probability of occurrence within a specific time period in a given area of potentially damaging phenomena.

Historical Tsunami:

A Tsunami documented to occur through eyewitness or instrumental observation within the historical record.

Hypocenter:

An earthquake occurs as a result of the motion of a fault. The point where the rupture originates is called the hypocentre or the focus and the point directly above this on the ground is called the epicentre. Depth to the hypocentre is known as the focal depth.

Importance Factor:

A factor used to obtain the design seismic force depending on the functional use of the structure characterized by hazardous consequences of its failure its post-earthquake functional need, historic value, or economic importance.

Intensity:

A measure of the strength of shaking during the earthquake, and is indicated by a number according to the Modified Mercalli (MM), M.S.K. or EMS-98 scales. A map showing intensities at individual locations may be contoured based on isoseismals, which are lines of equal intensity. An isoseismal map provides a representation of broad variations of shaking over the region surrounding the earthquake.

Intergovernmental Panel on Climate Change (IPCC):

The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue.

Liquefaction:

A state in saturated cohesionless soil where it tends to behave like a fluid mass due earthquake vibration. This is because the effective soil shear strength is reduced to negligible value for engineering purposes due to pore pressure approaching the total confining pressure.

Lithological Features:

The nature of the geological formation of the earths crust above bedrock classified on the basis of characteristics such as colour, mineralogical composition and grain size.

Local Tsunami:

A Tsunami from a nearby source for which its destructive effects are confined to coasts within about 100 km (or, alternatively, less than 1 hour travel Tsunami travel time) from its source. A local Tsunami is usually generated by an earthquake, but can also be caused by a landslide or a pyroclastic flow from a volcanic eruption.

Low:

An area enclosed by a closed isobar with minimum pressure inside when mean surface wind is less than 31 kmph.

Magnitude of Earthquake:

A number, which is a measure of energy released in an earthquake. It is defined as logarithm to the base 10 of the maximum trace amplitude, expressed in microns, which the standard short-period torsion seismometer (with a period of 0.8s, magnification 2,800 and damping nearly critical) would register due to the earthquake at an epicentral distance of 100 km. Richter magnitude, surface-wave and body-wave magnitudes are commonly used to indicate this measure.

Mainshocks, Foreshocks and Aftershocks:

A large earthquake is generally preceded and followed by many smaller shocks. The largest earthquake is called the main shock. The smaller ones that precede the main shock are called foreshocks and the subsequent shocks are called aftershocks.

Maximum sustained wind speed:

Winds averaged over a fixed time period depending upon regional practices.

Maximum sustained wind:

Maximum value of the average wind speed at the surface.

Mean Sea Level:

The average height of the sea surface, based upon hourly observation of tide height on the open coast or in adjacent waters which have free access to the sea. These observations are to have been made over a considerable period of time. In the United States, mean sea level is defined as the average height of the surface of the sea for all stages of the tide over a 19-year period. Selected values of mean sea level serve as the sea level datum for all elevation surveys in the United States. Along with mean high water, mean low water, and mean lower low water, mean sea level is a type of tidal datum.

Mean wind speed:

Speed of the wind averaged over the previous 10 minutes (mean surface wind) as read from an anemogram or the 3 minutes mean determined with the non-recording anemometer or estimated wind at sea by the mariners using the Beaufort scale.

Meteoroligical Tsunami or MeteoTsunami:

Tsunami-like phenomena generated by meteorological or atmospheric disturbances. These waves can be produced by atmospheric gravity waves, pressure jumps, frontal passages, squalls, gales, typhoons, hurricanes and other atmospheric sources. MeteoTsunamis have the same temporal and spatial scales as Tsunami waves and can similarly devastate coastal areas, especially in bays and inlets with strong amplification and well-defined resonant properties (e.g. Ciutadella Inlet, Baleric Islands; Nagasaki Bay, Japan; Longkou Harbour, China; Vela Luka, Stari Grad and Mali Ston Bays, Croatia). Sometime referred to as rissaga.

Peak Ground Acceleration (PGA):

The largest acceleration recorded by a particular seismological station during an earthquake

Regional Tsunami:

A Tsunami capable of destruction in a particular geographic region, generally within 1,000 km or 1-3 hours Tsunami travel time from its source. Regional Tsunamis also occasionally have very limited and localized effects outside the region.

Response Spectrum:

The representation of the maximum response of idealized single degree of freedom system having specified period and damping, during earthquake ground motion. The maximum response is plotted against the un-damped natural period for various damping values, and expressed in terms of maximum absolute acceleration, maximum relative velocity, or maximum relative displacement.

Return Period:

The recurrence interval, or return period, is the average time span between earthquakes at a particular site.

Runup:

Difference between the elevation of maximum Tsunami penetration (inundation line) and the sea level at the time of the Tsunami. In practical terms, runup is only measured where there is a clear evidence of the inundation limit on the shore. It is also defined as the elevation reached by seawater measured relative to some stated datum such as mean sea level, mean low water, sea level at the time of the Tsunami attack, etc., and measured ideally at a point that is a local maximum of the horizontal inundation. Where the elevation is not measured at the maximum of horizontal inundation this is often referred to as the inundation-height.

Seismograph:

An instrument to recording motions of the earth's surface caused by seismic waves, as a function of time. The simplest earthquake recording system consists of a sensor and an analog or digital recorder. The record is known as a seismogram. Location and magnitude of an earthquake are calculated from seismograms.

Severe cyclonic storm:

A cyclonic disturbance in which the maximum average surface wind speed is in the range of 89 to 118 kmph.

Significant Wave Height:

The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one-third of a selected number of waves, this number being determined by dividing the time of record by the significant period.

Storm season:

The periods April to May and October to December during which most of the cyclonic storms occur in the Bay of Bengal and Arabian Sea. The periods April to May and October to mid-December during which most of the cyclonic storms occur in the Bay of Bengal and Arabian Sea.

Storm tide:

The actual water level as influenced by a weather disturbance. The storm tide consists of the normal astronomical tide and the storm surge

Strom Surge[15]:

It is the difference between the actual water level under the influence of a meteorological disturbance (storm tide) and the level, which would have been reached in the absence of the meteorological disturbance (i.e. astronomical tide). Storm surge results mainly from the shoreward movement of water under the action of wind stress. A minor contribution is also made by the hydrostatic rise of water resulting from the lowered barometric pressure.

Specific Risk:

The expected degree of loss to a particular element at risk due to particular phenomena as a function of both hazard risk and vulnerability.

Super cyclone:

A cyclonic disturbance in which maximum wind speed is 222 kmph and above.

Tectonic Features:

The nature of geological formation in the earth's crust revealing regions characterized by structural features, such as dislocation, distortion, faults, folding, thrusts with their age of formation, which are directly involved in the earthquake resulting in the above consequences.

[15] *http://www.imd.gov.in/section/nhac/dynamic/cycterm.pdf*

Tide:

The rhythmic, alternate rise and fall of the surface (or water level) of the ocean, and of bodies of water connected with the ocean such as estuaries and gulfs, occurring twice a day over most of the Earth and resulting from the gravitational attraction of the moon (and, in lesser degrees, of the sun) acting unequally on different parts of the rotating Earth.

Tide Gauge:

A device for measuring the height (rise and fall) of the tide.

Tropical cyclone:

Generic term for a non-frontal synoptic scale cyclone originating over tropical or sub-tropical waters with organized convection and definite cyclonic surface wind circulation.

Tsunami:

Japanese term meaning wave ("nami") in a harbour ("tsu"). A series of traveling waves of extremely long length and period, usually generated by disturbances associated with earthquakes occurring below or near the ocean floor. (Also called seismic sea wave and, incorrectly, tidal wave). Volcanic eruptions, submarine landslides, and coastal rockfalls can also generate Tsunamis, as can a large meteorite impacting the ocean. These waves may reach enormous dimensions and travel across entire ocean basins with little loss of energy. They proceed as ordinary gravity waves with a typical period between 10 and 60 minutes. Tsunamis steepen and increase in height on approaching shallow water, inundating low-lying areas, and where local submarine topography causes the waves to steepen, they may break and cause great damage.

Tsunami amplitude:

Usually measured on a sea level record, it is: 1) The absolute value of the difference between a particular peak or trough of the Tsunami and the undisturbed sea level at the time, 2) Half the difference between an adjacent peak and trough, corrected for the change of tide between that peak and trough. It is intended to represent the true amplitude of the Tsunami wave at some point in the ocean. However, it is often amplitude modified in some way by the tide gauge response.

Tsunami Earthquake:

An earthquake that produces an unusually large Tsunami relative to the earthquake magnitude (Kanamori, 1972). Typical characteristics of Tsunami earthquakes include long rupture durations for the magnitude of the earthquake, rupture on the very shallow part of the plate interface (inferred from a location near the trench and a low-angle thrust mechanism), and high energy release at low frequencies. They are also slow earthquakes, with slippage along their faults occurring more slowly than would occur in normal earthquakes. The last events of this type were in 1992 (Nicaragua), 1994 (Java), 1996 (Chimbote, Peru) and 2006 (Java).

Tsunami Generation:

Tsunamis are most frequently caused by earthquakes, but can also result from landslides, volcanic eruptions, and very infrequently by meteorites or other impacts upon the ocean surface. Tsunamis are generated primarily by tectonic dislocations under the sea which are caused by shallow focus earthquakes along areas of subduction. The upthrusted and downthrusted crustal blocks impart potential energy into the overlying water mass with drastic changes in the sea level over the affected region. The energy imparted into the water mass results in Tsunami generation, i.e. energy radiating away from the source region in the form of long period waves.

Tsunami Zoning:

Designation of distinctive zones along coastal areas with varying degrees of Tsunami risk and vulnerability for the purpose of disaster preparedness, planning, construction codes, or public evacuation.

Very severe cyclonic storm:

A cyclonic disturbance in which maximum wind average is 119 to 221 kmph.

Vulnerability (V):

The degree of loss to a given element at risk or a set of elements resulting from the occurrence of a hazard of a given magnitude. This is expressed on a scale from 0 (no damage) to 1 (total loss).

Wind field:

A vector field that describes the attenuation or variation of wind speeds away from the cyclone's eye or center. Wind speeds are minimum in the cyclone's center, increase sharply toward the eye wall, and then drop again asymptotically away from the cyclone's center.

ANNEXES

Annex (A): Cyclone Tracks

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1972	12/11/1972	10.27	1001	109.7	18.3	281.3
1972	12/3/1972	30.85	983	46.7	7.8	315
1972	12/3/1972	30.85	983	62.3	10.4	315
1972	12/4/1972	30.85	983	62.3	10.4	315
1972	12/4/1972	30.85	983	76.7	12.8	270
1972	12/4/1972	28.28	987	54.8	9.1	270
1972	12/4/1972	23.14	992	32.8	5.5	270
1972	9/18/1972	10.27	1001	183.9	30.7	276.7
1972	8/29/1972	15.43	997	147.8	24.6	282.1
1972	8/29/1972	12.85	999	144.4	24.1	265.9
1972	4/10/1972	28.28	984	86.7	14.5	60.3
1973	11/17/1973	28.28	984	122.5	20.4	26.6
1973	11/17/1973	28.28	984	122.3	20.4	26.6
1973	11/17/1973	25.71	988	126.9	21.2	31
1973	11/17/1973	25.71	988	126.7	21.1	31
1973	7/9/1973	15.43	998	115.7	19.3	270
1973	7/9/1973	10.27	1001	84.8	14.1	277.1
1973	7/9/1973	7.71	1002	63	10.5	270
1973	7/9/1973	7.71	1002	84.8	14.1	277.1
1973	9/15/1973	18	996	109.6	18.3	286.7
1973	9/15/1973	12.85	999	89.8	15	290.6
1973	9/15/1973	10.27	1000	99.4	16.6	288.4
1973	9/15/1973	10.27	1000	116.4	19.4	280.3
1973	9/8/1973	10.27	1000	165.2	27.5	251.6
1973	9/8/1973	7.71	1001	191.6	31.9	236.3
1973	9/8/1973	7.71	1002	192.4	32.1	236.3
1973	11/17/1973	12.85	1000	77.5	12.9	278.1
1973	11/18/1973	12.85	1000	79.2	13.2	303.7
1973	11/18/1973	12.85	1000	98	16.3	296.6
1973	11/11/1973	12.85	1000	159.6	26.6	254.1
1973	11/12/1973	12.85	1000	186.6	31.1	266.6
1973	12/9/1973	25.71	988	222.9	37.2	39.1
1973	12/9/1973	23.14	991	250.1	41.7	43.3
1973	11/17/1973	28.28	984	122.5	20.4	26.6
1973	11/17/1973	28.28	984	122.3	20.4	26.6
1973	11/17/1973	25.71	988	126.9	21.2	31

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1973	11/17/1973	25.71	988	126.7	21.1	31
1974	6/14/1974	10.27	1001	99.6	16.6	288.4
1974	6/14/1974	10.27	1000	103.6	17.3	294
1974	10/27/1974	12.85	999	146.9	24.5	270
1974	11/5/1974	7.71	1002	193.5	32.3	270
1974	11/27/1974	38.57	966	123.4	20.6	37.9
1974	11/28/1974	36	971	136.7	22.8	28.6
1974	11/28/1974	33.43	976	151	25.2	30.3
1975	9/21/1975	8.23	1000	333.8	55.6	288.4
1975	9/21/1975	6.17	1004	209.2	34.9	270
1975	11/11/1975	20.57	994	106.4	17.7	45
1975	11/11/1975	20.57	994	106.2	17.7	45
1975	11/11/1975	18	997	114.3	19.1	41.2
1975	11/11/1975	18	997	120.8	20.1	45
1975	5/5/1975	18	997	61.7	10.3	315
1975	5/6/1975	20.57	994	96.7	16.1	296.6
1975	5/6/1975	25.71	988	82.1	13.7	293.2
1975	5/6/1975	33.43	976	39	6.5	56.3
1975	5/6/1975	38.57	966	54.6	9.1	78.7
1975	5/7/1975	38.57	966	24.5	4.1	26.6
1975	5/7/1975	36	971	49.1	8.2	26.6
1975	5/7/1975	33.43	976	92.9	15.5	54.5
1975	5/7/1975	20.57	994	125.3	20.9	59
1975	5/8/1975	12.85	1001	158	26.3	61.7
1975	5/8/1975	10.27	1003	176.2	29.4	65
1976	4/29/1976	18	997	24.6	4.1	26.6
1976	4/30/1976	20.57	994	64.1	10.7	31
1976	4/30/1976	23.14	991	79.1	13.2	33.7
1976	4/30/1976	23.14	991	45.5	7.6	14
1976	4/30/1976	25.71	988	56.3	9.4	11.3
1976	5/1/1976	25.71	988	91	15.2	14
1976	5/1/1976	20.57	994	89.1	14.9	7.1
1976	5/1/1976	18	997	56.3	9.4	11.3
1976	5/1/1976	20.57	994	56.3	9.4	11.3
1976	5/2/1976	23.14	991	59.2	9.9	21.8
1976	5/2/1976	23.14	991	63.7	10.6	31
1976	5/2/1976	18	997	54.3	9.1	36.9
1976	7/27/1976	10.28	996	207.5	34.6	264.3
1976	7/27/1976	9.25	998	103.2	17.2	270
1976	7/27/1976	9.25	998	103.2	17.2	270
1976	9/10/1976	20.57	994	60.8	10.1	315

