Government of the People's Republic of Bangladesh
Department of Disaster Management
Ministry of Disaster Management and Relief

MULTI HAZARD
RISK AND
VULNERABILITY
ASSESSMENT,
MODELING AND MAPPING

FINAL REPORT OF MULTI HAZARD RISK AND VULNERABILITY ASSESSMENT, MODELING AND MAPPING IN BANGLADESH

VOLUME V: VULNERABILITY AND RISK ASSESSMENT

EARTHQUAKE, TSUNAMI, TECHNOLOGICAL AND HEALTH

Government of the People's Republic of Bangladesh

Report on Multi-Hazard, Risk and Vulnerability Assessment, Modelling and Mapping in Bangladesh

Volume V: Vulnerability and Risk Assessment

(Earthquake, Tsunami, Technological and Health)

Department of Disaster Management
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Message from Secretary, MoDMR

Government of the Peoples' Republic of Bangladesh had initiated the 'Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)' under DDM, LGED & BWDB with the assistance of the World Bank for Disaster Risk Mitigation and Reduction. Multi-hazard Risk and Vulnerability Assessment, Modeling and Mapping (MRVAM) is one of the initiatives under ECRRP, D1(DDM component) to assess risk and vulnerability of 8(eight) major hazards like Flood, Cyclone induced Storm Surge, Landslide, Drought, Earthquake, Tsunami, Technological & Health hazards. Component D1 is designed to contribute towards 'building long-term preparedness by strengthening disaster risk management' through strengthening and enhancement of long-term disaster risk mitigation and reduction ability of the DDM. This study is very important, due to the geographical location and topographical features of Bangladesh, exposed the country to almost all kinds of natural disasters and a large-scale disasters in Bangladesh has been observed at a frequency of 5-6 years.

I am very happy to know that ECRRP-D1 project is going to publish comprehensive Report on MRVAM with the help of ADPC, Thailand and IWM, Bangladesh. This study will supplement the efforts of the government to incorporate disaster risk reduction issues in all development programmes to build a safe and disaster resilience nation, referring to the SOD-2010, Disaster Management Act-2012, Disaster Management Policy-2015, and National Disaster Management Plan 2010-15. Alongside by the government, all including non- governmental organizations (NGOs) and civil society should come forward to build an effective disaster management infrastructure to reduce the post-disaster losses. District and local level officials who are frequently involved with the disaster damage assessment, management, preparedness and risk & vulnerability reduction activities will be benefitted by using these national level risk assessment map and database from this project.

Md. Shah Kamal
Secretary
Ministry of Disaster Management and Relief

Message from DG, DDM

Bangladesh has made a strong commitment to implement Hyogo Framework for Action (HFA) during 2005-2015 for critical guidance in efforts to reduce disaster risk and the Multi-Hazard Risk and Vulnerability Assessment, Modeling and Mapping (MRVAM) project initiated under 'Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)' as D1 component has advanced Bangladesh's progress in Priority Action 2: Identify, assess and monitor disaster risks and enhance early warning. In continuation of this, outcome of this project "Multi-Hazard Risk Assessment at national level" is in line with Priority 1: 'Understanding disaster risk' of Sendai Framework for Disaster Risk Reduction 2015-2030, adopted in the 3rd World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Miyagi, Japan.

The findings of MRVAM project has create the basis for "building long term preparedness through strengthening disaster risk management capacity in the country as well as for enhancement of long term disaster risk mitigation and reduction ability of the Department of Disaster Management (DDM)". On the other hand, MRVAM project outcome has created awareness among the district and upazila level officials and will help in contributing towards incorporating appropriate risk-reduction strategies and prioritizing them into the country's development planning process.

In addition to this, the findings of this study 'risk information of population, housing and livelihood at upazila level' will allow decision makers to prioritize risk mitigation investments and measures to strengthen the emergency preparedness and response mechanisms for reducing the losses and damages due to future disaster events.

(Md. Reaz Ahmed)
Director General (Additional Secretary)
Department of Disaster Management

Message from PD, ECRRP-D1, DDM

Multi-Hazard Risk and Vulnerability Assessment, Modeling and Mapping (MRVAM) project implemented as a part of sub-component D1.2 'Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)', by Department of Disaster Management (DDM) is an efforts towards 'building long-term preparedness through strengthened disaster risk management', through the strengthening and enhancement of the long-term disaster risk mitigation and reduction ability of the DDM.

This project has developed enormous quantity of database representing multi-hazards of Flood, Cyclone induced Storm Surge, Landslides, Drought, Earthquake, Tsunami, Technological and Health along with national level database representing population, housing, livelihood, critical facilities, infrastructure which can be used at Union / Upazila level for development planning process.

DDM has established Multi-Hazard Risk and Vulnerability Assessment (MRVA) Cell, in which geo-database of hazard, exposure and risk assessment at upazila level developed in this project and hosted in the state of the hardware & software facilities. I take this opportunity to state that, this will enhance the capacity of the department to monitor the hazard, exposure and risk assessment, in this way, all the government agencies, professionals and researchers will be benefitted in contributing towards disaster risk reduction in Bangladesh.

(M. Khalid Mahmood)
Joint Secretary and Director (Planning & Development)
Project Director, ECRRP-D1
Department of Disaster Management

Preface

A category IV cyclone *SIDR* struck in the south west coast of Bangladesh on November 15, 2007 evening and moved inland, destroying infrastructure, causing numerous deaths, disrupting economic activities, and affecting social conditions. As most all of Bangladesh is considered as a Delta just above sea level, tidal surge of 15-20 feet and gail-force winds of approximately 150 mph creates havoc in most of the area. The aim of the assessment was to identify priority areas to support the Government of Bangladesh in cyclone recovery efforts as well as to recommend priority interventions for a long-term disaster management strategy. The preparation of Multi-Hazard Risk and Vulnerability Assessment, Modelling and Mapping (MRVAM) project has identified the damage needs and quantified financial and technical requirements and established MRVA Cell in DDM, that will facilitate formulating comprehensive early recovery actions, medium-term recovery and reconstruction plans and a long-term disaster risk management and reduction strategy. The main objective to establish MRVA Cell is to strengthen and enhance country capacity in carrying out systematic multi-hazard risk assessments and consolidating and maintaining hazard risk information at central (national) and disaggregated (district) levels. This will contribute towards the realization of the specific priority attached in the country's disaster management strategy of 'defining and redefining the risk environment' of the country. The Asian Disaster Preparedness Center (ADPC), Thailand, in partnership with the Institute of Water Modeling (IWM), the Norwegian Geotechnical Institute (NGI), the Asian Institute of Technology (AIT), and the Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC), the Netherlands have been worked together to deliver consulting services on the Multi-Hazard Risk and Vulnerability Assessment, Modeling and Mapping in Bangladesh and finally have prepared the Volume I: Hydro-meteorological Hazard Assessment (Flood, Storm Surge, Landslide, Drought), Volume II: Geological and Environmental Hazard Assessment (Earthquake, Tsunami, Technological, Health), Volume III: Elements at risk, Volume IV: Vulnerability and Risk Assessment (Flood, Storm Surge, Landslide, Drought), Volume V: Vulnerability and Risk Assessment (Earthquake, Tsunami, Technological, Health), Volume VI: Summary and Recommendations.

For flood hazard and vulnerability assessment, Flood Modeling used in this study is MIKE11 Hydrodynamic Model developed by DHI, coupled with Geographic Information System (GIS) to capture the hydraulic response of Bangladesh Rivers, in-depth Flood analysis and its floodplains in extreme flooding conditions. Then a frequency analysis was carried out in the river network at 7617 grid points in order to obtain return period-wise flood levels for 25 year, 50 year, 100 year and 150 years. The model used in MRVAM project for Cyclone induced Storm Surge is called Bay of Bengal Model (BoBM). The model is developed using a MIKE21 FM modelling system, which is a numerical modelling system for the simulation of water levels and flows in estuaries, bays and coastal areas. Storm Surge hazard depth was divided into seven different depth categories in order to find the extent of surge inundation and prepare inundation maps for all return periods: 25, 50 and 100 years for the entire coastal region. The depth categories are <1 m, 1-1.5 m, 1.5-2 m, 2-3 m, 3-4 m, 4-5 m, >5 m. Earthquake hazard maps were developed using the historical data and existing geological setting for 50 year, 100 year, 200 year, 500 year and 1000 years return periods at the sites of investigation derived and interpolated to develop earthquake hazard maps representing spatial variation of Peak Ground Acceleration (PGA) Map in Bangladesh.

Simultaneously, to model the tsunamigenic conditions and the possible hazard maps due to Tsunami, have been generated for 50, 100, 200, 500 and 1000 years return period and the SPI (Standardized Precipitation Index)-Return period plots used to calculate the severity of Drought with different return periods such as the SPI values for 10, 50 and 100 years return period.

The purpose of this Multi-Hazard Risk and Vulnerability Assessment (MRVA) Modelling and Mapping study is to develop a hazard and vulnerability framework using the progression of vulnerability model to identify the root causes (problems) and the underlying pressures within coastal belt as well as whole Bangladesh. The information provided in this study was intended to assist in identifying hazards and vulnerabilities thereby building a disaster resilient Districts and Upazilas by sharing local hazards and also establishing community structures. Combining the results of the theoretical framework and research findings with the argument constructed in these Volumes I-VI about the disaster risk reduction and mitigation; it was found that it is possible to reduce hazard risks, and vulnerability to disasters, through the application of the latest GIS & RS tools and Hydrodynamic modeling and the participation of the grass-root level community in disaster risk management activities.