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1976	9/10/1976	20.57	994	61.7	10.3	301
1977	5/12/1977	30.85	980	136.9	22.8	28.6
1977	5/12/1977	25.71	988	69.1	11.5	38.7
1977	5/12/1977	20.57	994	63.4	10.6	31
1977	5/13/1977	18	997	100.1	16.7	6.3
1977	5/13/1977	15.43	999	121.8	20.3	0
1977	7/21/1977	20.57	990	125.2	20.9	274.8
1977	7/22/1977	13.88	990	103.9	17.3	270
1977	7/22/1977	13.88	990	114.8	19.1	275.2
1977	9/5/1977	9.25	998	212.9	35.5	270
1977	9/6/1977	8.23	1000	76.7	12.8	315
1978	5/15/1978	15.43	999	56.3	9.4	11.3
1978	5/15/1978	15.43	999	69.7	11.6	18.4
1978	5/15/1978	18	997	34.8	5.8	18.4
1978	5/15/1978	18	997	45.5	7.6	14
1978	5/16/1978	18	997	78.1	13	8.1
1978	5/16/1978	20.57	994	88.5	14.8	0
1978	5/16/1978	20.57	994	66.4	11.1	0
1978	5/16/1978	23.14	991	66.4	11.1	0
1978	5/17/1978	25.71	988	94	15.7	20.6
1978	5/17/1978	30.85	980	132.8	22.1	35
1978	10/3/1978	5.14	1006	41.3	6.9	270
1978	10/4/1978	5.14	1006	51.6	8.6	270
1978	10/4/1978	5.14	1006	51.6	8.6	270
1978	10/4/1978	5.14	1006	51.6	8.6	270
1978	10/4/1978	5.14	1006	51.6	8.6	270
1978	9/27/1978	7.2	1002	132.3	22.1	235
1978	9/28/1978	7.2	1002	107.5	17.9	270
1978	9/28/1978	7.2	1002	107.5	17.9	270
1978	8/28/1978	10.28	996	155.9	26	270
1978	8/28/1978	9.25	998	155.9	26	270
1978	8/28/1978	8.23	1000	169.7	28.3	259.4
1978	8/12/1978	10.28	996	158.8	26.5	270
1978	8/13/1978	10.28	996	144.4	24.1	287.1
1978	8/13/1978	10.28	996	69.6	11.6	341.6
1979	8/3/1979	10.28	996	160.4	26.7	258.7
1979	8/4/1979	8.23	1000	264.2	44	263.2
1979	8/4/1979	8.23	1000	118.8	19.8	243.4
1980	9/16/1980	6.17	1004	238.4	39.7	243.4
1980	9/16/1980	5.14	1006	52.9	8.8	270
1980	7/23/1980	10.28	996	208.6	34.8	270

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1980	7/23/1980	9.25	998	117.9	19.7	296.6
1980	6/28/1980	11.31	994	155.8	26	277.6
1980	6/29/1980	10.28	996	157.4	26.2	281.3
1981	8/20/1981	10.28	996	121.2	20.2	315
1981	8/20/1981	9.25	998	51.6	8.6	270
1981	8/21/1981	8.23	1000	51.6	8.6	270
1981	8/21/1981	8.23	1000	151.1	25.2	315
1981	8/10/1981	9.25	998	105.1	17.5	264.3
1981	7/5/1981	9.25	998	104.6	17.4	270
1981	7/5/1981	9.25	998	104.6	17.4	270
1981	7/5/1981	8.23	1000	104.6	17.4	270
1981	10/15/1981	6.17	1004	154.7	25.8	315
1981	10/15/1981	6.17	1004	154.4	25.7	315
1981	10/15/1981	5.14	1006	154.1	25.7	315
1981	10/16/1981	5.14	1006	153.7	25.6	315
1981	11/19/1981	38.57	966	104.5	17.4	18.4
1981	11/19/1981	38.57	966	91	15.2	14
1981	11/20/1981	33.43	976	104.4	17.4	18.4
1981	11/20/1981	30.85	980	93.9	15.7	20.6
1981	11/20/1981	28.28	984	69.6	11.6	18.4
1982	5/3/1982	54	928	127.9	21.3	85.2
1982	5/4/1982	59.14	913	159.2	26.5	90
1982	5/4/1982	61.71	905	202.1	33.7	93
1982	5/4/1982	51.43	936	149.1	24.9	85.9
1982	5/4/1982	41.14	961	108.4	18.1	78.7
1982	5/5/1982	28.28	984	67.3	11.2	71.6
1982	5/5/1982	20.57	994	24.5	4.1	26.6
1983	7/18/1983	23.14	990	156.8	26.1	277.6
1983	7/18/1983	20.57	992	207.9	34.7	275.7
1983	7/18/1983	18	994	206.8	34.5	272.9
1983	6/27/1983	8.23	1000	105.1	17.5	275.7
1983	6/27/1983	8.23	1000	444	74	345.6
1983	10/17/1983	6.17	1004	147.5	24.6	287.1
1983	10/18/1983	6.17	1004	154.9	25.8	282.1
1983	10/18/1983	6.17	1004	132.7	22.1	305
1983	10/18/1983	6.17	1004	102.3	17.1	302
1983	10/11/1983	4.57	1007	107	17.8	270
1983	10/11/1983	5.14	1006	220.8	36.8	284
1983	10/1/1983	6.17	1004	104.5	17.4	270
1983	11/8/1983	23.14	991	67.2	11.2	9.5
1983	11/8/1983	25.71	988	56.3	9.4	11.3

Year	Start Date	Wind (m/s)	Pressure (lbs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1983	11/9/1983	28.28	984	169	28.2	11.3
1983	11/9/1983	28.28	984	183.7	30.6	40.2
1983	11/9/1983	28.28	984	105.9	17.7	45
1983	10/18/1983	10.27	1003	152.3	25.4	278.1
1983	10/18/1983	12.85	1001	164.7	27.5	281.3
1983	10/19/1983	12.85	1001	147.5	24.6	306
1983	10/19/1983	15.43	999	138.4	23.1	315
1983	10/19/1983	15.43	999	124.3	20.7	322.1
1983	10/19/1983	15.43	999	84.9	14.2	320.2
1983	10/20/1983	12.85	1001	103	17.2	328
1983	10/20/1983	12.85	1001	98	16.3	333.4
1983	10/20/1983	12.85	1001	115	19.2	343.3
1984	6/26/1984	12.85	992	155.4	25.9	270
1984	6/26/1984	11.31	994	214.8	35.8	256
1984	6/26/1984	10.28	996	207.9	34.7	270
1984	6/27/1984	9.25	998	155.9	26	270
1984	7/10/1984	9.25	998	241.3	40.2	290
1984	7/10/1984	9.25	998	162	27	288.4
1984	7/10/1984	8.23	1000	161.5	26.9	288.4
1985	5/24/1985	23.14	991	83.6	13.9	23.2
1985	5/24/1985	25.71	988	97.9	16.3	26.6
1985	5/24/1985	28.28	984	112.3	18.7	29.1
1985	5/24/1985	30.85	980	125.6	20.9	15.3
1985	5/25/1985	30.85	980	160.3	26.7	15.9
1985	9/8/1985	7.2	1002	91.5	15.3	270
1985	9/8/1985	6.17	1004	81.4	13.6	270
1985	10/22/1985	4.01	1008	105.2	17.5	270
1985	10/22/1985	1.74	1012	315.8	52.6	270
1985	10/16/1985	8.23	1000	170.2	28.4	266.4
1985	10/17/1985	6.17	1004	119.6	19.9	296.6
1985	10/17/1985	6.17	1004	211.8	35.3	270
1986	11/9/1986	25.71	988	177	29.5	37.6
1986	11/9/1986	20.57	994	176.4	29.4	37.6
1986	9/6/1986	30.86	975	168.7	28.1	262.9
1986	9/6/1986	23.14	985	212.1	35.4	261.5
1986	9/6/1986	10.28	996	166.2	27.7	243.4
1986	9/6/1986	7.2	1002	105.2	17.5	270
1986	7/24/1986	6.17	1004	101.7	17	270
1986	7/24/1986	6.17	1004	101.7	17	270
1987	5/30/1987	10.27	1003	79.2	13.2	326.3
1987	5/30/1987	10.27	1003	78.5	13.1	303.7

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1987	5/30/1987	10.27	1003	85.5	14.3	320.2
1987	5/31/1987	10.27	1003	63.2	10.5	301
1987	5/31/1987	10.27	1003	70	11.7	321.3
1987	5/31/1987	12.85	1001	61.6	10.3	315
1987	5/31/1987	12.85	1001	46.2	7.7	315
1987	6/1/1987	12.85	1001	54.1	9	306.9
1987	6/3/1987	20.57	994	84.6	14.1	39.8
1987	6/3/1987	23.14	991	84.5	14.1	39.8
1987	6/4/1987	25.71	988	102.7	17.1	32
1987	6/4/1987	28.28	984	90.9	15.2	14
1987	6/4/1987	25.71	988	99.6	16.6	0
1987	6/4/1987	20.57	994	100.1	16.7	6.3
1987	6/5/1987	15.43	999	93.7	15.6	20.6
1987	2/3/1987	15.43	999	122.5	20.4	45
1987	2/3/1987	12.85	1001	168	28	45
1987	2/4/1987	10.27	1003	174.8	29.1	47.5
1987	8/22/1987	23.14	985	159.3	26.6	277.6
1987	8/23/1987	20.57	990	176.8	29.5	287.4
1987	8/23/1987	11.31	994	171.1	28.5	299.7
1987	8/23/1987	10.28	996	191.2	31.9	303.7
1987	8/17/1987	10.28	996	218.6	36.4	284
1987	8/17/1987	10.28	996	105.6	17.6	270
1987	11/9/1987	12.85	1001	56.3	9.4	348.7
1987	11/9/1987	12.85	1001	56.3	9.4	348.7
1987	11/10/1987	12.85	1001	55.1	9.2	281.3
1987	11/10/1987	12.85	1001	48.5	8.1	243.4
1987	11/10/1987	12.85	1001	55.1	9.2	258.7
1988	11/17/1988	15.43	999	108.3	18.1	24
1988	11/18/1988	20.57	994	139.3	23.2	38.7
1988	11/18/1988	25.71	988	175.9	29.3	52.4
1988	11/18/1988	28.28	984	228.5	38.1	52.6
1988	10/17/1988	12.85	1001	100.3	16.7	310.6
1988	10/17/1988	12.85	1001	147.3	24.6	306
1988	10/17/1988	12.85	1001	154.9	25.8	320.7
1988	10/18/1988	15.43	999	118.5	19.8	338.2
1988	10/18/1988	18	997	142.8	23.8	337.4
1988	10/18/1988	18	997	151.6	25.3	329.7
1988	10/18/1988	15.43	999	171.1	28.5	333.4
1988	10/19/1988	15.43	999	136.4	22.7	346
1988	11/29/1988	56.57	921	126.8	21.1	31
1988	11/29/1988	46.28	949	117	19.5	33.7

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1989	11/2/1989	23.14	992	39.8	6.6	326.3
1989	11/3/1989	23.14	990	84.1	14	336.8
1989	11/3/1989	28.29	980	55.1	9.2	323.1
1989	11/3/1989	30.86	975	59	9.8	291.8
1989	11/3/1989	33.43	970	64	10.7	301
1989	11/4/1989	38.57	960	90.2	15	284
1989	11/4/1989	33.43	970	172.9	28.8	288.4
1989	6/12/1989	8.23	1000	75.6	12.6	315
1989	10/14/1989	9.25	998	211.8	35.3	275.7
1989	10/3/1989	23.14	990	176.8	29.5	287.4
1989	10/3/1989	10.28	996	181.1	30.2	280
1990	10/19/1990	5.14	1006	165.1	27.5	258.7
1990	12/17/1990	23.14	991	122.2	20.4	52.1
1990	12/18/1990	23.14	991	106.8	17.8	53.1
1990	12/18/1990	18	997	100.1	16.7	58
1990	12/18/1990	18	997	108.6	18.1	60.9
1990	12/18/1990	15.43	999	99	16.5	71.6
1991	6/1/1991	18	997	128.8	21.5	20
1991	6/1/1991	20.57	994	128.7	21.5	20
1991	6/1/1991	23.14	991	142.6	23.8	22.6
1991	6/2/1991	25.71	988	175.4	29.2	29.7
1991	6/2/1991	23.14	991	182.2	30.4	40.2
1991	6/2/1991	18	997	189.5	31.6	60.6
1991	6/2/1991	15.43	999	219.8	36.6	62.2
1991	7/14/1991	9.25	998	145.2	24.2	291
1991	7/14/1991	8.23	1000	103.1	17.2	270
1991	8/18/1991	9.25	998	53.2	8.9	270
1991	4/29/1991	61.71	905	132.6	22.1	24.4
1991	4/29/1991	66.87	887	157	26.2	33.7
1991	4/29/1991	72.01	868	171.5	28.6	34.7
1991	4/29/1991	69.43	878	203.6	33.9	47.1
1991	4/30/1991	56.57	921	214.3	35.7	60.9
1991	4/30/1991	43.71	955	239.7	40	70
1991	4/30/1991	30.85	980	282.6	47.1	75.5
1992	7/23/1992	9.25	998	166.2	27.7	262.9
1992	7/24/1992	8.23	1000	144.7	24.1	265.9
1992	7/24/1992	8.23	1000	146.1	24.4	261.9
1992	7/24/1992	8.23	1000	134.2	22.4	270
1992	11/15/1992	23.14	998	101.6	16.9	282.5
1992	11/15/1992	23.14	996	133.1	22.2	294.4
1992	11/15/1992	23.14	996	168.3	28.1	281.3

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1992	7/14/1992	10.28	996	210.7	35.1	278.5
1992	7/14/1992	8.23	1000	155.9	26	270
1992	7/14/1992	8.23	1000	214.8	35.8	284
1992	10/4/1992	7.71	1004	144.1	24	278.7
1992	10/4/1992	7.71	1004	142.8	23.8	274.4
1992	10/20/1992	12.85	1001	91.6	15.3	45
1992	10/21/1992	12.85	1001	99.8	16.6	40.6
1992	10/21/1992	15.43	999	151.9	25.3	50.7
1992	10/21/1992	15.43	999	152.8	25.5	56.3
1992	10/21/1992	15.43	999	168.6	28.1	79.4
1992	9/21/1992	10.27	1003	179.9	30	270
1992	9/21/1992	10.27	1003	180.2	30	273.4
1992	9/21/1992	10.27	1003	139.2	23.2	278.7
1992	9/21/1992	12.85	1001	128.6	21.4	279.5
1992	9/22/1992	15.43	999	130.7	21.8	305
1992	9/22/1992	15.43	999	93.5	15.6	324.5
1992	9/22/1992	15.43	999	88	14.7	330.3
1992	9/22/1992	15.43	999	76.5	12.8	303.7
1992	9/23/1992	15.43	999	33	5.5	288.4
1992	9/23/1992	15.43	999	23.5	3.9	296.6
1992	9/23/1992	15.43	999	38.1	6.4	303.7
1992	9/23/1992	15.43	999	32.9	5.5	288.4
1992	9/24/1992	12.85	1001	42.8	7.1	284
1992	11/8/1992	10.27	1003	132.7	22.1	265.2
1992	11/8/1992	7.71	1004	154.7	25.8	265.9
1992	11/8/1992	5.14	1005	187.8	31.3	266.6
1992	11/9/1992	5.14	1005	187.8	31.3	266.6
1992	5/18/1992	28.28	984	138.6	23.1	51.3
1992	5/18/1992	30.85	980	153.4	25.6	50.7
1992	5/19/1992	33.43	976	213.8	35.6	49.1
1992	5/19/1992	30.85	980	220.8	36.8	50.9
1992	5/19/1992	23.14	991	249.9	41.7	46.7
1992	5/19/1992	18	997	256.5	42.8	45
1993	7/12/1993	20.57	992	147	24.5	270
1993	7/12/1993	9.25	998	53.6	8.9	281.3
1993	7/12/1993	9.25	998	31.4	5.2	270
1993	7/13/1993	9.25	998	31.4	5.2	270
1993	11/28/1993	10.27	1003	121.3	20.2	270
1993	11/28/1993	10.27	1003	121.8	20.3	275.2
1993	11/29/1993	10.27	1003	110.2	18.4	270
1993	11/29/1993	10.27	1003	121.2	20.2	270

Year	Start Date	Wind (m/s)	Pressure (lbs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1993	11/29/1993	10.27	1003	132.3	22.1	270
1994	8/29/1994	18	996	146.9	24.5	278.1
1994	8/29/1994	8.23	1000	155.8	26	273.8
1994	7/31/1994	10.28	996	105.2	17.5	270
1994	7/31/1994	9.25	998	157.9	26.3	270
1994	7/31/1994	9.25	998	105.2	17.5	270
1994	7/31/1994	9.25	998	105.2	17.5	270
1994	8/1/1994	8.23	1000	63.1	10.5	270
1994	5/1/1994	48.85	942	125.8	21	15.3
1994	5/1/1994	54	928	125.8	21	15.3
1994	5/2/1994	59.14	913	118.4	19.7	21.8
1994	5/2/1994	64.29	896	118.3	19.7	21.8
1994	5/2/1994	56.57	921	122.2	20.4	26.6
1994	5/2/1994	41.14	961	120.9	20.2	52.1
1994	5/3/1994	25.71	988	122.3	20.4	59
1994	5/3/1994	15.43	999	125.4	20.9	65.6
1995	9/12/1995	7.71	1004	178.7	29.8	295
1995	9/12/1995	7.71	1004	185.1	30.9	280
1995	9/12/1995	7.71	1004	182.3	30.4	273.4
1995	9/13/1995	7.71	1004	161.9	27	277.6
1995	9/13/1995	10.27	1003	174.1	29	280.6
1995	9/13/1995	10.27	1003	145.8	24.3	312
1995	9/13/1995	10.27	1003	103.1	17.2	328
1995	9/14/1995	10.27	1003	76.5	12.8	315
1995	9/14/1995	12.85	1001	61.1	10.2	315
1995	9/14/1995	12.85	1001	47.5	7.9	296.6
1995	9/14/1995	15.43	999	47.4	7.9	296.6
1995	9/15/1995	15.43	999	53.6	8.9	281.3
1995	9/15/1995	15.43	999	43.3	7.2	284
1995	9/15/1995	15.43	999	52.4	8.7	270
1995	9/15/1995	12.85	1001	53.5	8.9	281.3
1995	11/25/1995	46.28	949	260.2	43.4	55
1995	11/25/1995	43.71	955	281.8	47	55.7
1995	11/25/1995	23.14	991	244.3	40.7	59
1995	11/5/1995	7.71	1004	133	22.2	294.4
1996	5/7/1996	15.43	999	99.9	16.7	40.6
1996	5/7/1996	18	997	144.5	24.1	48
1996	5/7/1996	20.57	994	159.7	26.6	53.1
1996	5/8/1996	20.57	994	167.3	27.9	55.3
1996	5/8/1996	18	997	169	28.2	60.3
1996	5/8/1996	15.43	999	162.8	27.1	63.4

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1996	9/23/1996	6.17	1004	210.9	35.2	300.5
1996	9/10/1996	7.2	1002	167.9	28	284
1996	9/10/1996	6.17	1004	125.6	20.9	284
1996	8/23/1996	23.14	990	163	27.2	284.9
1996	8/23/1996	9.25	998	175.7	29.3	287.4
1996	7/24/1996	20.57	990	86.5	14.4	284
1996	7/24/1996	20.57	994	70.9	11.8	296.6
1996	7/24/1996	9.25	998	121.5	20.3	315
1996	7/25/1996	9.25	998	83.2	13.9	309.8
1996	7/25/1996	9.25	998	60.5	10.1	315
1996	7/25/1996	8.23	1000	82.9	13.8	309.8
1996	11/1/1996	7.71	1004	115.6	19.3	311.2
1996	11/1/1996	7.71	1004	57.9	9.7	291.8
1996	11/1/1996	7.71	1004	91.8	15.3	290.6
1996	11/1/1996	7.71	1004	98.6	16.4	282.5
1996	11/2/1996	7.71	1004	85.4	14.2	270
1996	11/2/1996	7.71	1004	64	10.7	270
1996	11/2/1996	7.71	1004	88.3	14.7	256
1996	11/2/1996	7.71	1004	75.6	12.6	261.9
1996	11/3/1996	10.27	1003	65.1	10.9	260.5
1997	8/23/1997	10.28	996	158.7	26.5	281.3
1997	8/23/1997	8.23	1000	256.4	42.7	284
1997	11/3/1997	23.14	990	122.8	20.5	296.6
1997	11/3/1997	23.14	990	118.7	19.8	303.7
1997	11/3/1997	20.57	992	147.9	24.7	318
1997	11/3/1997	18	998	210.6	35.1	291.3
1997	9/26/1997	28.28	984	183.2	30.5	54.5
1997	9/26/1997	30.85	980	136.3	22.7	51.3
1997	9/26/1997	33.43	976	121	20.2	45
1997	9/27/1997	33.43	976	165.9	27.7	45
1997	9/27/1997	33.43	976	165.2	27.5	45
1997	9/27/1997	18	997	166.7	27.8	39.8
1997	5/18/1997	51.43	936	111.1	18.5	5.7
1997	5/18/1997	54	928	104.4	17.4	18.4
1997	5/19/1997	56.57	921	104.4	17.4	18.4
1997	5/19/1997	59.14	913	122.2	20.4	26.6
1997	5/19/1997	59.14	913	141.4	23.6	32.5
1997	5/19/1997	46.28	949	352.4	58.7	46.2
1997	5/20/1997	33.43	976	377.6	62.9	50.6
1997	11/4/1997	18	1006	102.9	34.3	302
1997	11/4/1997	18	1006	21.6	7.2	270

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1997	11/4/1997	18	1004	77.4	25.8	315
1997	11/4/1997	18	1004	77.3	12.9	315
1997	11/4/1997	18	1004	108	18	270
1997	11/5/1997	18	1004	121.2	10.1	296.6
1997	11/5/1997	18	1004	53.8	4.5	270
1997	11/6/1997	18	1004	55.3	18.4	0
1997	11/6/1997	18	1004	53.7	17.9	270
1997	11/6/1997	18	1004	107.5	35.8	270
1997	11/6/1997	18	1004	30.8	3.4	45
1997	11/6/1997	18	1004	33.1	5.5	0
1997	11/7/1997	18	1004	75.1	25	270
1997	11/7/1997	18	1004	53.6	2.2	270
1998	12/11/1998	7.2	1002	143.6	23.9	265.6
1998	11/16/1998	12.85	1001	110.1	18.4	275.7
1998	11/16/1998	12.85	1001	76.7	12.8	270
1998	11/16/1998	12.85	1001	77.4	12.9	278.1
1998	11/16/1998	12.85	1001	98.5	16.4	270
1998	11/17/1998	12.85	1001	110	18.3	275.7
1998	11/17/1998	12.85	1001	87.6	14.6	270
1998	11/17/1998	12.85	1001	87.6	14.6	270
1998	11/17/1998	12.85	1001	98.5	16.4	270
1998	11/18/1998	12.85	1001	88.2	14.7	277.1
1998	11/22/1998	20.57	994	136.2	22.7	51.3
1998	11/22/1998	18	997	143.7	24	54
1998	5/18/1998	18	997	128.8	21.5	20
1998	5/19/1998	20.57	994	128.7	21.5	20
1998	5/19/1998	23.14	991	88	14.7	29.7
1998	5/19/1998	28.28	984	54.1	9	36.9
1998	5/19/1998	30.85	980	78.2	13	33.7
1998	5/20/1998	36	971	84	14	39.8
1998	5/20/1998	30.85	980	170.9	28.5	34.7
1998	5/20/1998	20.57	994	106.9	17.8	60.9
1999	6/8/1999	10.27	1003	21.1	3.5	270
1999	6/8/1999	12.85	1001	21.1	3.5	270
1999	6/8/1999	12.85	1001	15.2	2.5	315
1999	6/9/1999	12.85	1001	39.3	6.6	326.3
1999	6/9/1999	12.85	1001	49	8.2	333.4
1999	6/9/1999	12.85	1001	69.6	11.6	341.6
1999	6/9/1999	12.85	1001	54.2	9	323.1
1999	6/10/1999	12.85	1001	68.4	11.4	308.7
1999	6/10/1999	12.85	1001	122.7	20.5	290

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
1999	10/25/1999	12.85	1001	152.1	25.4	291
1999	10/25/1999	12.85	1001	133.5	22.3	305
1999	10/25/1999	12.85	1001	85.4	14.2	309.8
1999	10/25/1999	12.85	1001	109.1	18.2	306.9
1999	10/26/1999	18	997	85.2	14.2	309.8
1999	10/26/1999	18	997	132.6	22.1	305
1999	10/26/1999	23.14	991	108.5	18.1	306.9
1999	10/26/1999	25.71	988	96.4	16.1	296.6
1999	10/27/1999	33.43	976	96.3	16.1	296.6
1999	10/27/1999	38.57	966	72.1	12	296.6
1999	10/15/1999	10.27	1003	159.9	26.7	298.3
1999	10/15/1999	12.85	1001	130.7	21.8	279.5
2002	5/10/2002	15.43	1000	59.4	9.9	21.8
2002	5/11/2002	23.14	991	122.1	20.4	5.2
2002	5/11/2002	23.14	991	147.4	24.6	13
2002	5/11/2002	23.14	991	171.4	28.6	14.9
2002	5/12/2002	18	997	171.3	28.6	14.9
2002	5/12/2002	12.85	1002	130.5	21.8	41.6
2002	11/27/2002	18	1004	57.6	9.6	68.2
2002	11/27/2002	15.43	1006	33.2	5.5	0
2002	11/27/2002	12.85	1006	53	5.9	90
2002	11/28/2002	12.85	1008	76.6	8.5	45
2002	5/10/2002	18	997	55.3	9.2	0
2002	5/11/2002	18	997	88.5	14.8	0
2003	5/18/2003	15.43	1000	113.2	18.9	29.1
2003	5/18/2003	15.43	1000	115.6	19.3	48.8
2003	5/18/2003	15.43	1000	115.9	19.3	41.2
2003	5/18/2003	15.43	1000	91	15.2	14
2003	5/19/2003	18	997	89.1	14.9	7.1
2003	5/19/2003	23.14	991	88.2	14.7	29.7
2003	5/19/2003	23.14	991	108.1	18	24
2003	8/26/2003	10.28	996	210.5	35.1	249.8
2003	7/22/2003	20.57	990	210.3	35.1	264.3
2004	11/25/2004	18	1000	202.3	33.7	292.4
2004	11/25/2004	6.17	1004	113.6	18.9	330.9
2004	6/15/2004	7.2	1002	61.2	10.2	315
2004	5/16/2004	12.85	1000	76.7	8.5	315
2004	5/16/2004	15.43	998	76.6	25.5	315
2004	5/16/2004	15.43	998	55.3	18.4	0
2004	5/17/2004	15.43	998	52.8	17.6	270
2004	5/18/2004	28.28	980	52.6	8.8	90

Year	Start Date	Wind (m/s)	Pressure (Ibs)	Length (km)	Translational Velocity (kmh)	Orientation (Degree)
2004	5/18/2004	33.43	974	76.3	25.4	45
2004	5/18/2004	33.43	974	76.3	25.4	135
2004	5/18/2004	33.43	972	122.5	40.8	26.6
2004	5/19/2004	39.6	962	76.1	25.4	45
2005	7/31/2005	18	990	142.9	23.8	252.9
2005	9/18/2005	18	994	248.3	41.4	282.3
2005	9/18/2005	8.23	1000	283.4	47.2	285.1
2005	9/27/2005	18	996	127.9	21.3	279.5
2005	9/27/2005	6.17	1004	168.6	28.1	304.7
2005	9/28/2005	5.14	1006	179.4	29.9	290.6
2006	12/5/2006	5.14	1006	198.3	33.1	289.4
2006	12/5/2006	4.01	1008	188	31.3	276.7
2006	4/27/2006	36	971	548.5	15.2	44.2
2006	4/28/2006	59.14	913	200.8	16.7	40.6
2006	4/29/2006	51.43	936	130.7	10.9	41.6
2007	11/15/2007	69.43	878	178.3	29.7	7.1
2007	11/15/2007	66.87	887	226	37.7	22.8
2007	11/15/2007	54	928	293.1	48.9	36
2007	11/16/2007	30.85	980	242.3	40.4	32.3
2007	5/13/2007	18	997	227.6	19	14
2007	5/14/2007	28.28	984	369	30.8	8.6
2007	5/14/2007	33.43	976	114.9	9.6	16.7
2008	10/26/2008	23.14	989	278.2	46	18.4
2008	10/27/2008	18	996	178.3	30	7.1
2008	5/1/2008	51.43	948	107.6	18	95.7
2008	5/1/2008	51.43	948	107.1	18	90
2008	5/2/2008	56.58	941	97	16	83.7
2008	5/2/2008	59.15	937	118.2	20	84.8
2008	5/2/2008	59.15	937	105.9	18	66
2008	5/2/2008	43.72	963	96.1	16	63.4
2008	5/3/2008	36	970	99.7	17	49.4
2008	5/3/2008	25.71	985	112.8	19	29.1
2008	5/3/2008	20.57	993	123.5	21	10.3
2008	5/3/2008	15.43	1000	171.4	29	26.6
2008	8/8/2008	0	996	157.2	26	277.6
2008	9/25/2008	0	998	124.1	21	265.2

Annex (B): **Earthquake Events**

Year	Month	Day	Magnitude	Depth (km)
1912	5	23	8	10
1917	7	5	6.7	10
1923	6	22	7.3	12
1927	12	17	7	10
1929	8	8	7	10
1930	5	5	7.3	10
1930	12	3	7.3	30
1931	8	10	7.1	10
1931	1	27	7.6	33
1941	12	26	7	33
1943	10	23	7.2	33
1946	9	12	7.4	19
1950	2	2	7	22
1956	7	16	7	10
1970	1	4	7.5	31
1970	7	29	6.5	59
1973	5	31	5.9	30
1973	7	4	5.2	26
1973	8	16	6.4	33
1973	11	2	4.8	20
1973	12	26	5.1	50
1974	4	5	5	49
1974	11	21	5.1	33
1974	12	21	4.9	33
1975	5	30	5.6	57
1975	6	10	5.1	26
1975	7	8	6.5	157
1975	10	27	5.1	33
1975	12	30	5.2	33
1976	5	29	7	10
1976	8	12	6.4	27
1976	11	6	6.5	33
1976	12	25	4.9	84
1977	3	16	5.1	33
1977	5	12	5.7	40
1978	4	19	4.9	51
1978	8	2	5.2	33
1978	9	1	4.9	48
1978	9	30	5.7	10
1979	1	1	5.3	62

Year	Month	Day	Magnitude	Depth (km)
1979	1	9	4.9	33
1979	2	18	5.1	33
1979	3	15	6.2	33
1979	9	29	5.1	33
1979	10	3	5.6	56
1979	12	6	5.2	33
1979	12	21	5.5	33
1980	2	2	5.3	33
1980	3	26	4.7	33
1980	10	30	5	33
1980	11	20	5.3	33
1981	4	25	5.7	148
1981	8	14	5.1	32
1981	8	23	5.2	79
1982	1	24	5.4	113
1982	3	30	5	34
1982	4	24	4.9	33
1982	7	3	5.1	33
1982	11	26	5.1	33
1983	4	15	5.3	10
1983	4	22	5.9	10
1983	4	22	5.2	33
1983	6	24	6.9	33
1983	7	31	5.2	33
1984	1	15	5.2	58
1984	2	3	4.9	33
1984	2	6	5.2	33
1984	4	23	5.9	16
1984	5	6	5.7	33
1984	5	21	5.3	33
1984	11	28	5.9	17
1985	2	21	5.4	33
1985	7	15	5	33
1985	8	1	5.4	45
1985	8	25	5	33
1985	10	12	5.3	9
1986	1	27	4.8	33
1986	2	5	5.1	33
1986	3	13	5.4	29
1986	7	23	5.4	33
1987	4	29	5.3	49
1988	1	1	5.2	25

Year	Month	Day	Magnitude	Depth (km)
1988	2	6	5.8	33
1988	2	19	5.2	66
1988	5	9	5.1	30
1988	5	10	5	25
1988	8	6	7.3	90
1988	11	6	7.3	17
1989	2	22	4.7	46
1989	3	1	5.4	15
1989	4	21	4.7	58
1989	7	15	5.4	107
1989	9	24	5.3	134
1989	9	28	5.7	10
1989	9	30	5.6	13
1989	12	8	5.6	47
1990	2	9	4.7	10
1990	2	13	5.2	33
1990	3	8	5.1	33
1990	8	18	5.7	12
1991	1	5	7	19
1991	1	28	5	33
1991	3	5	5	33
1991	7	22	5.1	33
1991	11	15	4.6	78
1991	12	20	5.3	40
1992	2	6	5.6	15
1992	4	23	6.1	12
1992	4	23	6.2	9
1993	1	26	5.6	33
1993	4	1	5.1	104
1993	5	3	5.1	10
1993	7	17	5.4	30
1993	8	14	5.2	33
1994	1	11	6.1	9
1994	5	29	6.5	35
1994	9	11	5.2	33
1994	12	6	4.9	10
1995	2	17	5.5	39
1995	2	18	4.8	33
1995	4	24	5.2	33
1995	5	6	6.4	117
1995	7	11	6.8	12
1995	12	12	5.1	33