It is a great pleasure to successfully launch this Scientific MRVA National Document, signifying the needs and opportunities for the protection of the coastal environment as well as overall most vulnerable districts of Bangladesh and associated lives and livelihoods. The Department of Disaster Management (DDM), Ministry of Disaster Management and Relief would like to thank all those involved in the preparation and finalization of this document and would like to believe that materialization of these policies and programmes will improve overall catastrophic environment of the country as a whole and coastal environment in particular.

We would like to express our in-depth gratitude to the prominent experts of Technical Advisory Committee (TAC), the well-known and reverend group of professionals of the Country, specially, Dr. A. S. M. Maksud Kamal, Convener-TAC and Dean, Faculty of Earth and Environmental Sciences, Dhaka University; Dr. Umme Kulsum Navera, Professor, Department of Water Resources Engineering, BUET; Dr. Md. Atiqur Rahman, Joint Secretary (Admin.), Ministry of Disaster Management and Relief (MoDMR), Mr. M. A. Rouf Hawlader, Director, Survey of Bangladesh; Mr. Shamsuddin Ahmed, Director in Charge, Bangladesh Meteorological Department (BMD), Mr. Md. Shahidul Islam, GIS Analyst, CDMP-II; Mr. Mir Ahmed, Member Secretary-TAC & Director-MIM, DDM; Mr. M. Khalid Mahmood, Director (Planning & Development) & PD-ECRRP-D1, DDM; and Mr. Reaz Ahmed, Director General and MRVAM Advisor, DDM & last of all, those associated with MRVA Cell; under whose overall guidance and supervision, these MRVA Volumes were duly checked and scientifically verified, who had worked relentlessly for years to generate scientific information required for these risk and vulnerability assessments. A special appreciation to the World Bank, ERD and PCMU – Planning Commission Team, whose financial and project extension support from the beginning helped us to reach its ultimate destination.

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List of Abbreviations

ADPC	Asian Disaster Preparedness Center
AEGL	Acute Exposure Guideline Levels
AFCCL	Ashuganj Fertilizer & Chemical Company Factory Limited
ALOHA	Areal Locations of Hazardous Atmospheres
ARCGIS	ARC Geographic Information System
CDMP	Comprehensive Disaster Management Programme
CUFL	Chittagong Urea Fertilizer Ltd.
DAPFCL	DAP Fertilizer Company Ltd.
DDM	Department of Disaster Management
DRR	Disaster Risk Reduction
EA	Exposure Assessment
EVRA	Exposure, Vulnerability and Risk Assessment
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
IWM	Institute of Water Modeling
JFCL	Jamuna Fertilizer Company Ltd.
MRVA	Multi-Hazard Risk and Vulnerability Assessment
MRVAM	Multi-Hazard Risk and Vulnerability Assessment Modelling and Mapping
MODMR	Ministry of Disaster Management and Relief
MPO	Master Plan Organisation
NGI	Norwegian Geo-technical Institute
NGFFL	Natural Gas Fertilizer Factory Ltd.
PFFL	Polash Fertilizer Factory Limited
PGA	Peak Ground Acceleration
TAC	Technical Advisory Committee
UNDP	United Nations Development Program
UNISDR	United Nations International Strategy for Disaster Reduction

Multi-Hazard Risk and Vulnerability Assessment (MRVA) Report

Volume V: Vulnerability and Risk Assessment (Earthquake, Tsunami, Technological and Health)

Chapter 1: Vulnerability and Risk Assessment

1.1 Introduction

Components of risk assessment are hazard, elements at risk, exposure, vulnerability. The first step of a risk assessment is Hazard Assessment, in which natural disaster phenomena are modelled to develop hazardous areas. The exposure, which involves evaluating the elements at risk exposed to different levels of hazards, is a function of the geographic location of the elements at risk and co-existence of hazard at the same location. Vulnerability (damage curves or risk matrices) is assessing the relationship between hazard and *physical damage or monetary value* of exposed elements at risk. Risk can be defined as the total *physical damage or monetary value* of elements at risk *(*properties or assets) that can potentially be affected by hazards. Risk is assessed using damage curves as quantitative risk (*physical damage or loss of monetary value)* or using risk matrices for qualitative risk assessment. A Risk Matrix represents the qualitative relation between the hazard intensity and level of damage expected for each element at risk.

The Exposure, Vulnerability and Risk Assessment approach adopted in this study is based on definitions from UNISDR (UNISDR, 2009). The basic function of risk can be divided into the three components: hazard, exposure of elements at risk and vulnerability. The definitions of these terms are given in Table and concept of Exposure, Vulnerability and Risk Assessment (EVRA) Approach is shown in figure 1.1.

Table 1.1: The Definition of Exposure, Vulnerability and Risk

Exposure	The degree to which the elements at risk are exposed to a particular hazard.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Can be subdivided into physical, social, economic and environmental vulnerability.
Risk	The probability of harmful consequences, or expected losses (deaths, injuries, property loss, livelihoods loss, economic activity disruption or environmental damaged) resulting from interactions between (natural and/ or human-induced) hazards and vulnerable conditions in a given area and time period.

Source: UNISDR, 2009

Risk can be presented conceptually with the following basic equation:

Risk = Hazard x Vulnerability x Element at risk

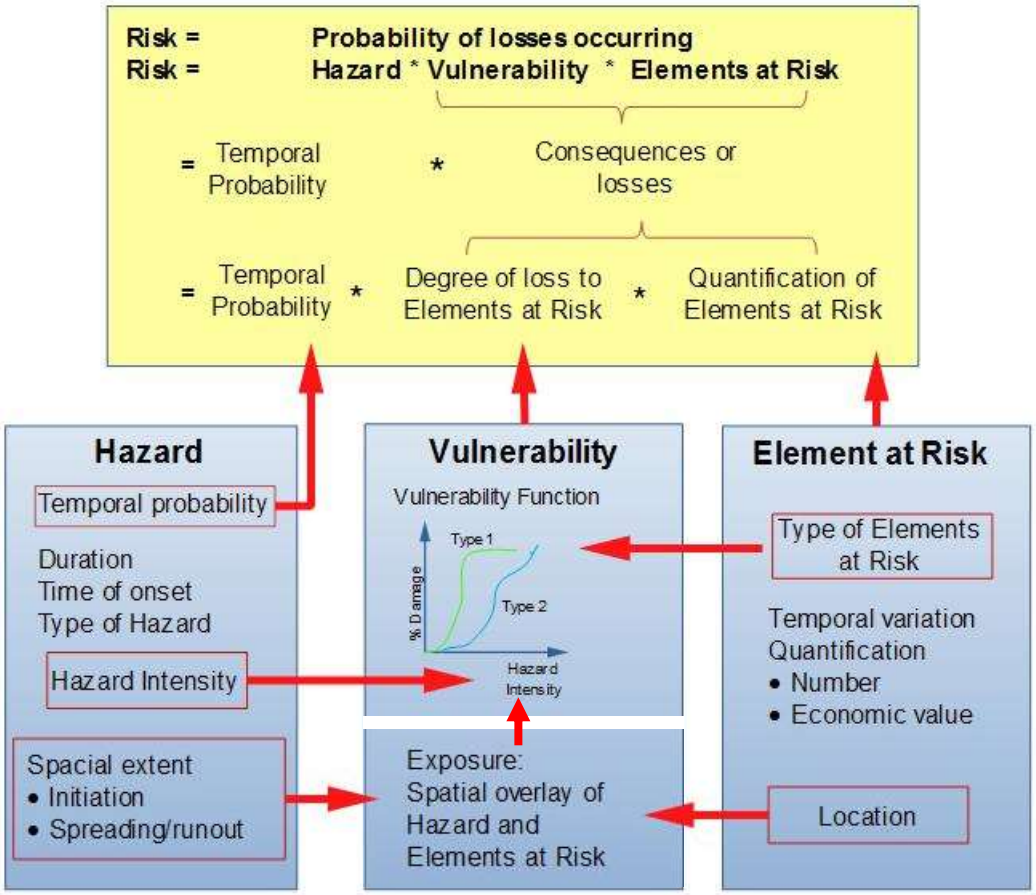

Figure 1.1: Exposure, Vulnerability and Risk Assessment (EVRA) Approach

Source: ADPC, 2014

1.2 Exposure, Vulnerability and Risk Assessment (EVRA) Approach

EVRA results largely depend upon availability of data. The project scope is to develop an EVRA profile based on available authentic secondary information. The elements at risk data is mostly collected from authentic government/non-government and reputed international sources. The risk assessment has been carried out mainly based on data collected from various sources, which is mentioned in detail in table 2.2 of Volume I of this report.

EVRA is developed based on national level hazard assessment of Flood, Cyclone storm surge, Earthquake, Tsunami, Landslide, Drought, Technological, Health and Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors, which are elements at risk considered in this project. Hazard assessment was carried out for various return periods as given in table 1.2. The details of hazard assessment are presented in Volume I, II and elements at risk in Volume III of this report.