Year	Month	Day	Magnitude	Depth (km)
1996	2	3	6.6	11
1996	9	25	5	33
1996	11	11	6	80
1996	11	20	5	33
1997	1	30	5	10
1997	5	8	6	34
1997	5	16	5.2	33
1997	7	11	5.4	138
1997	8	9	5.2	33
1997	11	21	6.1	54
1997	12	30	5.8	33
1998	5	2	5.5	121
1998	12	2	5	33
1999	4	5	5.6	66
1999	5	31	4.8	51
1999	7	22	5.2	10
1999	8	15	5.2	18
1999	10	5	5.2	33
1999	10	28	4.6	97
2000	1	14	5.9	33
2000	1	19	5.4	33
2000	1	25	5.2	33
2000	6	7	6.3	33
2000	10	6	5.4	33
2000	10	9	4.8	33
2000	10	11	5.6	116
2000	11	13	5.5	33
2001	2	19	4.9	10
2001	3	3	5.2	55
2001	4	12	5.6	10
2001	4	30	4.6	33
2001	5	23	5.5	33
2001	6	14	4.7	108
2001	8	25	4.7	33
2002	2	2	4.6	33
2002	12	4	5.6	53
2003	7	4	4.8	33
2003	7	21	6	10
2003	7	26	5.7	10
2003	7	27	5.5	10
2003	8	1	4.7	10
2003	8	18	5.5	33

Year	Month	Day	Magnitude	Depth (km)
2003	9	21	6.6	10
2003	11	23	4.6	37
2003	12	19	5.2	10
2004	9	23	4.7	31
2004	10	18	4.8	30
2004	12	9	5.4	34
2004	12	26	5.8	38
2004	12	30	5.1	20
2005	6	1	5.8	25
2005	9	18	5.7	84
2006	3	3	5.2	112
2006	3	25	4.8	10
2006	5	11	5.6	30
2006	6	4	4.9	40
2007	6	2	6.1	5
2007	6	23	5.6	22
2007	6	29	5.2	52
2007	7	30	5.6	14
2007	7	31	5	10
2007	9	18	5.1	32
2007	11	7	5.5	28
2008	3	12	4.7	17
2008	8	21	6	10
2008	12	20	5.3	10
2009	7	9	5.7	7
2009	8	19	5	10
2009	9	3	5.9	104
2009	9	21	5.7	84

Annex (C): Vulnerability Indicator

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
Rural Vulnerability Analysis					
1.	**Locational Vulnerability** (Distance from road, river & coast)	**Distance (in m)**	**Point**	Proximity to linkages such as road, river and coast can affect the human settlements and their timely safe evacuation at particular locations during specific severe weather events.	Minimum distance from nearest linkages such as road, river and coast. Point's were assigned to calculate locational vulnerability ranging from 1 to 10. In order to calculate locational risk, low value assigned to those villages which have nearest linkages within range of 500 mts.
		>4000	10		
		>3000	8		
		>2000	6		
		>1000	4		
		>500	2		
		>0	1		
2.	**Accessibility Vulnerability**	**Road Type**	**Point**	Settlements were awarded points on the basis of the type of road facility available.	Minimum of the access to road, road type, distance to boat and navigation during different weather season indicator were used to calculate the accessibility vulnerability in study area.
		Mud Road	10		
		Macadam Road	5		
		Tar Road	1		
		Access to Road	**Point**	Settlements were awarded points on the basis of the access to available road facility in different weather season.	
		Island	10		
		Non-rainy season	5		
		All Weather	1		
		Distance to Boat (in m)	**Point**	Points were awarded to all settlements on the basis of distance to nearest water ways and boat facility.	
		>4000	10		
		>3000	8		
		>2000	6		
		>1000	4		
		>500	2		
		>0	1		

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
		Navigation in Season	**Point**	Settlements were awarded points on the basis of the navigation of boats during different weather season.	
		Not Accessible	10		
		Rainy Season	5		
		Annual	1		
3.	**Flood & Water Logging Inundation Vulnerability**	**Flood Inundation Level (in ft)**	**Points**	Flood inundation levels experienced by the households during recent reported floods were aggregated at the settlement level.	Maximum flood inundation level and average number of inundation days were assigned points ranging from 1 to 10. In order to calculate the flood risk at the settlement level; 75 percent and 25 percent weightage were assigned to maximum flood inundation levels and average number of inundation days respectively.
		>10	10		
		>5	7		
		>3	5		
		>1	2		
		>0	1		
		Flood Duration (in days)	**Points**	The inundation/deluge period experienced by the households during the last reported floods was aggregated at the settlement level.	
		>3	10		
		>2	5		
		>1	3		
		>0	1		
		Rural Capacity Analysis			
1.	**Social Capacity**	**Instances of Social Group Presence**	**Points**	Respondent's awareness about the presence of social/ community based groups was surveyed and aggregated at the settlement level.	The sub indicators were assigned points ranging from 0 to 10. The average of all these sub indicator points was used to calculate the social capacity index at the settlement level.
		>0	1		
		>1	1		
		>2	3		
		>3	5		
		>4	7		

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
		>6	9		
		>8	10		
		Instances of Membership to Social Group (%)	**Points**	Household level involvement (membership) within the social/community based groups were aggregated at the settlement level and expressed as the percentage of total.	
		>0%	1		
		>10%	1		
		>20%	2		
		>30%	3		
		>40%	4		
		>50%	5		
		60%	6		
2.	**Income Stability**	**Dependency ratio (HH level)**	**Points**	Dependency ratio was derived and is expressed as percentage using the total number of non-working members ratio to working members in the household.	The sub indicators were assigned points ranging from 0 to 10. The income capacity index at settlement level was calculated from the average of all the mentioned sub indicator points.
		0	10		
		100	7.5		
		200	5		
		300	2.5		
		500	0		
		Occupation (Stable/Unstable) (HH Level)	**Points**	Employment types were classified as / unstable on the basis of the criterions like skill level, regularity of income, job security, skill demand in the market and the remuneration which the skill fetches in the market.	
		If, No Unstable Jobs	10		
		If, Number of Stable Jobs/ Unstable Jobs > 1	10		

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
		If, Number of Stable Jobs (S)/ Unstable Jobs (U) < 1	(S/U)*10		
		Per capita annual income (in Kyat)	**Points**	Household level per capita income (in kyat) was calculated based on the survey results.	
		0	0		
		30000	4		
		60000	8		
		100000	10		
		Total Working members	**Points**	Total working members per household was derived from the survey results.	
		1	5		
		2	7		
		3	10		
3.	**Education Capacity**	**Education level**	**Points**	Maximum educational level information within the households was surveyed. Using this information the maximum educational level of the settlements was calculated.	Education index for the settlement = Sum of educational level points / Total number of sample households in the settlement.
		Illiterate	0		
		Primary	1		
		High school	2		
		SSC	3		
		HSC	4		
		Graduate	6		
		Post Graduate	10		
4.	**Natural Capacity**	**Effective Agriculture Land Per Household (in Acre)**	**Point**	As agriculture is practiced across the delta depending on soil type and fresh water availability. Average effective agriculture	The natural resource accessibility index was derived by taking maximum index value of gross
		0.0	1		

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
		0.5	2	land available per household.	cropped area per capita, land holding distribution across the villages, average number of boats per sample families and percentage households owning boats.
		1.0	3		
		2.5	5		
		5.0	10		
		HH with > 1 Acre Effective Agriculture Land	**Point**	As agriculture is practiced across the delta depending on soil type and fresh water availability. Average effective agriculture land (> 1 Acre) available at household level in %.	
		0%	1		
		10%	2		
		25%	3		
		50%	5		
		75%	10		
		Average Boat at Village Level (in %)	**Point**	Majority of livelihoods are natural resource based (fisheries and related labour), fishery resource (such as boat) availability at village was also used to assess the natural capacity.	
		10%	1		
		20%	2		
		40%	4		
		60%	6		
		80%	8		
		100%	10		
		Boat Presence at HH Level (in %)	**Point**	Majority of livelihoods are natural resource based (fisheries and related labour), fishery resource (such as boat) availability at household level was also used to assess the	
		10%	1		
		20%	2		

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
		40%	4	natural capacity.	
		60%	6		
		80%	8		
		100%	10		
		Urban Vulnerability Analysis			
1.	**Physical Vulnerability** (Building Typology and Accessibility)	**Building Construction Material**	**Point**	Building typology and accessibility is directly related to the physical vulnerability. Inaccessible and non-engineered buildings are most vulnerable during most natural hazards.	Building typology and accessibility is directly related to the physical vulnerability. Inaccessible and non-engineered buildings are most vulnerable during most natural hazards.
		T1: Bricks(Wall)_RCC(Roof)	2.5		
		T2: Bricks(Wall)_Tin/ Ce-ment sheet or Tiles (Roof)	5		
		T3: Wood/ Bamboo(Wall)_ Biomass/ Thatch/ Bamboo(Roof)	10		
		Built-Up Area Ratio (in Sec)	**Point**		
		0%	0		
		1%	1		
		10%	2		
		20%	4		
		40%	6		
		60%	8		
		80%	10		

SI. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
2.	Income Instability Vulnerability	**Dependency ratio (HH level)**	**Points**	Dependency ratio was derived and is expressed as percentage using the total number of non-working members ratio to working members in the household.	The sub indicators were assigned points ranging from 0 to 10. The income capacity index at settlement level was calculated from the average of all the mentioned sub indicator points.
		0	10		
		50	8		
		100	6		
		200	4		
		300	2		
		400	0		
		Occupation (Stable/Unstable) (HH Level)	**Points**	Employment types were classified as stable/ unstable on the basis of the criterions like skill level, regularity of income, job security, skill demand in the market and the remuneration which the skill fetches in the market.	
		If, No Unstable Jobs	10		
		If, Number of Stable Jobs/ Unstable Jobs > 1	10		
		If, Number of Stable Jobs (S)/ Unstable Jobs (U) < 1	(S/U)*10		
		Per capita annual income (in Kyat)	**Points**	Household level per capita income (in kyat) was calculated based on the survey results.	
		0	1		
		15000	2		
		30000	4		
		70000	6		
		100000	8		
		300000	10		

Sl. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
		Total Working members	**Points**	Total working members per household was derived from the survey results.	
		1	5		
		2	7		
		3	10		
3.	**Flood & Water Logging Inundation Vulnerability**	**Flood Inundation level (in ft)**	**Points**	Flood inundation levels experienced by the households during recent reported floods were aggregated at the settlement level.	Maximum flood inundation level and average number of inundation days were assigned points ranging from 1 to 10. In order to calculate the flood risk at the settlement level; 75 percent and 25 percent weightage were assigned to maximum flood inundation levels and average number of inundation days respectively.
		>10	10		
		>5	7		
		>3	5		
		>1	2		
		>0	1		
		Flood Duration (in days)	**Points**	The inundation/deluge period experienced by the households during the last reported floods was aggregated at the settlement level.	
		>3	10		
		>2	5		
		>1	3		
		>0	1		
		Urban Capacity Analysis			
4.	**Work Diversification**	**Total Working Member in HH**	Equal Weightage	Work diversity in total working member provides resilience during disasters, and increases the redundancy.	Ratio of total working member in HH and their diversified occupation.
		Job Diversity in HH			

Sl. No.	Major Indicators	Sub Indicators and Corresponding Points		Explanation of Sub Indicators	Calculation Process
5.	**Early Warning Mechanism Capacity**	**Total communication devices at household**	**Points**	Presence of landline telephone, mobile telephone, radio or television at household level is very important to disseminate the hazard warning. Early warning index is derived from analysis of communication devices available at household level.	The early warning index (capacity) ranges from 1 to 10. Weightage were assigned based on the availability of communication devices and the ability of the devices to communicate the information in a timely manner.
		Presence of TV	10		
		Presence of Radio	5		
		Presence of Mobile Phone	2.5		
6.	**Education Capacity**	**Education level**	**Points**	Maximum educational level information within the households was surveyed. Using this information the maximum educational level of the settlements was calculated.	Education index for the settlement = Sum of educational level points / Total number of sample households in the settlement.
		Illiterate	0		
		Primary	1		
		High school	2		
		SSC	3		
		HSC	4		
		Graduate	6		
		Post Graduate	10		

Annex (D): Rice Crop Loss

Division	District	Township	Looses (Million Kyat)
Ayeyarwady	Hinthada	Hinthada	299
		Ingapu	371
		Kyangin	225
		Laymyethnar	399
		Myanaung	442
		Zalun	371
	Maubin	Danubyu	258
		Maubin	9,813
		Nyaungdon	2,090
		Pantanaw	7,651
	Myaungmya	Einme	9,454
		Labutta	3,767
		Mawlamyinegyunn	3,062
		Myaungmya	10,740
		Wakema	12,700
	Pathein	Kyaunggon	2,916
		Kyonpyaw	877
		Ngapudaw	3,320
		Pathein	3,752
		Thabaung	5,214
	Pathein	Yekyi	7,382
		Bogale	8,014
		Dedaye	4,853
		Kyaiklat	5,155
		Pyapon	6,926
Bago (E)	Bago	Bago	141
		Daik-U	813
		Kyauktaga	53
		Nyaunglebin	1,001
		Shwegyin	136
		Waw	913
	Taungoo	Kyaukkyi	107
		Oktwin	68
		Pyu	73

Division	District	Township	Looses (Million Kyat)
		Taungoo	19
		Yedashe	74
Bago (W)	Pyay	Padaung	457
		Pyay	2
		Shwedaung	401
	Thayarwaddy	Gyobingauk	0.2
		Letpandan	556
		Minhla	34
		Monyo	953
		Thayarwaddy	80
Yangon	Yangon(N)	Hlinethaya	197
		Hmawbi	213
		Htantabin	1,759
		Insein	23
		Mingaladon	68
		Shwepyitha	62
		Taikkyi	98
	Yangon(S)	Kawhmu	256
		Kungyangon	157
		Twantay	1,555

Source: TARU Analysis, 2010

Annex (E): Loss Due to Cyclone & Earthquake to the Building Typology

Division	District	Township	Loss due to Cyclone to buildings (Million Kyat)			Loss due to Earthquake buildings (Million Kyat)		
			Bio-Mass on Bio-Mass	Tiles on Bio-Mass	Tiles on Brick & Concrete	Bio-Mass on Bio-Mass	Tiles on Bio-Mass	Tiles on Brick & Concrete
Ayeyarwady	Pathein	Pathein	9,419	12,377	15,034	538	1,933	1,582
		Thabaung	4,875	6,406	7,781	278	1,000	819
		Ngapudaw	10,094	13,263	16,111	576	2,072	1,695
		Kyonpyaw	8,089	10,629	12,911	462	1,660	1,359
		Yekyi	6,984	9,177	11,148	399	1,433	1,173
		Kyaunggon	4,874	6,404	7,779	278	1,000	818
	Hinthada	Hinthada	12,597	16,551	20,105	813	2,639	2,391
		Zalun	6,972	9,161	11,129	1,359	2,058	3,900
		Laymyethnar	3,895	5,117	6,216	222	799	654
		Myanaung	8,795	11,557	14,038	502	1,805	1,477
		Kyangin	3,745	4,921	5,978	214	769	629
		Ingapu	8,501	11,170	13,569	485	1,745	1,428
	Myaungmya	Myaungmya	6,051	7,951	9,659	345	1,242	1,016
		Einme	5,507	7,236	8,790	314	1,130	925
		Labutta	11,824	15,536	18,872	675	2,427	1,986
		Wakema	23,081	30,327	36,839	1,318	4,738	3,877
		Mawlamyinegyunn	10,021	13,167	15,994	647	2,100	1,904
	Maubin	Maubin	11,305	14,854	18,043	2,278	3,372	6,554
		Pantanaw	6,493	8,531	10,363	392	1,345	1,154
		Nyaungdon	6,483	8,518	10,347	1,348	1,938	3,908
		Danubyu	6,920	9,093	11,046	1,221	1,895	3,590
	Pyapon	Pyapon	8,011	10,526	12,787	783	1,832	2,304
		Bogale	13,696	17,995	21,859	1,004	2,939	2,952

Division	District	Township	Loss due to Cyclone to buildings (Million Kyat)			Loss due to Earthquake buildings (Million Kyat)		
			Bio-Mass on Bio-Mass	Tiles on Bio-Mass	Tiles on Brick & Concrete	Bio-Mass on Bio-Mass	Tiles on Bio-Mass	Tiles on Brick & Concrete
		Kyaiklat	7,017	9,220	11,199	1,391	2,049	4,042
		Dedaye	8,362	10,987	13,347	1,653	2,417	4,831
Yangon	Yangon (N)	Insein	7,220	9,487	11,524	3,094	4,447	7,278
		Mingaladon	5,134	6,745	8,194	2,200	3,162	5,175
		Hmawbi	4,493	5,904	7,172	1,925	2,767	4,529
		Hlegu	5,344	7,022	8,530	2,290	3,291	5,387
		Taikkyi	7,682	10,093	12,261	3,153	4,531	7,488
		Htantabin	3,330	4,375	5,315	1,177	1,691	2,897
		Shwepyitha	5,170	6,793	8,251	2,215	3,184	5,211
		Hlinethaya	5,982	7,859	9,547	2,563	3,684	6,030
	Yangon (S)	Tanyin	4,406	5,790	7,033	1,888	2,714	4,442
		Kyauktan	5,145	6,760	8,212	1,269	1,824	3,467
		Thongwa	4,665	6,172	7,428	1,109	1,594	3,081
		Kayan	4,716	6,292	7,487	1,942	2,791	4,641
		Twantay	7,287	9,574	11,630	3,042	4,372	7,198
		Kawhmu	3,446	4,528	5,500	1,441	2,071	3,408
		Kungyangon	3,800	4,992	6,064	1,076	1,546	2,815
		Dalla	1,655	2,175	2,642	709	1,019	1,668
		Seikkyi Khanaungto	548	720	875	234	337	552

Source: TARU Analysis, 2010

Annex (F): List of Key Resource Persons Visited

Sl. No.	Name	Designation	Contact Details
1.	Mr. Shafique Rahman	Senior Policy Advisor, UNDP (Policy Unit)	No. 6 Natmauk Road, P. O. Box 650 Yanogn, 11181, Myanmar Email: Shafique.rahman@undp.org
2.	Mr. U Aye Kyaing	Data Management Coordinator, UNDP (Policy Unit)	No. 6 Natmauk Road, P. O. Box 650 Yanogn, 11181, Myanmar Email: Aye.kyaing@undp.org
3.	Ms. Elisabet Frisk	Programme Analyst , UNDP (Policy Unit)	No. 6 Natmauk Road, P. O. Box 650 Yanogn, 11181, Myanmar Email: elisabet.frisk@undp.org
4.	Mr. Joe Crowley	Manager, MIMU	Chatrium Hotel, 40 Natmauk Road, Tamwe Township, Yangon, Myanmar Email: Joe.crowley@undp.org
5.	Mr. Kyaw Naing Win	GIS Analyst, MIMU	Chatrium Hotel, 40 Natmauk Road, Tamwe Township, Yangon, Myanmar Email: kyaw.naing.win@undp.org
6.	Mr. Nway Aung	GIS Analyst, MIMU	Chatrium Hotel, 40 Natmauk Road, Tamwe Township, Yangon, Myanmar Email: nway.aung@undp.org
7.	Ms. Ye Ye Nyein	Deputy Director, DMH	DMH, Kaba-Aye Pagoda Road, Mayangon 11061, Yangon, Myanmar Email: dg.dmh@pmtmail.net.mm
8.	Ms. May Khin Chaw	Assistant Director (Cyclone and Storm Surge), DMH	DMH, Kaba-Aye Pagoda Road, Mayangon 11061, Yangon, Myanmar Email: mkchaw@gmail.com
9.	Mr. Sein Lin	Staff Officer (Hydrological Division), DMH	DMH, Kaba-Aye Pagoda Road, Mayangon 11061, Yangon, Myanmar
10.	Ms. Han Swe	Data Officer (Record Section), DMH	DMH, Kaba-Aye Pagoda Road, Mayangon 11061, Yangon, Myanmar
11.	Mr. Bernard Cartella	International Consultant Agronomist, ERCU FAO Representation in Myanmar	Seed Division Compound, MAS Building Insein Road, Yangon, Myanmar (P.O. Box 101) Email: Cartella.Bernard@fao.org
12.	Mr. Apollo N. Arara	Coordination Support Officer, ERCU, (FAO Representation in Myanmar	Seed Division Compound, MAS Building Insein Road, Yangon, Myanmar (P.O. Box 101) Email: Apollo.Arara@fao.org
13.	Mr. U Kyaw Thura	Deputy Director, Fire Service Department (FSD)	FSD (H.Q.) Oakponseik Street, Mayangone Township, Yangon, Myanmar Email: kyawthura@gmail.com
14.	Mr. U That Htwe Aung	Station Officer, Fire Service Department (FSD)	FSD (H.Q.) Oakponseik Street, Mayangone Township, Yangon, Myanmar Email: thyumaw@gmail.com

Sl. No.	Name	Designation	Contact Details
15.	Mr. U Han Zaw	President, Myanmar Engineering Society (MES)	MES Building, Hlaing University Campus, Hlaing Township, Yangon, Myanmar Email: mes@mptmail.net.mm
16.	Mr. U Myint Soe	Executive Director, Myanmar Engineering Society (MES)	MES Building, Hlaing University Campus, Hlaing Township, Yangon, Myanmar Email: myintsoe.mes@gmail.com
17.	Mr. U Than Myint	Past President, Myanmar Engineering Society (MES); President, Myanmar Earthquake Committee (MEC)	MES Building, Hlaing University Campus, Hlaing Township, Yangon, Myanmar
18.	Mr. Soe Thura Tun	Secretary, Myanmar Earthquake Committee (MEC)	MES Building, Hlaing University Campus, Hlaing Township, Yangon, Myanmar Email: soethuratun@gmail.com
19.	Mr. Kyaing Sein	Consultant Geologist and Secretary, Myanmar Geo-Science Society (MGS)	MES Building, Hlaing University Campus, Hlaing Township, Yangon, Myanmar Email: mgs.sein2003@gmail.com
20.	Mr. Sudhir Kumar	Country Representative, ADPC	Hotel Park Royal, 33, Alan Pya Phaya Road, Dagon Township, Yangon
21.	Mr. Khuung Lwan	Project Coordinator, ADPC	Hotel Park Royal, 33, Alan Pya Phaya Road, Dagon Township, Yangon Email: khaunglwan.adpc@gmail.com
22.	Dr. Balathandan T. P.	Aid Coordination and Reporting Officer Tripartite Core Group (TCG)	Room No. 818, Chatrium Hotel, 40 Natmauk Road, Tamwe Township, Yangon, Myanmar Email: Dr.Balathandan@gmail.com
23.	Dr. Niken Gandini	Senior Technical Advisor ASEAN	ASEAN Office, Near Chatrium Hotel, 40 Natmauk Road, Tamwe Township, Yangon, Myanmar
24	Mr. Kyaw Kyaw Lin	Staff Officer and Tsunami and Earthquake Specialist MHEWC under DMH	Multi Hazard Early Warning Center (MHEWC) Ministry Of Transport Office Building No. (5), Nay Pyi Taw Email: kyawkyawlin@gmail.com
25.	Mr. San Myint	Deputy DG, CSO Ministry of Nation Planning and Economics Development	CSO Building Building No. 32, Nay Pyi Taw, Myanmar Email: dydg-cso@mptmail.com.mm
24.	Ms. Marlar Aung	Director, CSO Ministry of Nation Planning and Economics Development	CSO Building Building No. 32, Nay Pyi Taw Myanmar Email: marlaraung26@gmail.com

Sl. No.	Name	Designation	Contact Details
25.	Mr. U Oo Tun Hlaing	Director, CSO Ministry of Nation Planning and Economics Development	CSO Building Building No. 32, Nay Pyi Taw Myanmar Email: ootunhlaing@gmail.com
26.	Mr. Sanjeev Kumar Kafley	DM Delegate	Red Cross Building First Floor, 42 Strand Road Botataung Township, Yangon, Myanmar
27	Mr. Bobby	Coordinator, Myanmar E-Gress	Thamada Business Suite, Thamada Hotel, Alan Pya Phaya Road Dagon Township, Yangon, Myanmar Email: info@myanmaregress.org
28	Mr. Virendar Khatana	Advisor for LIFT Project (The Livelihoods and Food Security Trust Fund)	c/o Hotel Park Royal Yangon, Room 307 33, Alan Pya Phaya Road, Dagon Township, Yangon, Myanmar Email: vkhatana@hotmail.com
29.	Mr. Kyaw Hlaing	President	Myanmar Survey Reasearch (MSR) 55, Maha Bandoola, Garden Street, Yangon, Myanmar Email: msr@myanmar.com.mm
30	Mr. Dilip Kumar Bhanja	Advisor, DRR, UN Habitat	No. 6 Natmauk Road, Yanogn, 11181, Myanmar Email: dilipkumar.bhanja@gmail.com
31	Mr. Noel Puno	Specialist-DRR	No. 6 Natmauk Road, P. O. Box 650 Yanogn, 11181, Myanmar Email: noel.puno@undp.org

Annex (G): Field Survey Questionnaires

Vulnerability Assessment Survey

(Taru Leading Edge Pvt Ltd & MSR)

Urban (Town) Household Questionnaire

A Background Information

Questionnaire No.________________________ Date: _________________________________

Village/ Town_____________________________Village Tract __________________________

Township_____________________________ Division/ State _____________________

Name of the Respondent ____

Contact Number respondent (Phone, if any): ____

Investigator _____________________________ Supervisor ________________________

Survey Start Time _______________________

Main Instructions

1. Mention all units wherever applicable (Kyat, Kg, Quintal etc)
2. Preferably get data on from reliable sources.
3. Some information can be gathered by observation e.g. house type etc. So please avoid asking observed information.
4. Please ensure that all data is filled. If the respondent is unable to provide data, please terminate the interview and meet another respondent group.
5. Please try to get information within the options as far as possible. If you are using **"Others"** category, please write the description is space provided

B Household Information

1. **Household Details** **(Circle the Serial Number against the respondent name)**

Sl. No.	Relationship with Head of Household	Sex (M/F)	Marital Status*	Age (Yrs)	Education #	Occupation	Migration Status			Disability Status**	Average Annual Income from Occupation (*Kyat*)		Months of work (only for temporary/ seasonal workers)
							Type of Work	Place	No of Months		Local income	Migration/ Remittance	
1													
2													
3													
4													
5													
6													

Relationship with Head of Household		Education				Disability status		Occupation (Including migratory)					
1	Head of Household	1-11	1=1st Grade 11=11th Grade	14	Vocational training	1	No disability	1	Wage labor (skilled)	7	Non-timber forest product producer	13	Professional (Doc. Engg)
2	Spouse	12	Graduate	15	MBBS, Engg, Lawyer etc	2	Mentally disabled	2	Wage labor (unskilled)	8	Agriculture	14	Contractor
3	Son, daughter, son/daughter-in-law	13	Post-graduate	16	Under-5 who has not gone to school	3	Physically disabled	3	Fisheries	9	Agricultural laborer	15	Salt pan worker
4	Parents/parents-in-law	**Marital status**		17	KG	4	Visual impairment	4	Street stall/vendor	10	Govt (lower level)	16	Industry/ workshop
5	Other relatives	1	Single	18	Illiterate	5	Hearing impairment	5	Pvt transport services	11	Govt (middle level)	17	Dependant
		2	Married			6	Speech disability	6	Trade & small business	12	Govt (Upper level)	18	Other (Specify)
		3	Divorced, widow, widower			7	Multiple disaility						

C Housing & Environmental Services

2. House type *(record by observation)*

a. Roof & Wall Type *(Tick only one type of roof and one type of wall)*

Roof Types: ☐ Cement concrete ☐ Tin/cement Sheet ☐ Tiles
☐ Biomass/Thatch ☐ Tarpaulin ☐ Others (Specify) ________

Wall Type: ☐ Bricks ☐ Wood/ Bamboo/ Wattle and Daub
☐ Mud/ Earth ☐ Tin/Cement Sheet
☐ Others (Specify) …………

b. Building Type and floors

Type of building	1--Owned 2--Rented	No. of floors in the building *(include ground floor also)*	No. of Housing units in the building	Your house floor number (if fully owned, Write all)	Total area of your house (sq ft)	Building Age (No of years)	Approximate value of your house(Kyat)
☐ Individual ☐ Row house ☐ Multi- storied flats							

c. Stilt Details ☐ Stilted ☐ Non-stilted
If stilted, then height of stilt (in ft above ground) _________

3. Water Supply and Sanitation

a. Water Supply

Source	Distance from house	Rainy months Usage (1--Yes/2--No)	Other months Usage (1--Yes/2--No)
Piped water supply			
Tube well/ Hand Pump			
Dug well			
Rain water harvesting			
Others (………………..)			

b. Sanitation Facility

Description	Owned/shared	Usability during Floods (1--Yes/2--No)
Wet toilet with Septic Tank		
Wet toilet with sewerage		

Dry Latrine		
River/Floating toilet		
No latrine/toilet		
Others (specify)		

c. Electricity

Source	Owned (O)/ Shared (S)	Availability (hrs/day)	Usage (hrs/day)	Reliability (1--Yes/2--No)	Monthly expenses	If interrupted in last disaster (Nargis), mention duration for recovery (in days)
Government						
Self-owned Generator						
Private electric supply						
Battery operated						
Others						

D Asset & Expenditure

4. Asset Ownership

Sl. No.	Asset	Number	Approximate value	Impact of last disaster (**1.** Not damaged / **2.** Repairable damage/ **3.** Complete damage)	Repairing/ Replacement cost of asset lost (whichever is applicable) (mention in % or MMK)
1	Radio				
2	Television				
3	Mobile phone				
4	Shop/small business				
5	Micro processing unit				
6	Boat personal use				
7	Boat (hiring)				
8	Bicycle				
9	Motorcycle				

10	Private car/hired car				
11	truck				
12	Refrigerator				
11	Gas stove				
12	Truck				
13	Refrigerator				
14	Washing machine				
15	Sewing machine				
16	Other (Mention) _______				

5. Expenditure Pattern (For monthly payments, use monthly expense column and for annual expenses use only Annual expenses column only)

Sl. No	Item	Average Monthly Expenses (Kyat)	#Annual Expenses (Kyat)	Remarks
1	Food			
2	Cooking Fuel (…………….)			
3	Electricity/ lighting			
4	Transport			
5	Telephone/ Mobile			
6	Education Fees etc			
7	Health and Medicines			
8	Entertainment			
9	Cigarette, tobacco, liquor etc			
10	Clothes and Footwear			
11	Buying/ Repair and Maintenance of assets			
12	Loan Repayment			
13	Other major expenses on wedding, social events etc.			
14	Insurance □ House, □ Vehicle □ Medical			
15	Others(………………………).			
Total				

6. Access to credit

a. Whether you have access to credit? □ Yes □ No
If Yes, then

Sl. No.	Credit Source	Normal Situation (√)	Disaster Situation (√)	Amount Range (in kyat)	Interest rate (%)	Mortgage*	Purpose for loan #	Ever availed (Yes/No)
1	Money lenders							
2	Relatives/ Friends							
3	Religious Groups							
4	SHGs/SRGs							
5	Banks/ Financial Institutions							
5	Others (specify)							
6	Others (specify)							

# Purpose of Borrowing' Code		* Mortgage code	
(1) House	(5) Household consumption	1- House	5- Shop-Business assets
(2) Medical expenses	(7) Asset purchase	2- Livestock	6- None
(3) Marriage	(8) Other1 (specify......................)	3- Jewellery	7- Other (specify ……………………….)
(4) Business	(9) Other2 (specify.......................)	4- Land	
(6) Education			

E Social Capital

7. Social Capital of the Household

Name of Institution	Type of Institution		If Yes, since how long? (mention in years)	What benefits did you get?
Others *(Specify)*				

Type of institution: 1. Member of Community based Organizations 2. Member of Savings/ Thrift Group/ SHGs 3. Member of occupation/professional group /traders association 4. Youth association 5. Women association 6. Committee set up by local administration 7. Local disaster management committee 8. Other (Specify) ________________________

8. Status of Family lineage ☐ Influential ☐ Somewhat Influential ☐ Non Influential

9. Who do you rely on for support in financial need?

1 Neighbours	5 Relatives	9 Youth Association
2 Saving/ Thrift Group/SHG	6 Women's Association	10 Friends/acquaintances
3 Money Lenders	7 Employer	11 Bank
4 Neighbourhood Committee	8 Religious groups	0 No access to Credit

12 Others (Specify)..

F Health

10. Morbidity Pattern

a. What are the major diseases in last one year in your family and highlight the expenses towards it?