Table 1.2: Summary of Hazard maps developed in this study

Hazards	Return Period							
	10	**25**	**50**	**100**	**150**	**200**	**500**	**1000**
Flood		√	√	√	√			
Cyclone induced Storm Surge		√	√	√				
Earthquake			√	√		√	√	√
Landslide	Not Applicable as there is no return period							
Tsunami			√	√		√	√	√
Drought	√		√	√				
Technological	Not Applicable as there is no return period							
Health	Not Applicable as there is no return period							

1.2.1 Exposure Assessment (EA)

Exposure Assessment (EA) is an intermediate stage of risk assessment, which links hazard assessment with assets under consideration for risk assessment. The objectives of the exposure assessment (EA) under the project are

1) To create an extensive national-level database of Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors
2) To quantify the number of elements at risk located in each hazard prone areas of Flood, Cyclone induced storm surge, Earthquake, Tsunami, Landslide, Drought, Technological, Health hazards at union/upazila/district/division/national level.

The concept of exposure assessment is given in figure 1.2.

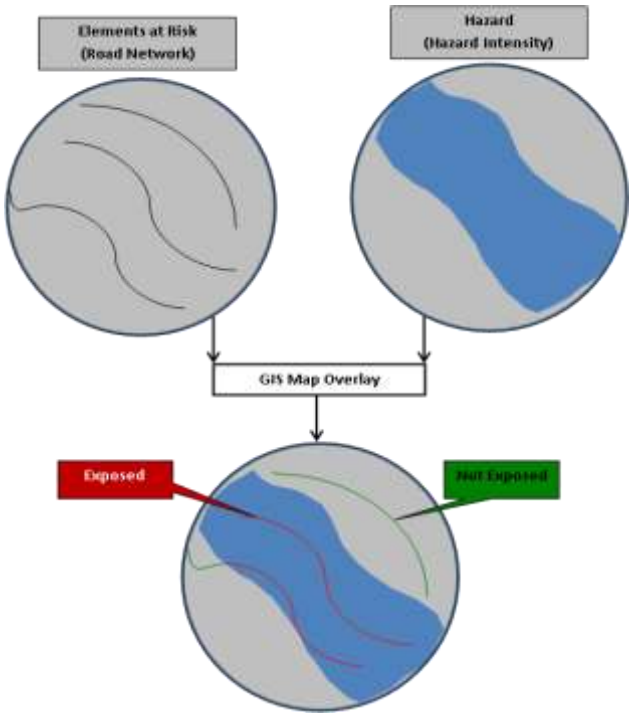

Figure 1.2: Concept of exposure Assessment

The scope of the EA includes:

- All the available elements at risk data for Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors was collected and compiled as geo-database in GIS environment.
- Hazard assessment is carried out for several return periods (table 1.2), exposure is assessed using the most frequent and damaging hazard maps with relevant return period as approved by Technical Advisory committee (TAC) of this project and is given in table 1.3. Using the hazard maps (Flood, Cyclone induced storm surge, Earthquake, Tsunami, Landslide, Drought, Technological and Health) developed by various experts and elements at risk data is combined in GIS environment to analyze elements at risk located in different hazard zones at union level, which are aggregated to quantify exposed elements at risk at upazila / district / division / national levels.

Table 1.3: Summary of exposure assessment and return period of hazards

Hazard	Elements at Risk				
	Population	**Housing**	**Livelihood**	**Critical Facilities**	**Infrastructure**
Flood	25	25	25	100	100
Storm Surge	25	25	25	100	100
Landslide	Not Applicable (NA)				
Drought	10	NA	25	NA	NA
Earthquake	50	50	NA	50	50
Tsunami	50	50	50	50	50
Technological	Not Applicable				
Health	Not Applicable				

Exposure of elements at risk is assessed based on indicators of hazard levels in each hazard, which is indicated in table 1.4. EA will provide inputs to the vulnerability and risk assessment.

Table 1.4: Hazard level indicators considered for exposure assessment

Hazard	Indicator of Hazard level considered
Flood	Inundation area with different flood depths at 25 / 100 year return period
Storm Surge	Inundation area with different depth due to cyclone storm surge at 25 / 100 year return period
Landslide	Landslide susceptibility category
Drought	Drought hazard category representing severity
Earthquake	Peak Ground Acceleration (PGA) zones at 50 year return period
Tsunami	Inundation area with different depth due to tsunami at 50 year return period

Hazard	Indicator of Hazard level considered
Technological	Area of influence (3 zones) due to chemical release
Health	Area representing number of cases reported for each disease at district level

1.2.2 Vulnerability Assessment

Based on exposure assessment, damage curves are developed for all hazards and elements at risk for vulnerability and risk assessment, where ever possible. Damage curves represent the relationship between hazard level and percentage of physical damage. The description and tables given below are the summary of damage curves developed for this study by Norwegian Geo-Technical Institute (NGI) (mode details in the Annexure I of Volume IV). In this final report only physical damage of elements at risk is provided.

1.2.2.1 Vulnerability of Population

Based on the area of exposure of the settlements in each union, the vulnerability of population is calculated as number of population exposed to a hazard. All hazards except Technological and health hazards are considered for total population exposed at national, district, upazila level is accumulated from union level. In case of Technological hazards population affected only in the hazardous area of each industry is assessed. In case of health hazard, affected population at district level is analyzed and presented as hazard assessment in volume II of this report.

1.2.2.2 Vulnerability of Household structures

Factors affecting vulnerability of household structures are different in each hazard, damage curves are developed accordingly, as indicated in table 1.5.

Table 1.5: Factors affecting used for vulnerability of household structures

Hazard	Factor considered for damage curves	Vulnerability of Household structures
Flood	Inundation depth due to Flood	Damage curves
Cyclone induced Storm surge	Inundation depth due to storm surge	Damage curves
Landslide	Landslide susceptible category	Risk matrix
Earthquake	Peak Ground Acceleration (PGA)	Damage curves
Tsunami	Inundation depth due to Tsunami	Damage curves

1.2.2.3 Vulnerability of Livelihood

Elements at risk considered in livelihood are crop (transplanted Aman). Vulnerability of crop is developed using the published literature and technical discussions with concerned authors form Sher-E-Bangla Agricultural University, Dhaka.

Damage curves for crop area are developed using the factors affecting a hazard as given in table 1.6.

Table 1.6: Factors affecting used for vulnerability for crops

Hazard	Factor considered for damage curves	Crops
Flood	Inundation depth due to Flood	Damage curves
Cyclone induced Storm surge	Inundation depth due to storm surge	Damage curves
Landslide	Landslide susceptible category	Risk matrix
Drought	Drought hazard category	Risk matrix
Tsunami	Inundation depth due to Tsunami	Damage curves

1.2.2.4 Vulnerability of Critical facilities

Elements risk considered in livelihood are Healthcare, Education Institutions, First Responders (Fire and Police stations), and Cyclone Shelters. Keeping in view of the type of data of all critical facilities (only point location and type of critical facility), only exposure i.e. number of critical facilities existing in each hazard category is possible, not damage curves and is indicated in table 1.7.

Table 1.7: Summary of vulnerability assessment of critical facilities

Hazard	Healthcare institutions	Educational institutions	First Responders (Fire and Police stations)	Cyclone Shelters
Flood	Exposure	Exposure	Exposure	Exposure
Cyclone induced Storm surge	Exposure	Exposure	Exposure	Exposure
Earthquake	Exposure	Exposure	Exposure	Exposure
Tsunami	Exposure	Exposure	Exposure	Exposure

1.2.2.5 Vulnerability of Infrastructure

Elements risk considered in Infrastructure are Road, Bridge, Railway, Air, Sea and River Ports, Power. Damage curves are developed only for road due to earthquake based on the type of road, for other infrastructure only exposure i.e. number/length of infrastructure existing in each hazard category is possible not damage curves, keeping in view of the type of data (only point location and type of infrastructure) available, as indicated in table 1.8.

Table 1.8: Summary of vulnerability assessment of Infrastructure

Hazard	Road	Bridge	Railway	Airports	Sea ports	River ports	Power
Flood	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Cyclone induced Storm surge	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Earthquake	Damage curves	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Tsunami	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure

1.2.3 Risk Assessment

Risk Assessment is a combination of hazard and vulnerability as shown in figure 1.3.

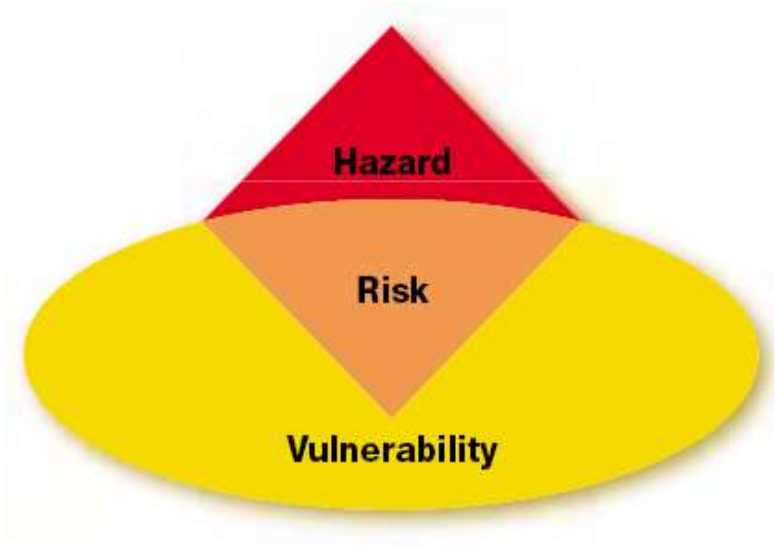

Figure 1.3: Concept of Risk

Using the hazard and vulnerability data, risk is calculated using the damage curves / risk matrix. Risk can be provided as parentage of physical damage or monetary value. In this report, risk is expressed as physical damage only, which will be converted to monetary value later. The parentage of physical damage is grouped into 5 classes and given in table 1.9. These risk classes are used to represent risk in GIS maps at district and upazila level.

Table 1.9: Risk class, Risk level, Range of damage and risk score

Risk class	Risk level	Range of Damage	Risk score
D0	No	No Damage	1
D1	Low	1 - 15%	2
D2	Moderate	15 - 35%	3
D3	High	35 - 60%	4
D4	Very High	Damage >60%	5

Where ever damage curves are not available (refer to section 1.4), the exposure assessed at upazila level is used to derive minimum and maximum exposure at national level, which are categorized into 5 equal levels, as shown in table 1.10 and is used to represent exposure levels in GIS maps at upazila / district level representing upazila exposure levels.

Table 1.10: Exposure class, Exposure level, Range of exposure and risk score

Exposure class	Exposure level	Range of exposure (%)	Exposure score
E 1	Very Low	0 – 20 %	1
E 2	Low	20 – 20 %	2
E 3	Moderate	40 – 60 %	3
E 4	High	60 – 80 %	4
E 5	Very High	80 – 100 %	5

1.3 Application of EVRA

Application of EVRA is,

- VRA provides a basic framework of understanding about linkages between hazards, exposure, vulnerability and risk of various physical and infrastructural assets existing in various parts of the country.
- The vulnerability assessment identifies the characteristics of physical elements with respect to a specific hazard's severity, which reflects the asset's strengths and weaknesses. Vulnerability assessments provide basic understanding about a sector's vulnerability and therefore provide an evidence-based approach for DRR. This volume highlights vulnerability assessment of all elements at risk considered in this study i.e. Population, Housing, Livelihoods, Critical Facilities and Infrastructure, which will further help decision makers, policy makers and planners when it comes to safer sectoral development.
- The risk assessment will provide details of sectoral elements at risk (Population, Housing, Livelihoods, Critical Facilities and Infrastructure) for various types of hazards. This will further enable policy makers and decision makers to understand potential damage and losses to specific sectors. The risk assessment is an essential tool for planning bodies such as the Planning Department and those in charge of allocating funds and resources for DRR.
- VRA will help develop recommendations for sustainable development plans or projects within national DRR planning.

1.4 Key Issues of EVRA

- Though this report is submitted to Government of Bangladesh through Department of Disaster Management (DDM), which leads the disaster related activities in Bangladesh, the respective departments and ministries which are supporting DDM in disaster risk reduction can use these results for the planning, relief and rescue operations in future. However, updation of hazard maps, elements at risk data is a continuous process, which can be co-ordinated by MRVA cell (established as a part of this project) with the

support of local scientific / research institutions and relevant government departments using the suggested methodology for carrying out detailed risk assessment in future at local level.

- The characterizing vulnerability of various assets needs extensive technical and scientific inputs. Though significant work has been carried out in the past to characterize vulnerability of Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors internationally, limited work has been carried out in Bangladesh. An attempt has been made under the scope of the project, to develop damage curves for housing, livelihoods and infrastructure (road) using technical assistance of Norwegian Geo-Technical Institute (NGI), Oslo, Norway using literature available for similar geographical, cultural locations and limited ground data collected.
- But the challenge of validating these damage functions is possible only based on the detailed data collected during or after the disaster events affecting the elements at risk, which was not possible earlier due to non-availability of compiled scientific data for this purpose. It is proposed to validate these damage functions based on the necessary relevant field data to be collected in future, as well as expert opinions and field-based judgment.
- The results are represented in more simplistic terms so as to be understood by various stakeholders. This report will be largely used by policy-makers, decision makers, planners, community and non-government agencies involved in DRR planning.
- The scale of VRA is at national / division / district / upazila / union levels based on the results presented in this report. However, the entire GIS database will be hosted in MRVA cell in DDM, which can be used to view the results at much larger scale than what is presented in this report, using the latest ARCGIS software provided in MRVA cell.

1.5 Structure of this report

Geological and Environmental hazards considered in this study are Earthquake, Tsunami, Technological hazards only. Volume II of this report consists of the methodology and results of hazard assessment. Elements at Risk considered in this study are discussed in volume III of this report. In this volume of Exposure, Vulnerability and Risk Assessment (EVRA) of elements at risk to Geological and Environmental hazards is given.

Exposure, Vulnerability and Risk Assessment is carried out for all the elements at risk (as explained in sections 1.2.1 and 1.2.2) to Earthquake and Tsunami and only exposure assessment to Technological and Health hazards. Concepts of Exposure, Vulnerability and Risk Assessment is given in chapter 1. Risk assessment due to Earthquake hazard is given in chapter 2, Risk assessment due to Tsunami is given in chapter 3, exposure assessment due to Technological hazard is given in chapter 4 and exposure assessment due to Health hazard is given in chapter 5.

Chapter 2: Exposure, Vulnerability, Exposer and Risk Assessment to Earthquake

2.1 Exposure Assessment

Peak Ground Acceleration (PGA) value ranges of earthquake hazard map of 50 years return period is categorized into 3 zones of Very Low (< 0.5), Low (0.5 – 1.5) and Moderate (0.15 – 0.35). This is used for exposure assessment of elements at risk.

2.1.1 Population

As explained in section 1.1, based on the area of exposure of the settlements in each union, the vulnerability of population is calculated as affected population for earthquake hazard at division / district / upazila level.

2.1.1.1 Gender

Total population (male) exposed to earthquake at division level is given in table 2.1and figure 2.1. Population (male) exposed to moderate level of earthquake at district level is shown in figure 2.2.

Table 2.1: Population (male) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	**Low (0.05 - 0.15)**	**Moderate (0.15 - 0.35)**
Barisal	-	4,089,508	-
Chittagong	-	1,825,793	12,107,521
Dhaka	-	18,471,111	245,664
Khulna	-	7,842,533	-
Mymensingh		3,167,145	2,288,397
Rajshahi	3,010	5,078,249	4,175,650
Rangpur	-	1,291,330	6,590,494
Sylhet	-	-	4,933,390
Total	3,010	41,765,669	30,341,116

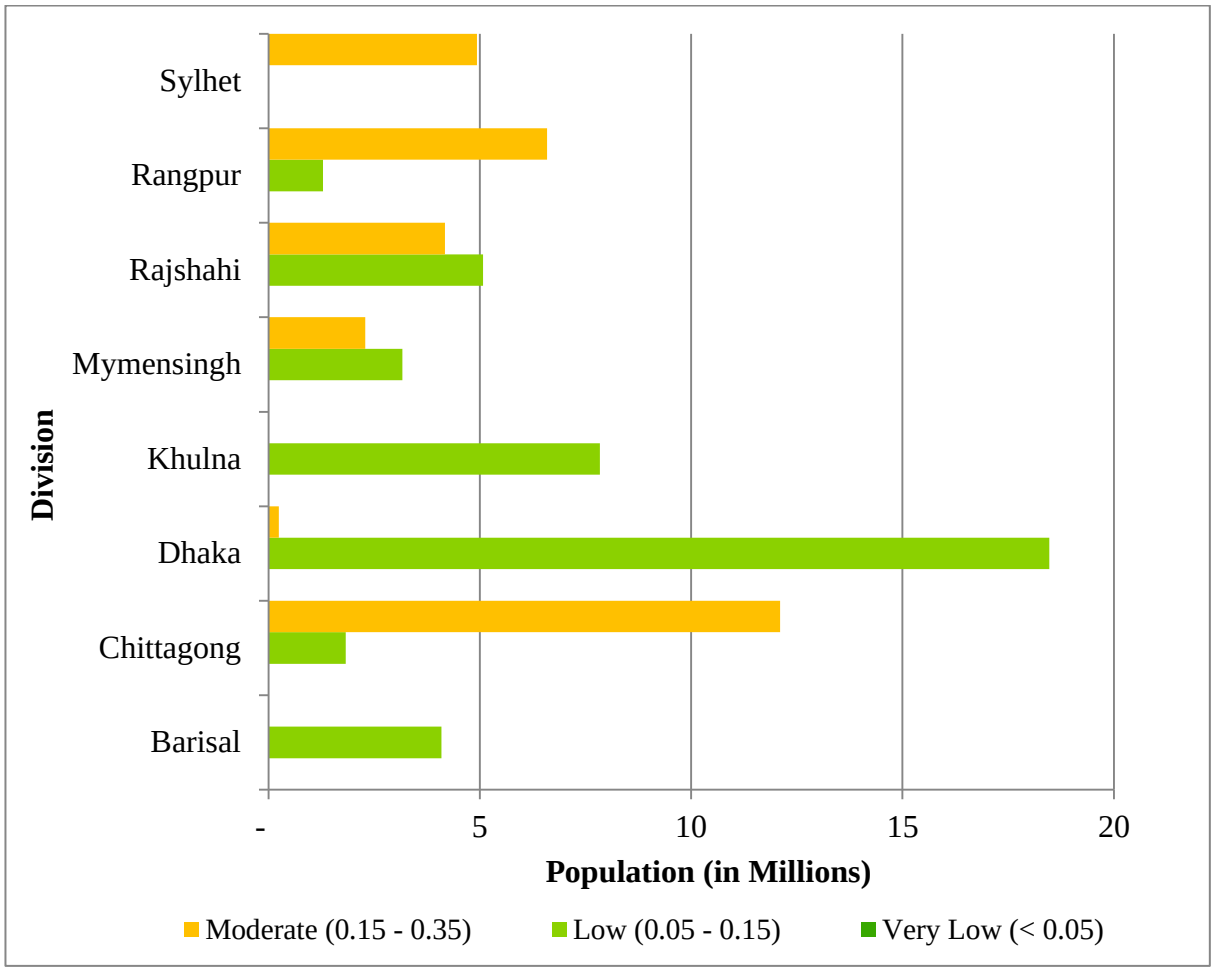

Figure 2.1: Population (male) exposed to different intensity of earthquake at division level