Type of Ailment	Season/ Months #	How many family members effected in a year	Source of Treatment **	Estimated Expenditure (MMK)			
				Medicine	Fees	Others	Total
Water/Vector Borne Diseases							
Cholera							
Typhoid							
Jaundice							
Malaria							
Filaria/Elephantiasis							
Other Diseases							

Season: 1 - Rainy 2- Post Rainy season 3 - Winter 4 - Summer

**Source of Treatment:

1. Hospital
2. General Clinic/ Dispensary
3. Rural Health Centre/BHS
4. Traditional Medicine Hospital
5. Traditional Medicine Clinic
6. Home Remedy
7. Over the Counter Medicine from Chemist
8. Others (Specify) ....

11. Medical Insurance

a. Is your family covered under a medical insurance policy? ☐ Yes ☐ No
b. If yes, highlight the insurance premium __________ (MMK/year)

G Exposure to Hazard Events in Past

12. Exposure to past hazards and its impact at the house level *(during the last 10 Years)*

Hazard Event Type	Year	Loss of Life & Injury			Category of Damage to House	Damage to House (Kyats)	Damage to household assets (Kyats)	Damage to Vehicles (Kyats)	Damage to Productive assets (Kyats)
		Life Lost	Persons Injured	Treatment Cost					

* **Damage to House**: Minor, Moderate, Severe, Collapse

H Early Warning System and Emergency Shelter

13. Is there a system of early warning in your local community Yes | No
If yes, fill the table below

Description	**Event 1**	**Event 2**	**Event 3**	**Event 4**
Event Type (Flood, Cyclone, Storm Surge, Tsunami)				
Year				
Early Warning				
Type of warning system for message relay (TV, Radio, Public addressal system, human chain. mobile)				
Source of information				
How many hours of advance warning did ou receive?				
Was evacuation ordered through the warning message? (Yes/No)				
If yes, did you shift to a safe location? (Yes/No)				
% population of evacuated in your locality				
Mode of evacuation (by motorized vehicles, by boat, by foot)				
Was there any resistance for evacuation? (Yes/No)				
Emergency Shelter				
If Yes, distance from the house (in km)				
If Yes, Did the facility have sufficient place for standing/sitting/sleeping?				
Was there sufficient food and water? (Yes/No)				
Did you get any other suggestions/information after the event? (Yes/No)				

I Institution Response Post-Nargis

14. What has been the role of institutions after Nargis

Type of Institution	Role Played *(tick mark against the right one)*		
	Rescue	Relief	Rehabilitation/ Reconstruction
Local administration			
Community based organizations			
NGOs			
Donors Institutions			
Others *(Specify)*			

15. Post Nargis - Community Based Disaster Preparedness (CBDP) Programme

a. Has there been any CBDP exercise/ training conducted in your locality

∟ Yes ⌋ No If Yes, then

Key Activities under CBDP	Locality Population covered (in %)	Has the Community/ Local government unit internalized the CBDP? *(tick against the right box)*			
		Community	Local Govt	Both	None
Disaster Management Plan					
Community Disaster Management Teams with Standard Operating Procedures					
Training on life saving skills (First Aid/Search and Rescue)					
Mock Drills					

J Investigator's Remark

……………………………………………………………………………………………….

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Survey End Time ____________________________________

Vulnerability Assessment Survey
(Taru Leading Edge Pvt Ltd & MSR)

Urban Community Questionnaire

SECTION 1: URBAN COMMUNITY SCHEDULE

A PANEL IDENTIFICATION

Ref. No.		Date	
Neighborhood name		Ward No.	
TownName		Investigator	
Starting time			

Main Instructions

6. **Try to define the neighborhood based on the key informant information. It is generally a fairly homogeneous area with similar socio economic groups.**
7. **Draw a synoptic map showing boundary of the neighborhood, major roads and approximate length and breadth, with large land marks like parks, water bodies etc.**
8. Mention all units wherever applicable (Kyat, Kg, Quintal etc)
9. Preferably get data from key informants like teachers, retired government employees, social workers etc.
10. Please ensure that all data is filled. If the respondent is unable to provide data, please terminate the interview and meet another respondent group.
11. Please try to get information within the options as far as possible. If you are using **"Others"** category, please write the description is space provided
12. If you are unable to get reliable data, terminate and try with other groups of key informants

List key Informants:

No	Name	Age	Male/ Female	Farmer/ Teacher/ retd. govt employee/ Trader etc	Contact Number (If any)
1					
2					
3					
4					
5					
6					

B Context

1. Location

a. Location

∟ River bank ∟ Flat land ∟ Coastal
⌈ Island ⌈ Others (specify)................

b. Approximate Area______________sq-miles

or
Length ____________________miles
Width_____________________miles

c. Approximate No. of Households ______________

2. Education

Education level	Percentage of Total		Remarks
	Male	Female	
Illiterate			
Up to 5 years (Primary)			
6-10 years (Middle & High)			
Graduates			
Post graduate			
Professionals			

C Neighborhood Details

3. Occupation Structure

No	% of Households	Socio economic Category (1--Poor, 2--Middle, 3--Rich)	Occupation	
			Primary Occupation	Secondary Occupation
1				
2				
3				
4				
5				

a. **Housing Roof and Wall Type (% of total)**

Roof ► / Wall ▼	RCC	Tin/ Cement sheet	Tiles	Biomass/ Thatch/ Bamboo	Others (specify)
Bricks					
Tin/ Cement sheet					
Wood/ Bamboo					
Others (specify)					

b. **Building sizes**

Type	Average Age	Average No. of Floors
Informal/mixed houses		
Individual Houses		
Row houses		
Flats		

D Basic Infrastructure and Services

4. Type of basic Infrastructure and Services

a. Type of Roads ∟ Unpaved ⌋ Tar Road ⌋ Macadam Road

b. Transport

Mode	Distance to Access service (in miles)	Frequency (numbers/day)	Regularity (1--Regular/ 2--Irregular)	Seasonality (Annual, Non-rainy season)
Bus				
Shared Taxi				
Boat				
Ferry				
Others				

5. Health Facilities Access

Type	Distance to facility (0 if located in the locality, otherwise distance in miles)		
	Allopathic	Traditional	Service reliability (1—Good 2—Average 3—Poor)
Clinic/Dispensary (with doctor)			
Hospital (with beds)			

6. Education

	Distance	No. of students	Private /Government	Whether used as emergency shelter (1--Yes/2--No)
Primary School				
Middle School				
High school				
College				
Technical vocational colleges				
Others (_______)				

7. Access to Drinking Water

Source	Accessed by % Households	Rainy months Usage (Y/N)	Other months Usage (Y/N)
Piped water supply			
Tube well/ Hand Pump			
Dug well			

8. Access to Sanitation

Description	Accessed by % Households	Usability during Floods (1—Yes 2—No)
WC-Septic Tank		
WC-Sewerage		
Dry Latrine		
River/Floating toilet		
No toilet/laterine		

9. Electrification/ Energy sources for lighting

Source	% households	Availability Hrs/day	Usage in hours/day	Reliability (1—Yes 2—No)
Grid electricity				
Private Generator				
Shared private electricity services				

Source	% households	Availability Hrs/day	Usage in hours/day	Reliability (1—Yes 2—No)
Battery powered				
Solar				
Other				

10. Common services

Type	Numbers	Service Quality (1--Excellent 2--Medium 3--Poor)
Post office		
Money lenders/pawn brokers		
Bank/Credit institutions		

11. Access to communication services

Ownership/Services	% households
Landline phone	
Mobile phone	
TV	
Radio	

E Community Institutions and Linkages

12. Community Institutions

Type of Institution	Functional Since (Year).	Member households	Main support offered (1--Monetary, 2--Materials, 3--Technical, 4--Training, 5--Marketing, 6--Medical)	
			Primary normal period	Emergency period
Self help groups				
Occupation Groups				
Trader Groups				
Government agency I				
Government Agency II				
NGOs/ CBOs *Name:*				

13. Industrial Activities

No.	Major Industries	Number of Units	Functional Since (Year)	Avg. Quantity Produced (Per Unit Per Annum)	Avg. Turnover (Per Unit Per Annum in Kyat)	Avg. Employment (Per Unit)
1	Agro based					
2	Food/fish Processing					
5	Handicrafts					
7	Boats					
8	Others*(Specify)*… … … …					
9	Others*(Specify)*----------					

F Hazards and Its Impacts

14. Death and Injury

Year	Type (Cyclone/Flood/Storm surge/Tsunami/Earthquake/ Fire)	Year	Inundation In case of Floods/Storm surge/Tsunami (in yard)	Persons dead	Morbidity / Injured

15. Damageability and Recovery Period

Year	Hazard Type Cyclone/ Flood/ Storm Surge/ Tsunami/ Earthquake/Fire)	Damage class	Damage % Predominant Building types Note: Total each column should be 100%			Road		Electricity		Communication	
			Roof* 1 Wall**	Roof 2 Wall	Roof 3 Wall	Damage (Y/N)	Recovery (days)	Damage (Y/N)	Recovery (days)	Damage (Y/N)	Recovery (days)
		A									
		B									
		C									
		D									
		E									

Year	Hazard Type Cyclone/ Flood/ Storm Surge/ Tsunami/ Earthquake/Fire)	Damage class	Damage % Predominant Building types Note: Total each column should be 100%			Road		Electricity		Communication	
			Roof* 1 Wall**	Roof 2 Wall	Roof 3 Wall	Damage (Y/N)	Recovery (days)	Damage (Y/N)	Recovery (days)	Damage (Y/N)	Recovery (days)
		A									
		B									
		C									
		D									
		E									
		A									
		B									
		C									
		D									
		E									
		A									
		B									
		C									
		D									
		E									

Predominant building type: **1** thatch roof + bamboo matting walls **2** zinc/iron sheet roof + timber walls **3** zinc/iron sheet roof + brick walls

A	Collapsed
B	Badly damaged
C	Moderately damaged
D	Slightly damaged
E	Not damaged

Flood and water logging			
Event	Year(if every year mention)	Max. Depth	Duration
Water logging			

G Early Warning System and Emergency Shelter

16. Is there a system of early warning □ Yes □ No

If yes, fill the table below

Description	Event 1	Event 2	Event 3	Event 4
Event Type (Flood, Cyclone, Storm Surge, Tsunami)				
Year				
Early Warning				
Type of warning system for message relay (TV, Radio, Public address system, human chain. mobile)				
Source of information				
How many hours of advance warning you got?				
Was evacuation ordered through the warning message? (Yes/No)				
If yes, did the neighborhood shift to a safe location? (Yes/No)				
% population evacuated from the neighbourhood				
Mode of evacuation (by Boat, by foot, by motorized vehicles)				
Was there any resistance for evacuation? (Yes/No)				
Emergency Shelter				
Do you have emergency shelter?				
If Yes, Did the facility have sufficient place for standing/sitting/sleeping?				
Was there sufficient food and water? (Yes/No)				
Did you get any other suggestions/information after the event? (Yes/No)				

H Institution Response Post-Nargis

17. What has been the role of institutions after Nargis

Type of Institution	Role Played in *(Tick mark against the right one)*		
	Rescue	Relief	Rehabilitation/ Reconstruction
Local administration			
Community based organizations			
NGOs			
Donors Institutions			
Others *(Specify)*			

18. Post Nargis - Community Based Disaster Preparedness (CBDP) Programme

b. Has there been any exercise/ training conducted in past with respect to community based disaster preparedness (CBDP) | Yes No

If Yes, then

Key Activities under CBDP	Population covered (in %)	Has the Community/ Local government unit internalized the CBDP? *(tick against the right box)*			
		Community	Local Govt	Both	None
Disaster Management Plan					
Community Disaster Management Teams with Standard Operating Procedures					
Training on life saving skills (First Aid/Search and Rescue)					
Mock Drills					

I INVESTIGATORS REMARKS

………

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………

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………

………

………

Ending Time:

Signature:

SECTION 2: TRANSECT

Instructions

1. Select at least 3 neighborhoods in one each from poor/middle/rich income neighborhoods
2. Select a road section (preferably not main road) about 50 buildings on each side
3. Draw a schematic map shopwing the neighborhood with major land marks in the neighboring areas
4. Do a quick survey filling details of each building. Preferably work with a local person with good area knowledge

Transect Code : ______________________________ Date : ____

Town: _____________________________________ Locality: ________________________________

Unit No	A. House Details													B. House							C. Street type in front of the house			D. Water supply					F. Sanitation				G. Electricity connection					
	Use Type		Unit Details					Population				Ownership		Roof				Walls																				
	Residential	Mixed	1 floor	2 floors	3 floors	4-5-6 floors	Age (Years)	No of house units	No of com. Units	No of Nargis deaths	No of Nargis injured	Owned	Rented	Tile	Tin/ACC	RCC	Thatch/Weed	Brick/cement	Bamboo/wood	% damage Nargis	Unpaved road	Tar road	Macadam road	Piped water supply	Public stand post	Dug well	Tube well	Recovery days	WC septic tank	WC sewered	Dry toilet	Connected to open drains	Have connection	Diesel set based	Battery	Solar powered	Other	Recovery days
1																																						
2																																						
3																																						
4																																						
5																																						

Unit No	A. House Details													B. House							C. Street type in front of the house			D. Water supply					F. Sanitation				G. Electricity connection					
	Use Type		Unit Details					Population				Ownership		Roof				Walls																				
	Residential	Mixed	1 floor	2 floors	3 floors	4-5-6 floors	Age (Years)	No of house units	No of com. Units	No of Nargis deaths	No of Nargis injured	Owned	Rented	Tile	Tin/ACC	RCC	Thatch/Weed	Brick/cement	Bamboo/wood	% damage Nargis	Unpaved road	Tar road	Macadam road	Piped water supply	Public stand post	Dug well	Tube well	Recovery days	WC septic tank	WC sewered	Dry toilet	Connected to open drains	Have connection	Diesel set based	Battery	Solar powered	Other	Recovery days
6																																						
7																																						
8																																						
9																																						
10																																						
11																																						
12																																						
13																																						
14																																						
15																																						

SECTION 3: SCHEDULE OF RATES (SOR)

Note: 5 Town level SOR schedules to be completed under this survey.

A Building Material Prices

Item	Unit	Price including transport (in MMK)	
		Normal Cost	After Nargis cost
Earth			
Stone			
Aggregate / Brickbats			
Sand			
Lime			
Cement			
Brick			
Timber 1 (best quality)			
Timber 2 (normal quality)			
Bamboo			
Thatch			
Steel Rods (MS)			
CGI Sheet			

B Labour Rates

Labour Rates (Daily)	In MMK	Meals served (if no then 0, otherwise number of meals/day)	Availability during the months of the year (all throughout the year/summer season/rainy season)
Skilled Labour Male (e.g. Mason, Carpenter etc)			
Skilled Labour Female (e.g. Mason, Carpenter etc)			
Unskilled (Male)			
Unskilled (Female)			

C Other Common Items

Item	Unit	Normal price (in MMK)	Peak price (in MMK)
Rice	per/kg		
Meat	per/kg		
Fish (normal quality)	per/kg		
Petrol	per/litre		
Kerosene	per/litre		
Diesel	per/litre		
Boat (small)	per unit		
Bicycle	per unit		
Motorcycle	per unit		
Doctor's consultation fee	per visit		
Student primary education	fee/month		
Student secondary and higher secondary education	fee/month		
Electricty	per unit (mention unit)		
Taxi Fare	per km		
Others (specify)			

SECTION 3: BUSINESS/TRADE ECONOMICS

Note: 15Town level Small Business/Trade Economics to be completed under this survey.
* To be asked to business men and local traders.