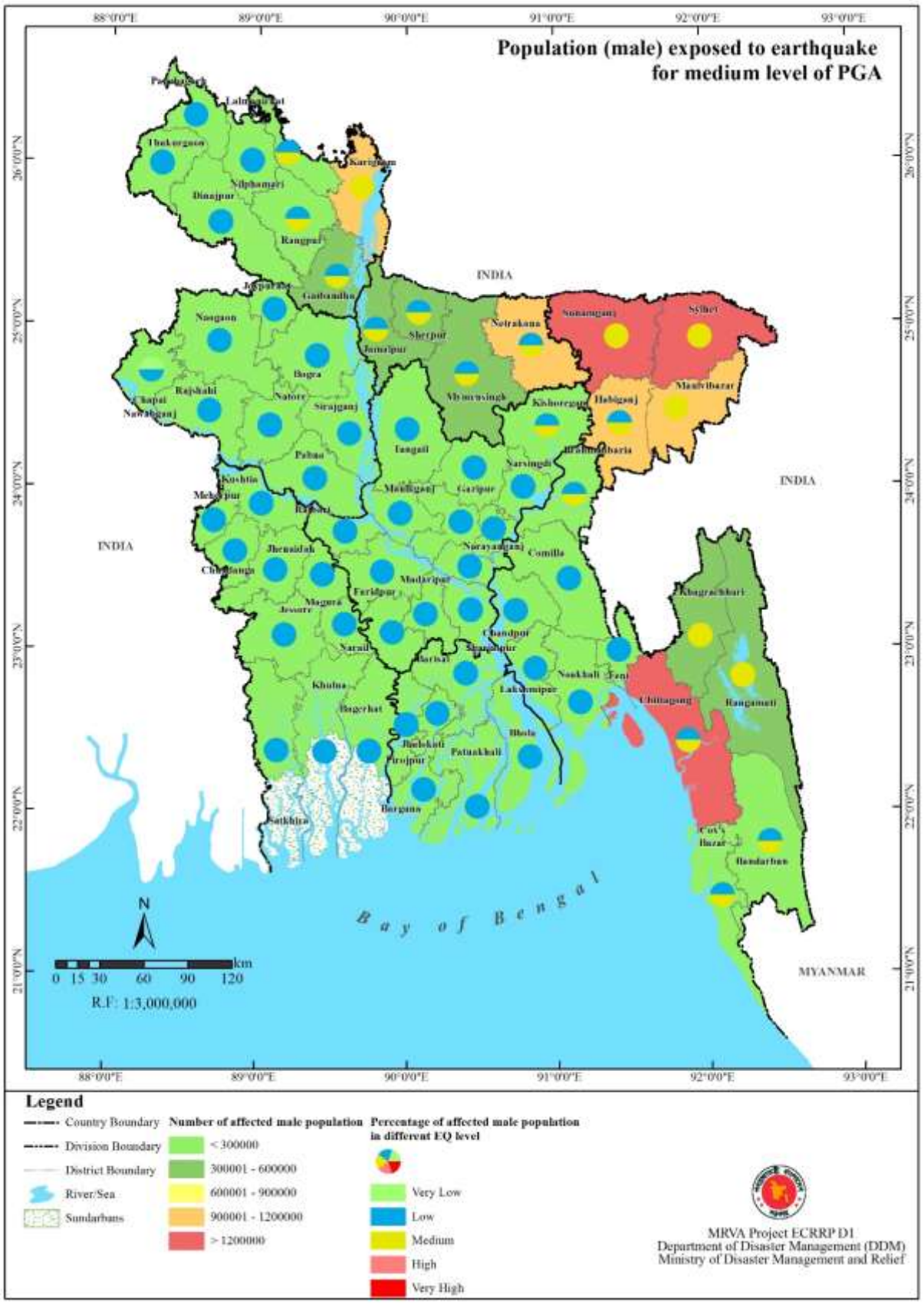

Figure 2.2: Population (male) exposed to moderate level of earthquake at district level

Total population (female) exposed to earthquake at division level is given in table 2.2 and figure 2.3. Population (female) exposed to moderate level of earthquake at district level is shown in figure 2.4.

Table 2.2: Population (female) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	4,236,158	-
Chittagong	-	1,898,701	12,591,004
Dhaka	-	17,462,932	253,798
Khulna	-	7,845,226	-
Mymensingh		3,220,405	2,314,966
Rajshahi	3,001	5,062,361	4,162,586
Rangpur	-	1,295,280	6,610,654
Sylhet	-	-	4,976,829
Total	3,001	41,021,064	30,909,837

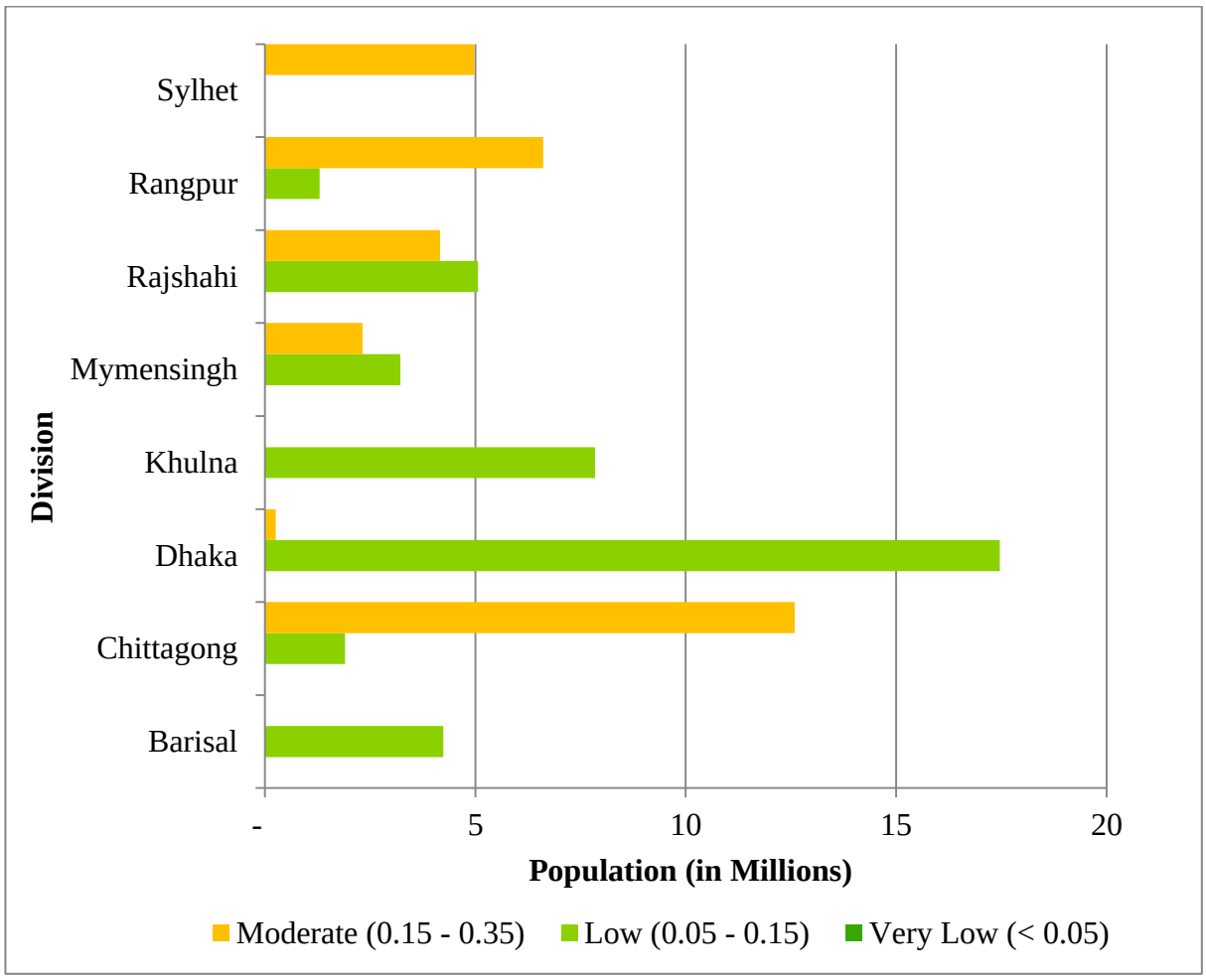

Figure 2.3: Population (female) exposed to different intensity of earthquake at division level