A. Basic Information

1. Trader Type ☐ Wholesale ☐ Retail
2. Name of the Enterprise:
3. Year since operational:
4. Address of premises (include contact details):

____

____

Ph: __________________________

5. Name of the respondent:

B. Unit Details

6. **Nature of Ownership:** ☐ Sole proprietorship ☐ Partnership ☐ Private Limited ☐ Others (Specify)_____________

7. **Trader Type**

- ☐ Selling of fish products
- ☐ Wholesale trade in agricultural raw materials, agriculture and forest produce, food, beverages etc
- ☐ Wholesale trade in wood, paper, cotton, chemicals, glass, ceramics, metals etc
- ☐ Wholesale trade in all types of machinery equipment including transport equipment
- ☐ Wholesale trade Others
- ☐ Retail trade in food, beverages (excluding non-specialised retail trade such as Departmental store, Super Bazar and General Stores)
- ☐ Retail trade in textiles
- ☐ Retail trade in wood, fuel and other household utilities & durables
- ☐ Retail trade Others (including Departmental store, Super Bazar and General store)

8. **Capital Assets & Expenses**

A. Land & Building

No.	Unit status	Area (specify unit in sqft/smt). Strike the non applicable unit		Rate (Kyat/ unit)		Total Value (Kyat)	
		Shop	Godown	Shop	Godown	Shop	Godown
1	Owned						
2	Hired						

B. Investment in Furniture, Fixtures & Other Equipment ________________Kyat

9. **Overehead Expenses**

a. Electricity : Kyat __________ per __________
b. Printing, Stationary, Postage etc. : Kyat __________ per __________
c. Telephone Charges : Kyat __________ per __________
d. Transportation Charges : Kyat __________ per __________
e. Marketing & Advertisement cost : Kyat __________ per __________
f. Rent : Kyat __________ per __________
g. Taxes & licence fees etc : Kyat __________ per __________
i. Insurance : Kyat __________ per __________
j. Others (Specify) _____________: Kyat __________ per __________
Total : Kyat __________ per __________

10. **Working Days**

a. No. of days per week
b. Average number of days closed in a year due to cyclonic disturbance or floods:

11. **Employment and Labour Cost**

No	Category of Employment	Average No. of Persons Employed/ Worked	Wages (MMK/month)
1	Workers Employed		
2	Workers Hired		
5	Unpaid Family Members/ Proprietor		
	Total		

12. **Trade Margins & Turnover**

a. Average Trade Margins (on the main products handled): __________%

b. Average Monthly Turnover Range (in Kyat) __________________________

13. **Stocks & Seasonality**

Sl. No.	Seasonality in Business		Average Monthly Stock Handled (in Kyat)	Normal stock
	Season	Months (From – To)		
1	Normal			
2	Peak			

14. **Impact of Hazard on Capital Stock & Employment (preferably events in the past 10 Years)**

Disaster Type	**Year**	**Damage Proportion (% to their annual value)**			**% Drop in Turnover compared to normal**	**No. of Days Business Interrupted**	**Business with reduced capacity**	
		Building	**Current Assets**	**Any other fixed Assets**			**No. of Days**	**% Capacity**

15. **Post Hazard Scenario (increase in business)**

Event & year	**Increase in business (in %), if any**	**Period of increase**

16. **Remarks**

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Vulnerability Assessment Survey
(Taru Leading Edge Pvt Ltd & MSR)

Rural Household Questionnaire

A Background Information

Schedule Ref. No.__________________ Date: ____

Village ___________________________Village Tract __________________________________

Township__________________________Division/ State _________________________________

Name of the Respondent ____

Contact Number respondent (Phone, if any): ____

Investigator ______________________ Supervisor ____________________________________

Survey Start Time ______________________________

Main Instructions

1. Mention all units wherever applicable (Kyat, Kg, Quintal etc)
2. Preferably get data on village tract (VT) from reliable sources like PDC members. If VT data is not available, collect the settlement/village level data.
3. Some information can be gathered by observation e.g. house type etc. So please avoid asking observed information.
4. Please ensure that all data is filled. If the respondent is unable to provide data, please terminate the interview and meet another respondent group.
5. Please try to get information within the options as far as possible. If you are using **"Others"** category, please write the description is space provided

B Household Information

1. Name of the Head of the household:……………………………………………….

2. No. of Members in Household: a. Adult ……… b. Children ……… c. Total …………

3. Household Details

Sl. No.	Relationship with Head of Household	Sex (M/F)	Marital Status*	Age (Yrs)	Education#	Occupation	Migration Status			Disability Status**	Average Annual Income from Occupation (*Kyat*)		Months of work (only for temporary/ seasonal workers)
							Type of Work @	Place	No of Months		Local income	Migration/ Remittance	
1	Head of the Household												
2	Respondent												
3													
4													
5													
6													
7													
8													

* Marital Status	# Education status	** - Disability types	Occupation- Primary/ Secondary		@- Migration- Type of work
01 – Single	IL-Illiterates	01 - No Disability	WLS - Wage Labour (Skilled)	AL – Agriculture Labour	1 – Wage Labour Unskilled
02 - Married	TO- Child <3 years	02 - Mentally Disabled	WLU - Wage Labour (Unskilled)	GL- Govt lower level	2 – Wage Labour Skilled e.g. Masonry
03- Divorced/ Widowed	KG-Kindergarten	03 - Physically Disabled	FS – Fishery	GM- Govt Middle level	3 – Fishery
	1-12 for Class 1-Class 12	04 - Visual impairment	VN-Street stall/Vendor	GU- Govt Upper level	4 –Vendor Trader/self employed
	GR – Graduate	05 - Hearing Impairment	TR- Transport. Pvt services	PRF– Professional (Doctor/Engr etc)	5 – Industry/ Workshop
	PG - Post Graduate	06 - Speech Disability	SB – Trade & Small Business	CN - Contractor	6 – Salt Pan worker
	VT - Vocational Training	07 - Multiple Disability	NT – Non-Timber Forest Produce Collection	SW – Saltpan worker	7- Professional
	Prof – MBBS, Engg, Lawyer etc		Fr – Farmer/Cultivator	Ot - Others (...................)	8 – Others (---------------)

C Housing & Environmental Services

4. House type (record by observation)

a. Roof & Wall Type (Tick only one type of roof and one type of wall)

Roof Types: ☐ Cement Concrete ☐ Tin/Cement Sheet ☐ Tiles
☐ Biomass/Thatch ☐ Others (……………………….........)

Wall Type: ☐ Bricks ☐ Wood/ Bamboo/ Wattle and Daub
☐ Mud/ Earth ☐ Tin/Cement Sheet
☐ Others (…………)

b. Building Type and floors

Type of building	Owned(O) / Rented(R)	No. of floors *(include ground floor also)*	Total built up area (in sq.ft)	Building Age (No of years)	Approx value of your house (MMK)	Was the house affected by floods or cyclones? (Y/N)	What was the cost to retrofit the structure? (in MMK)
☐ Individual (Single Unit) ☐ Attached Housing / Row Type		☐ One floor ☐ Two Floors ☐ Three floors and above					

c. Stilt Details ☐ Stilted ☐ Non-stilted
If stilted, then height of stilt (in ft above ground) _________

5. Water Supply and Sanitation

d. Water Supply

Source	Distance from house*	Rainy months Usage (Y/N)	Other months Usage (Y/N)
Piped water supply			
Tube well/ Hand Pump			
Dug well			
Tank/Pond			
Stream/River			
Rain water harvesting			
Others(…………..)			

* 1 - Within Premises 2 – Within 100 mts 3 – 100-500 mts 4 - 500 mts – 1 km 5 - > 1 km

e. Sanitation Facility

Description	Owned/shared	Usability during Floods (Y/N)
Wet toilet with Septic Tank		
Wet toilet with sewerage		
Dry Latrine		
River/Floating toilet		
Others (………………)		

f. Electricity

Source	Owned (O)/ Shared (S)	Availability (hrs/day)	Usage (hrs/day)	Reliability (Y/N)	Monthly expenses	If interrupted in last disaster (Nargis), mention duration for recovery (in days)
Government						
Private connection (generator based)						
Battery operated						
Others						

D Livelihood And Occupation

6. **Indicate livelihood option** *(Note: In a household it can be one or more):*
☐ Agriculture ☐ Fishery ☐ Others

Fill in relevant sections as indicated above.

7. **Agriculture**

a. Land Owned ☐ Yes ☐ No

b. Land share cropped/leased etc ☐ Yes ☐ No

If a or b is Yes,

Description	**Rainfed (in Acre)**	**Irrigated (in Acre)**	**Plantation (in Acre)**
Owned Land **A**			
Leased in/share cropped land **B**			
Other land (mortgage security etc) **C**			

Total Agricultural Land controlled D= A+B+C			
Fallow land E			
Actual cultivated land F=(D-E)			

c. Cropping Details

CROPPING PATTERN							
Season	**Land Type**	**Crop**	**Area (in Acres)**	**Source of irrigation***	**Productivity/ Yield (Qtl/ Acre)**	**Price (Kyat/ Qtl)**	**% Produce Sold**
Rainy Season	Irrigated						
	Rainfed						
Winter Season	Irrigated						
	Rainfed/ Residual moisture						
Summer Season	Irrigated						

* Source of Irrigation: 01- TW with Electrical Pump; 02 – TW with Diesel Pump; 03- River/ stream pumping; 04 – Dugwell with Electrical/ Diesel Pump; 05 – Dugwell with manual system; 06- Others (.................................)

d. Have you taken land on lease for cultivation ☐ **Yes** ☐ **No**

e. If yes, the details of land lease

Type of Land	**Crops Grown**	**Terms of Lease**			
		Months leased for	**Rent/ Amount Paid for Leasing in (Kyat)**	**% Share of Crop given to Owner**	**Input Provided by whom***
Irrigated					
Un-irrigated					

* Self/ Land Owner

8. Fishery

g. Are your/family members engaged in fishery for earning your livelihood ☐ Yes ☐ No

h. If Yes, then,

Type of Fishery engaged with	**Months during which fishing is done**	**Total catch in a year (in T/year)**	**Monitory Value (in Kyat)**
☐ Riverine ☐ Marine ☐ Aquaculture			

9. Other Sources of Livelihood

i. Is any of the household member engage in other sources of livelihood ☐ Yes ☐ No

j. If Yes,

Livelihood Type	**Period of engagement (in days/year)**	**Income or Wage/day (in MMK)**	**Annual Income (in Kyat)**
☐ Trade and Business			
☐ Labour			
☐ Skilled work			
☐ Govt Job			
☐ Pvt Job			
☐ Others _______			

E Asset & Expenditure

10. Asset Ownership

Sl. No.	Asset	Number	Approximate value	Impact of last disaster (Not damaged / Partially damaged / Completely damaged)	Repairing/ Replacement cost of asset lost (whichever is applicable) (mention in % or MMK)
1	Radio				
2	Television				
3	Mobile phone				
4	Shop/small business				
5	Micro processing unit				
6	Boat personal use				
7	Boat (hiring)				
8	Bicycle				
9	Motorcycle				
10	Private car				
11	Taxi				
12	Truck				
13	Refrigerator				
14	Gas connection/Stove				
15	Other (………………)				

11. Expenditure Pattern (For monthly payments, use monthly expense column and for annual expenses use only Annual expenses column only)

Sl. No	Item	Average Monthly Expenses (Kyat)*	Total Annual Expenses (Kyat)	Remarks
1	Food			
2	Cooking Fuel (……………..)			
3	Electricity/ lighting			
4	Transport			
5	Telephone/ Mobile			
6	Education Fees etc			
7	Health and Medicines			

8	Entertainment			
9	Cigarette, tobacco, liquor etc			
10	Clothes and Footwear			
11	Buying/ Repair and Maintenance of assets			
12	Loan Repayment			
13	Other major expenses on wedding, social events etc.			
14	Insurance House, Vehicle Medical			
15	Others (…………………)			
Total				

12. Access & use of credit

b. Have you accessed credit? Yes No

If Yes, then

Sl. No.	Credit Source	When taken	Amount (in MMK)	Interest rate (%)per year@	Mortgage*	Purpose for loan #	How much outstanding
1	Money lenders						
2	Relatives/ Friends						
3	Religious Groups						
4	SHGs						
5	Banks/ Financial Institutions						
5	Others (……….)						
6	Others (……….)						
@ If monthly mention as X%/m							

# Purpose of Borrowing Code		* Mortgage code	
(1) House	(5) Household consumption	H- House	SH Shop-Business assets
(2) Medical expenses	(7) Asset purchase	LS- Livestock	N- None
(3) Marriage	(8) Other1 (..................)	J- Jewellery	Ot- Other (…………………….)
(4) Business	(9) Other2 (.......................)	LN- Land	
(6) Education			

F Social Capital

13. Social Capital of the Household

Type of Institution	Are you a member (*Tick mark*)		If Yes, since how long? (mention in years)	What benefits did you get?
	Yes	No		
Member of Community based Organizations				
Member of Resident/Association Committee				
Member of Savings/ Thrift Group/ SHGs				
Member of occupation/professional group /traders association				
Member of Youth association				
Member of Women Association				
Member of committee set up by local administration				
Member of Local disaster management committee				
Others *(… … … …..)*				

14. Status of Family lineage

☐ Influential ☐ Somewhat Influential ☐ Non Influential

15. Who do you rely on for support in financial need?

☐ Neighbours ☐ Relatives ☐ Religious Groups

☐ Saving/ Thrift Group/SHG ☐ Women's Association ☐ Youth Groups

☐ Money Lenders ☐ Employer ☐ Friends

☐ Village Committee ☐ Banks/ FIs ☐ No access to Credit

☐ Others (......................................)

G Health

16. Morbidity Pattern

b. What are the major diseases in last one year in your family and highlight the expenses towards it?

Type of Ailment	Season/ Months #	How many family members effected in a year	Source of Treatment **	Estimated Expenditure (MMK)			
				Medicine	Fees	Others	Total
Water/Vector Borne Diseases							
Cholera							
Typhoid							
Jaundice							
Malaria							
Filaria/Elephantiasis							
Other Diseases							

Season:
1 - Rainy   2- Post Rainy season   3 - Winter   4 - Summer

**Source of Treatment:
1. Hospital
2. General Clinic/ Dispensary
3. Rural Health Centre/BHS
4. Traditional Medicine Hospital
5. Traditional Medicine Clinic
6. Home Remedy
7. Over the Counter Medicine from Chemist
8. Others (.............................)

17. Medical Insurance

a. Is your family covered under a medical insurance policy? ☐ Yes ☐ No

b. If yes, highlight the insurance premium __________ (MMK/year)

H Exposure to Hazard Events In Past

18. Exposure to past hazards and its impact at the house level *(during the last 10 Years)*

Hazard Event Type	Year	Loss of Life & Injury			Category of Damage to House*	Damage to House (Kyat)	Damage to household assets (Kyat)	Damage to personal transport vehicles, agricultural equipments, fishing equipments (Kyat)	Damage to Productive assets (Kyat)
		Life Lost	Persons Injured	Treatment Cost					

* Damage to House: Minor, Moderate, Severe, Collapse

I Early Warning System and Emergency Shelter

19. Is **there** a system of early warning in your local community ☐ Yes ☐ No
If yes, fill the table below

Description	Event 1	Event 2	Event 3	Event 4
Event Type (Flood, Cyclone, Storm Surge, Tsunami)				
Year				
Early Warning				
Type of warning system for message relay (TV, Radio, Public addressal system, human chain. mobile)				
Source of information (Agency)				
How many hours of advance warning did you receive?				
Was evacuation ordered through the warning message? (Yes/No)				
If yes, did you shift to a safe location? (Yes/No)				
% population of evacuated in your locality				
Mode of evacuation (by motorized vehicles, by boat, by foot)				
Was there any resistance for evacuation? (Yes/No)				
Emergency Shelter				
If Yes, distance from the house (in km)				
If Yes, Did the facility have sufficient place for standing/sitting/sleeping?				
Was there sufficient food and water? (Yes/No)				
Did you get any other suggestions/information after the event? (Yes/No)				

J Institution Response Post-Nargis

20. What has been the role of institutions after Nargis

Type of Institution	Role Played *(tick mark against the right one)*		
	Rescue	Relief	Rehabilitation/ Reconstruction
Local administration			
Community based organizations			
NGOs			
Donors Institutions			
Others *(----------)*			

21. Post Nargis - Community Based Disaster Preparedness (CBDP) Programme

c. Has there been any CBDP exercise/ training conducted in your locality ☐ Yes ☐ No

If Yes, then

Key Activities under CBDP	Locality Population covered (in %)	Has the Community/ Local government unit internalized the CBDP? *(tick against the right box)*			
		Community	Local Govt	Both	None
Disaster Management Plan					
Community Disaster Management Teams with Standard Operating Procedures					
Training on life saving skills (First Aid/Search and Rescue)					
Mock Drills					

K Investigator's Remark

……………………………………………………………………………………………………..