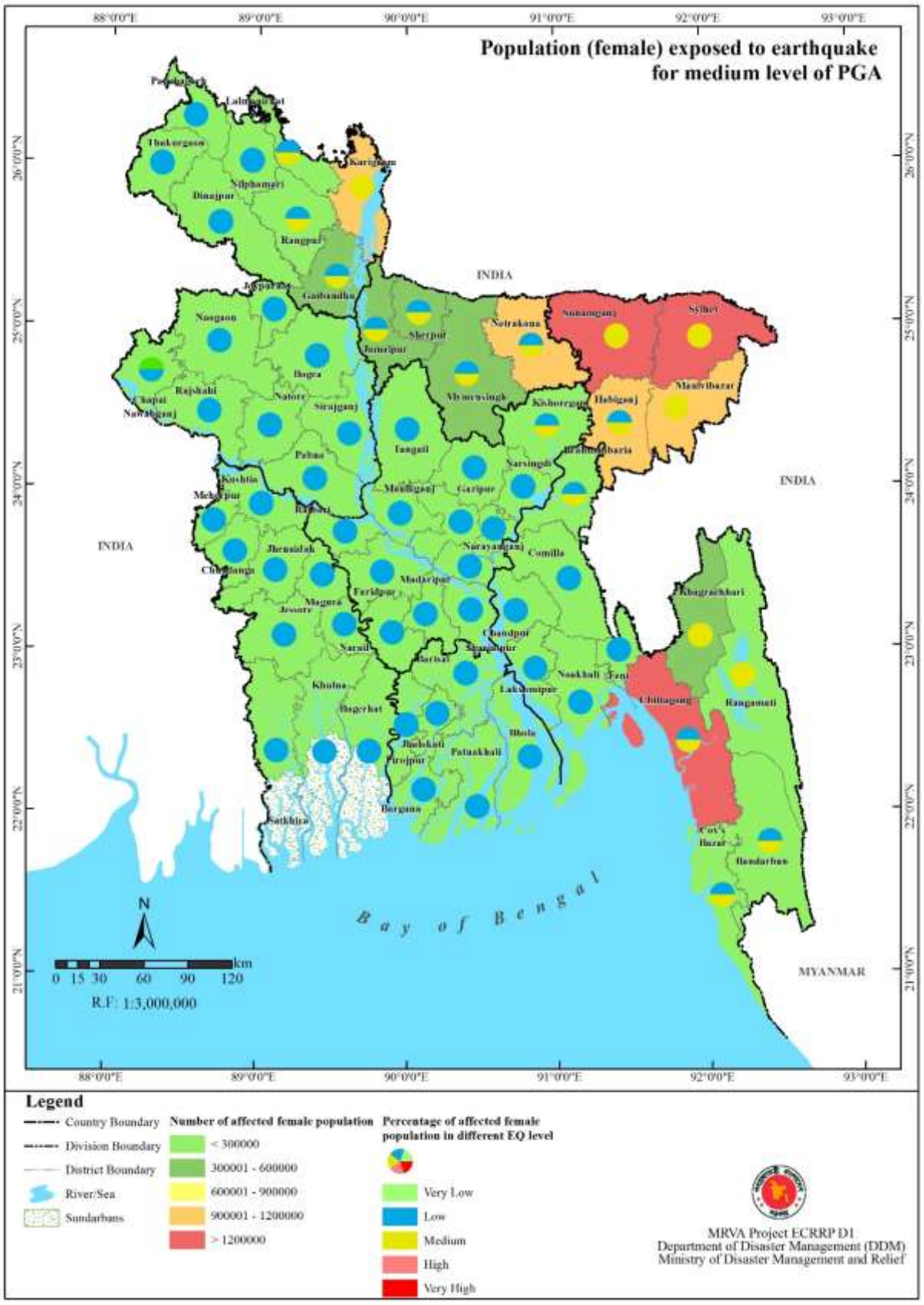

Figure 2.4: Population (female) exposed to moderate level of earthquake at district level

2.1.1.2 Age

As explained in section 1.1.2 of volume III of this report, population by age is regrouped into 0-14 years, 14 - 59 years and more than 59 years. Population in the age group of 0 - 14 years exposed to earthquake in each division is given table 2.3 and figure 2.5. Population in the age of 0 - 14 years exposed to moderate level of earthquake in each district is shown in figure 2.6. Population in the age group of 14 - 59 years exposed to earthquake in each division is given table 2.4 and figure 2.7. Population in the age group of 14 - 59 years exposed to moderate level of earthquake in each district is shown in figure 2.8. Population in the age of more than 59 years exposed to earthquake in each division is given table 2.5 and figure 2.9. Population in the age of more than 59 years exposed to moderate level of earthquake in each district is shown in figure 2.10.

Table 2.3: Population (0 - 14 years) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	3,027,086	-
Chittagong	-	1,417,000	9,396,662
Dhaka	-	11,425,135	202,782
Khulna	-	4,877,707	-
Mymensingh		2,415,991	1,778,685
Rajshahi	1,917	3,234,714	2,659,782
Rangpur	-	899,140	4,588,895
Sylhet	-	-	3,963,993
Total	1,917	20,474,892	29,412,680

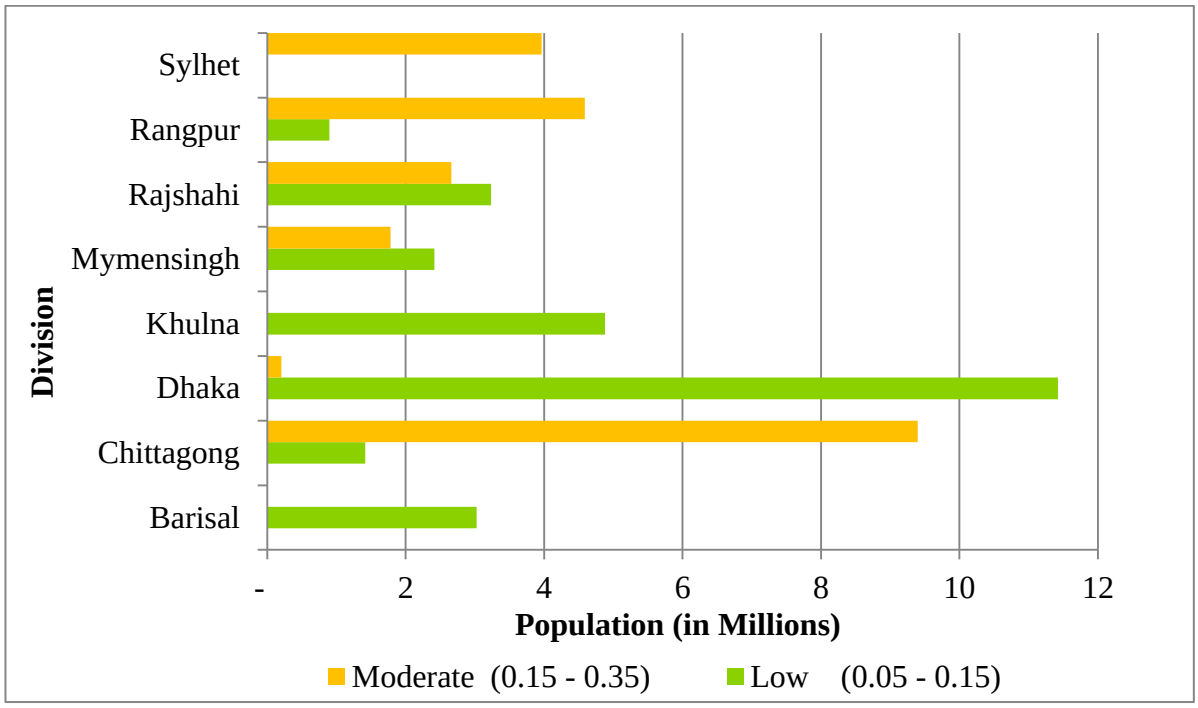

Figure 2.5: Population (0 - 14 years) exposed to different intensity of earthquake at division level