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Survey End Time ____________________

Vulnerability Assessment Survey
(Taru Leading Edge Pvt Ltd & MSR)

Village Questionnaire

A. Panel Identification

Ref. No.		Date	
Village Name		Village tract	
Township		Investigator	
Starting time			

Main Instructions

- Mention all units wherever applicable (Kyat, Kg, Quintal etc)
- Preferably get data on village tract (VT) from reliable sources like PDC members. If VT data is not available, collect the settlement/village level data.
- Some information can be gathered by observation e.g. house type etc. So please avoid asking observed information.
- Please ensure that all data is filled. If the respondent is unable to provide data, please terminate the interview and meet another respondent group.
- Please try to get information within the options as far as possible. If you are using **"Others"** category, please write the description is space provided
- Please fill relevant information in (…………………) areas provided to fill.

List key Informants:

No	Name	Age	Male/ Female	Farmer/ Teacher/ Govt Employee/ Village Headman/ Trader etc	Contact Number (If any)
1					
2					
3					
4					
5					
6					

B. Context

1. **Location**
   a. **Location of the Village**
      ☐ River bank ☐ Flat land ☐ Coastal
      ☐ Island ☐ Others (.................................)
   b. **Total Households of Village Tract (PDC)** _______________
   c. **Total no. of settlements in Village Tract (PDC)** ___________________
2. **Location of neighboring Settlements (within the Village tract, PDC)**

No.	Category	Numbers	Total households
1	River bank		

No.	Category	Numbers	Total households
2	Flat land		
3	Coastal		
4	Island		

3. Proximity to Natural Resources (from Settlement)

Resource	**Products *(Food, Fodder, Fuel, Timber, Thatch, None)***	**Tick mark, nearest reported distance**					**Damage to the Resource from last disaster (Full, Significant, Minor, None)**
		<500 m	**0.5-1 km**	**1-2.5 km**	**2.5- 5km**	**> 5km**	
Forest							
Mangrove							
Grass lands							

4. Education ☐ **Village Tract (PDC)** ☐ **Village (Tick mark one box)**

Education level	**Percentage of Total**		**Remarks**
	Male	**Female**	
Illiterate			
Up to 5 years			
6-10 years			
Graduates			
Post graduate			
Professionals			

C. Settlement Details

5. Occupation Structure ☐ **Village Tract (PDC)** ☐ **Village (tick mark one box)**

No	**No. of Households**	**Occupation**	
		Primary Occupation	**Secondary Occupation**
1			
2			
3			
4			
5			

6. **Housing** **Village Tract (PDC)** **Village (tick mark one box)**

a) **Roof and Wall Type(in numbers, can be approximate)**

Roof ► / Wall ▼	RCC	Tin/ Cement sheet	Tiles	Biomass/ Thatch/ Bamboo	Others (……….)
Bricks					
Tin/ Cement sheet					
Mud					
Wood/ Bamboo					
Others (……………)					

b) **Stilt Details (Settlement only)**

Stilt Details	Average stilt Height (in ft)	Average No. of Floors
No of Houses (Without Stilt)		
No of Houses (With Stilt)		

D. Land & Agriculture

7. **Land Holding Pattern** **Village Tract (PDC)** **Village (tick mark one box)**

Land Holding Pattern (in Acre)						
Landless	>0 to< 1Acre	1-2.5 Acre	2.5- 5 Acre	5-10 Acre	10-20 Acre	> 20 Acre

8. **Land Use** **Village Tract (PDC)** **Village (tick mark one box)**

Sl. No	Type of Land		Area (in Acre)	Primary Use/ Major Crops grown
1	Agriculture Land	Irrigated		
		Rainfed		
2	Orchards/ Plantation			
3	Pastures & Grazing land			
4	Fallow (Salination or other problems)			
5	Unclassified land not suitable for agriculture			
6	Forest			
7	Aquaculture			
8	Others			
Total				

9. Area Under Major Crops and Yield

∟Village Tract (PDC) ∟Village (tick mark one box)

Sl. No.	Main Crops	Area (acres)	Average Yield (Qtl/ Acre)	Harvest time Price (Kyat/ Qtl)	Peak price (Kyat/ Qtl)
Rainy Season					
1	Rice				
2					
3					
Winter Season					
1	Rice				
2	Pulses				
3	Vegetable				
4					
Summer Season					
1	Rice				
2	Vegetable				
3					
Plantation crops					
1	Coconut				
2	Betel nut				
3	Banana				

10. Irrigation source ❘ Village Tract (PDC) ❘Village (tick mark one box)

Source	**Numbers**	**Total Area Irrigated**	**Season**	**Irrigation Cost/acre**
Diesel/Kerosene pump				
Electric pump				
Canal				
Other …………				

E. Basic Infrastructure and Services

11. Type of basic Infrastructure and Services

∟Village Tract (PDC) ∟Village (tick mark one box)

a) Type of Roads ❘ Mud Road ❘ Tar Road ❘ None

b) Access to Roads ⌈ All weather ⌉ Non rainy season

c) Common Mode of Transport

Mode	Distance to Access service (in km)	Frequency (numbers/day)	Regularity (Regular/Irregular)	Seasonality (Annual, Nonrainy season)
Bus				
Shared Taxi				
Boat				
Ferry				
Others				

12. Health Facilities Access
Village Tract (PDC) Village (tick mark one box)

Type	Distance to facility (0 if located in the village, otherwise distance in km)		
	Allopathic	Traditional	Service reliability (Good/Average/Poor)
Midwifery/Nursing station			
Clinic/Dispensary (with doctor)			
Hospital (with beds)			
Others (…………..)			

13. Education Village Tract (PDC) Village (tick mark one box)

	Distance	No. of students	Private /Government	Whether used as emergency shelter (Yes/No)
Primary School				
Middle School				
High school				
College				
Technical vocational colleges				
Others (…………………..)				

14. Access to Drinking Water Village Tract (PDC) Village (tick mark one box)

Source	Accessed by % Households	Rainy months Usage (Y/N)	Other months Usage (Y/N)
Piped water supply			
Tube well/ Hand Pump			
Dug well			

Pond			
River/ Stream/ Creek			
Rain water harvesting			
Others (…………………..)			

15. Access to Sanitation ∟Village Tract (PDC) _ Village (tick mark one box)

Description	Accessed by % Households	Usability during Floods (Y/N)
Septic Tank		
Dry Latrine		
River/Floating toilet		
Others (-----------------------)		

16. Electrification/ Energy sources for lighting
∟Village Tract (PDC) ∟Village (tick mark one box)

Source	**% households**	**Availability Hrs/day**	**Usage in hours/day**	**Reliability (Y/N)**
Grid electricity				
Own generator				
Shared private electricity services				
Battery powered				
Solar				
Kerosene/Diesel lamp				
Local oil lamp				

17. Common services
⌈Village Tract (PDC) ⌈Village (tick mark one box)

Type	Distance from settlement	Service Quality (Excellent Medium, Poor)
Post office		
Money lenders/pawn brokers		
Bank/Credit institutions		
Emergency medical services		
Market		

18. **Access to communication services**

∟ **Village Tract (PDC)** ∟ **Village (tick mark one box)**

Ownership/Services	% households	Sharing with others(Y/N)
Landline phone		
Mobile phone		
TV		
Radio		

F. Community Institutions and Linkages

19. **Community Institutions in the Village**

Type of Institution	**Functional Since (Year).**	**Member households**	**Main support offered (Monetary, Materials, Technical, Training, Marketing, Medical)**	
			Primary normal period	**Emergency period**
Self help groups *(Nos. in the village: … … … …)*				
Fisherman Groups *(Nos. in the village: … … … …)*				
Farmers Groups *(Nos. in the village: … … … …)*				
Village committee/ Other Village level groups				
Trader Groups *(Nos. in the village: … … … …)*				
Government agency I				
Government Agency II				
NGOs/ CBOs *Name:*				

G. Local Economy

20. **Major Items Exported from the Village**

- **Village Tract (PDC)**
- **Village (tick mark one box)**

Sl. No.	Items Exported	Unit of Measure	Quantity Per Annum	Value of Export (Kyats/ Annum)	Reduction after Nargis %	Recovery period (years)
1	∟ Rice ∟ Paddy					
2	Pulses					
3	Groundnut					
4	Coconut					
5	Betel nuts					
5	Vegetables/Fruits					
6	Timber					
7	Minor Forest products					
8	Fish					
9	Poultry					
10	Meat					
	Others*(-----------)*					

21. Industrial Activities

⁪ Village Tract (PDC) ⁪ Village (tick mark one box)

Sl. No.	Major Industries	Number of Units	Functional Since (Year)	Avg. Quantity Produced (Per Unit Per Annum)	Avg. Turnover (Per Unit Per Annum in Kyat)	Avg. Employment (Per Unit)
1	Agro based					
2	Fish Processing					
5	Handicrafts					
7	Boats					
8	Saltpans					
9	Others(…………..)					

22. Fishery

⁪ Village Tract (PDC) ⁪ Village (tick mark one box)

Type of Fishery Engaged with	No.of households	Months During which fishing is done	Average Annual Household Income (in Kyat)
∟ Riverine ⁪ Marine ⁪ Aquaculture			

23. Out Migration ☐Village Tract (PDC)☐ Village (tick mark one box)

(a) Do any families out migrate from the village for livelihood ☐ Yes ☐ No

If Yes, fill the table below

Sl. No.	Type of Work	Number of Families Migrating		Months of migration	Destination	Average remittance Kyat/year
		Whole Family	Only working members			
1						
2						
3						
4						

H. Hazards and Its Impacts

24. Losses during past events

☐ Village Tract (PDC) ☐ Village (tick mark one box)

Year	Type (Cyclone/Flood/Storm surge/Tsunami/Earthquake/ Fire/Drought)	Inundation From Floods/Storm surge/Tsunami (in m)	Lives lost	Morbidity/ Injured	Houses lost %	Agriculture loss (in %)	Boat loss (in %)

Flood and water logging			
Event	Year (if every year, mention)	Max. Depth	Duration
Water logging			

25. Damageability and recovery period

∟ **Village Tract (PDC)**
∟ **Village (tick mark one box)**

Year	Hazard Type Cyclone/ Flood/ Storm Surge/ Tsunami/ Earthquake /Fire)	Damage class	Damage % Predominant Building types Note: total each column should be 100%			Road		Electricity		Communication	
			Roof* / Wall#	Roof / Wall	Roof / Wall	Damage (Y/N)	Recovery (days)	Damage (Y/N)	Recovery (days)	Damage (Y/N)	Recovery (days)
		>75%									
		50-75%									
		25-50%									
		>0-25%									
		0%									
		>75%									
		50-75%									
		25-50%									
		>0-25%									
		0%									
		>75%									
		50-75%									
		25-50%									
		>0-25%									
		0%									
		>75%									
		50-75%									
		25-50%									
		>0-25%									
		0%									

* Reinforced Cement Concrete, Tin/Cement Sheet, Tiles, Biomass/Thatch/Bamboo, Tarpaulin Sheet, Others (------------------)
# Bricks, Tim/Cement Sheet/Mud/Wood or Bamboo, Others (……………..)

I. Early Warning System and Emergency Shelter

26. Is there a system of early warning for your village □ Yes □ No

If yes, fill the table below

Description	**Event 1**	**Event 2**	**Event 3**	**Event 4**
Event Type (Flood, Cyclone, Storm Surge, Tsunami)				
Year				
Early Warning				
Type of warning system for message relay (TV, Radio, Public address system, human chain. mobile)				
Source of information				
How many hours of advance warning you got?				
Was evacuation ordered through the warning message? (Yes/No)				
If yes, did the village shift to a safe location? (Yes/No)				
% population of village evacuated				
Mode of evacuation (by Boat, by foot, by motorized vehicles)				
Was there any resistance for evacuation? (Yes/No)				
Emergency Shelter				
If Yes, distance from the village (in km)				
If Yes, Did the facility have sufficient place for standing/sitting/sleeping?				
Was there sufficient food and water? (Yes/No)				
Did you get any other suggestions/information after the event? (Yes/No)				

J. Institution Response Post-Nargis

27. What has been the role of institutions after Nargis

Type of Institution	Role Played in *(Tick mark against the right one)*		
	Rescue	Relief	Rehabilitation/ Reconstruction
Local administration			
Community based organizations			
NGOs			

Donors Institutions			
Others *(………………)*			

28. Post Nargis - Community Based Disaster Preparedness (CBDP) Programme

a) Has there been any exercise/ training conducted in past with respect to community based disaster preparedness (CBDP) in the village ˥ Yes ˥ No

If Yes, then

Key Activities under CBDP	Population covered (in %)	Has the Community/ Local government unit internalized the CBDP? *(tick against the right box)*			
		Community	Local Govt	Both	None
Disaster Management Plan					
Community Disaster Management Teams with Standard Operating Procedures					
Training on life saving skills (First Aid/Search and Rescue)					
Mock Drills					

K. Investigators Remarks

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Ending Time:

Signature:

____

SECTION 2: SCHEDULE OF RATES (SOR)

Note: 20 village SOR schedules to be completed under this survey.

A. Building Material Prices

Item	Unit	Price including transport (in MMK)	
		Normal Cost	After Nargis cost
Earth			
Stone			
Aggregate / Brickbats			
Sand			
Lime			
Cement			
Brick			
Timber 1 (best quality)			
Timber 2 (normal quality)			
Bamboo			
Thatch			
Steel Rods (MS)			
CGI Sheet			

B. Labour Rates

Labour Rates (Daily)	In MMK	Meals served (if no then 0, otherwise number of meals/day)	Availability during the months of the year (all throughout the year/summer season/rainy season)
Skilled Labour Male (e.g. Mason, Carpenter etc)			
Skilled Labour Female (e.g. Mason, Carpenter etc)			
Unskilled (Male)			
Unskilled (Female)			

C. Other Common Items

Item	Unit	Normal price (in MMK)	Peak price (in MMK)
Rice	per/kg		
Meat	per/kg		
Chicken/Duck			
Fish (normal quality)	per/kg		
Petrol	per/litre		
Kerosene	per/litre		
Diesel	per/litre		
Live Adult Pig	single		
Buffalo (Draught)	pair		
Ox (Draught)	pair		
Boat (small)	Per unit		
Bicycle	Per unit		
Motorcycle	Per unit		
Doctor's consultation fee	per/visit		
Electricity	Per KWH		
	Monthly mínimum		
	Monthly/bulb (pvt operator)		
Others (………………….)			

SECTION 3: CROP ECONOMICS

Note: 20 village crop economics schedule to be completed under this survey. Following type of crop shall be selected for investigation:*

Type of Crop	Number of Schedules
Winter paddy	3
Summer paddy	3
Monsoon paddy	3
Groundnut	3
Vegetables and Fruits	3
Plantation	3
Pulses	2
TOTAL	20

**Please meet a farmer who is conversant with numbers. Preferably, choose a farmer who keeps records of expenses and production.*

Please mention units in all cases (eg. Kyat, Litres, Kg, Kyat/kg etc.)

A. Basic Information

1. Name of the Respondent: ____________________

2. Village: ___________________

3. Village Tract_________________________

Contact Number respondent (Phone, if any): ______________________________

4. Land Ownership:

   a. Total Agricultural Land ....Acre
   b. Irrigated ....Acre
   c. Un-irrigated ....Acre

B. Crop and Crop Economics

a) Crop selected for investigation: ____
b) Variety: ☐ Traditional ☐ Improved ☐ Hybrid

c) Cost of Cultivation

Work out costs per acre of crop

Please write all units carefully, get details as far as possible and remember that some expenditure heads may not be relevant

Materials and Services Costs				
Description	**Crop Name**			
	Season			
Materials/Services	**Units**	**Amount Required**	**Rate /Unit**	**Total cost* (MMK) (write bulk if details not available)**
		A	B	C = A x B
Seeds				
Power tiller/Draught animals				
Farm yard manure				
Fertilizers				
Pesticide				
Irrigation				
Transport				
Taxes/ commissions/Marketing				
Total Materials/Services				