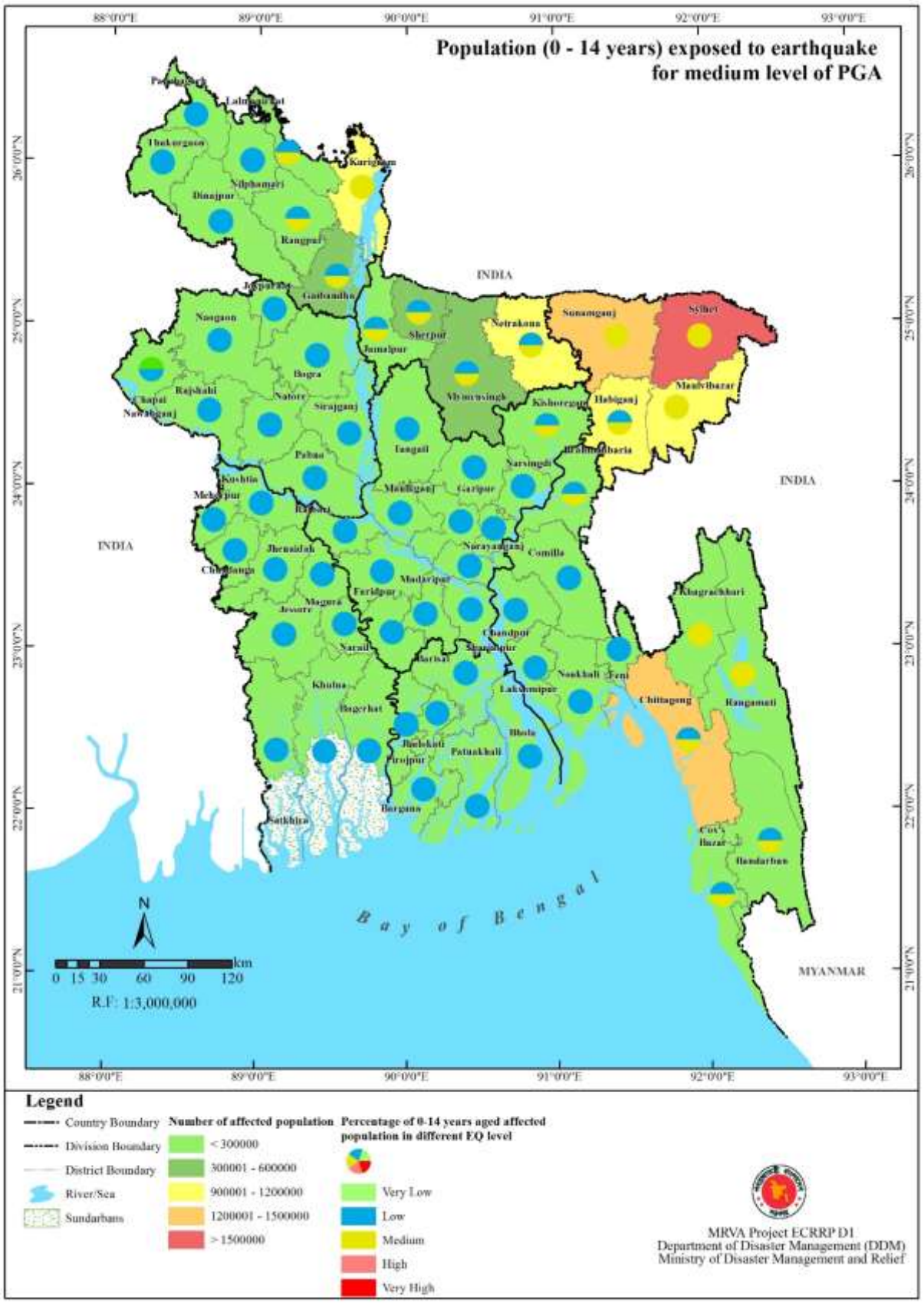

Figure 2.6: Population (0 - 14 years) exposed to moderate level of earthquake in each district

Table 2.4: Population (14 - 59 years) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	4,551,592	-
Chittagong	-	2,039,225	13,522,873
Dhaka	-	22,095,081	256,724
Khulna	-	9,494,346	-
Mymensingh	-	3,438,049	2,436,436
Rajshahi	3,635	6,132,556	5,042,567
Rangpur	-	1,494,514	7,627,472
Sylhet	-	-	5,245,526
Total	3,635	49,245,363	34,131,597

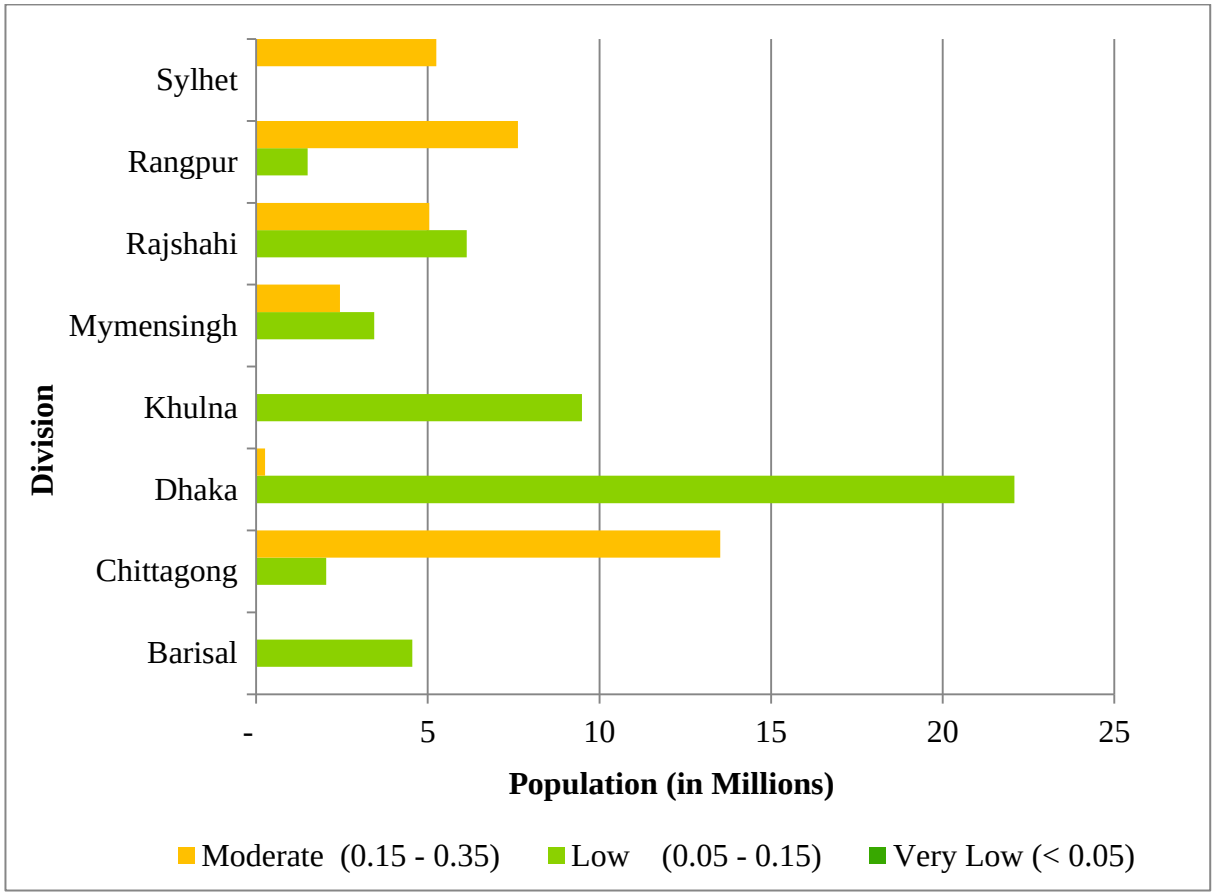

Figure 2.7: Population (14 - 59 years) exposed to different intensity of earthquake at division level

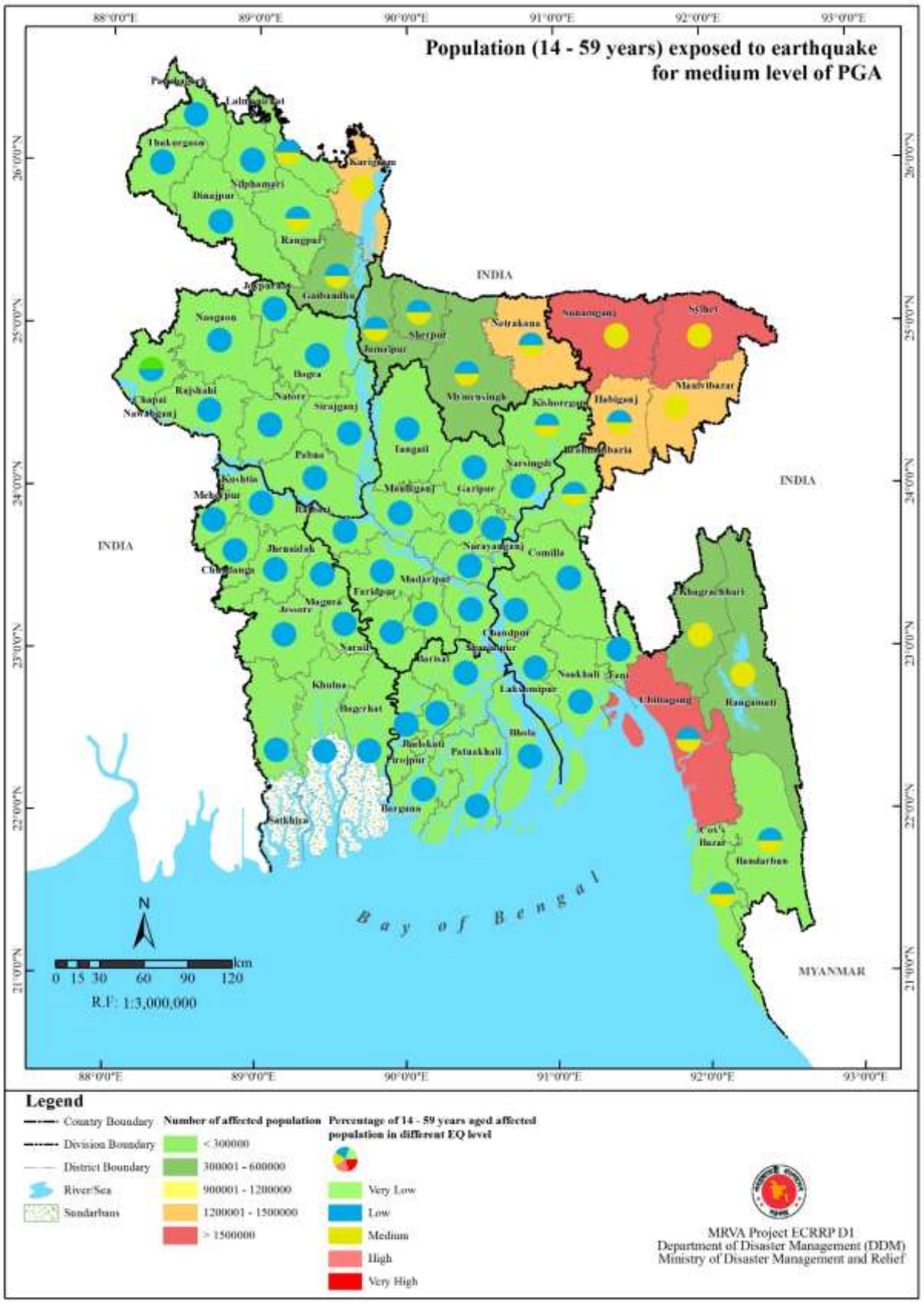

Figure 2.8: Population (14 - 59 years) exposed to moderate level of earthquake at district level

Table 2.5: Population (more than 59 years) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	746,986	-
Chittagong	-	268,269	1,778,990
Dhaka	-	2,413,823	39,957
Khulna	-	1,315,706	-
Mymensingh	-	533,510	388,242
Rajshahi	458	773,340	635,888
Rangpur	-	192,957	984,783
Sylhet	-	-	700,699
Total	458	6,244,591	4,528,560

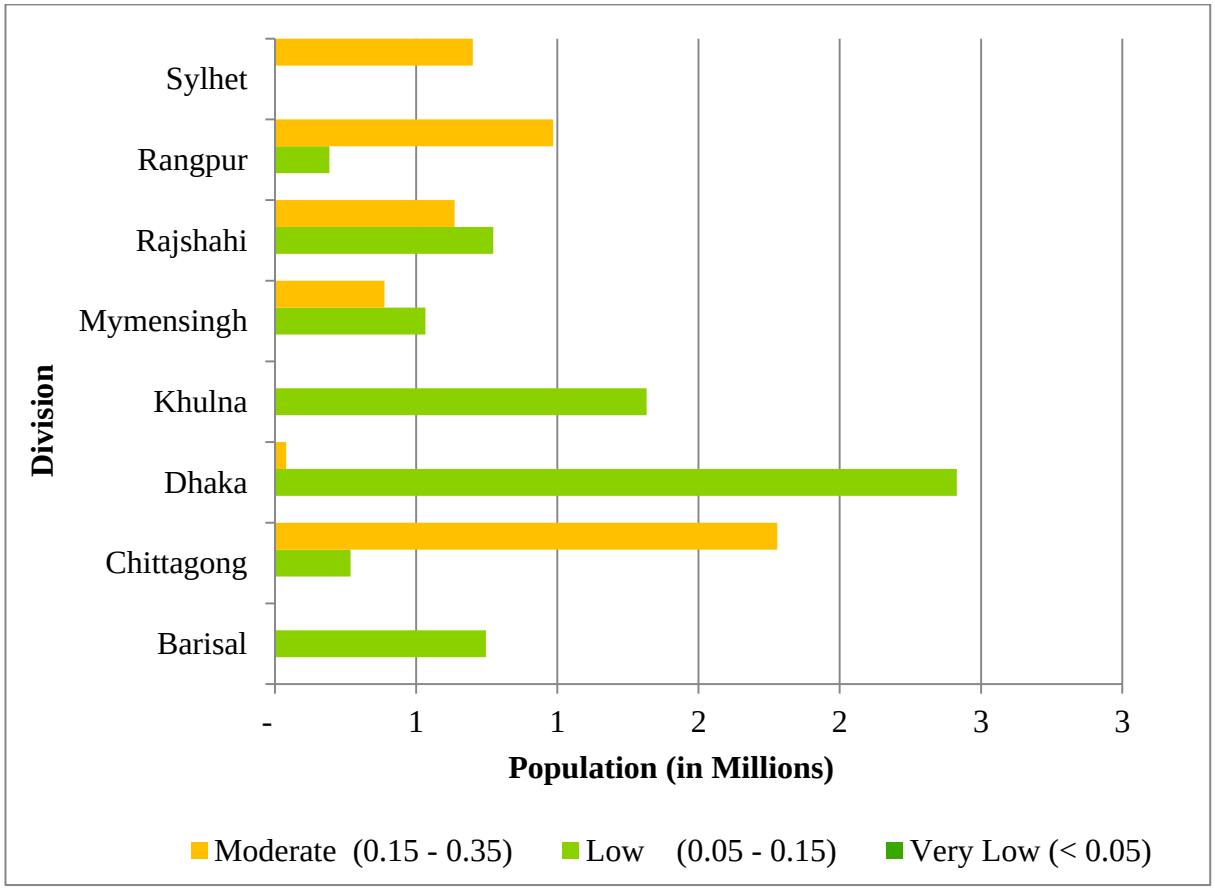

Figure 2.9: Population (more than 59 years) exposed to different intensity of earthquake at division level

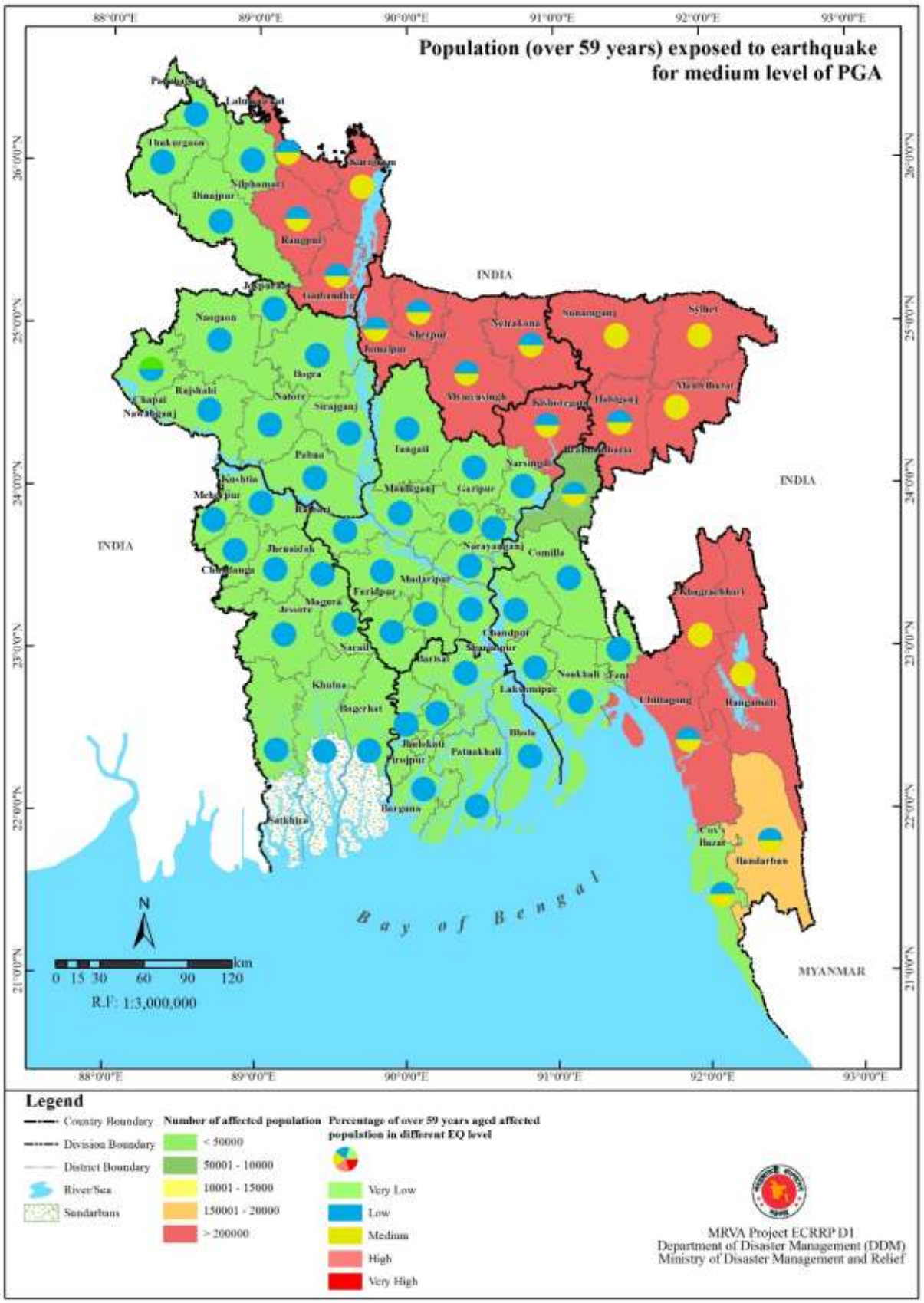

Figure 2.10: Population (more than 59 years) exposed to moderate level of earthquake at district level

2.1.1.3 Ethnicity

As the ethnicity population is very less, exposure to earthquake is not considered.

2.1.1.4 Employment

As explained in section 1.1.4 of volume III of this report, the employment types considered are agriculture and industry. Population employed in Agriculture activity at division level is given table 2.6 and figure 2.11. Population employed in agriculture sector exposed to earthquake at district level in figure 2.12. Population employed in industry sector at division level is given table 2.7 and figure 2.13. Population employed in industry sector exposed to earthquake at district level in figure 2.14.

Table 2.6: Employed (Agriculture) Population exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	458,034	-
Chittagong	-	195,464	1,296,193
Dhaka	-	1,745,593	48,053
Khulna	-	1,248,951	-
Mymensingh	-	721,733	573,677
Rajshahi	606	1,022,180	840,500
Rangpur	-	269,668	1,376,291
Sylhet	-	-	779,640
Total	606	5,661,623	4,914,354

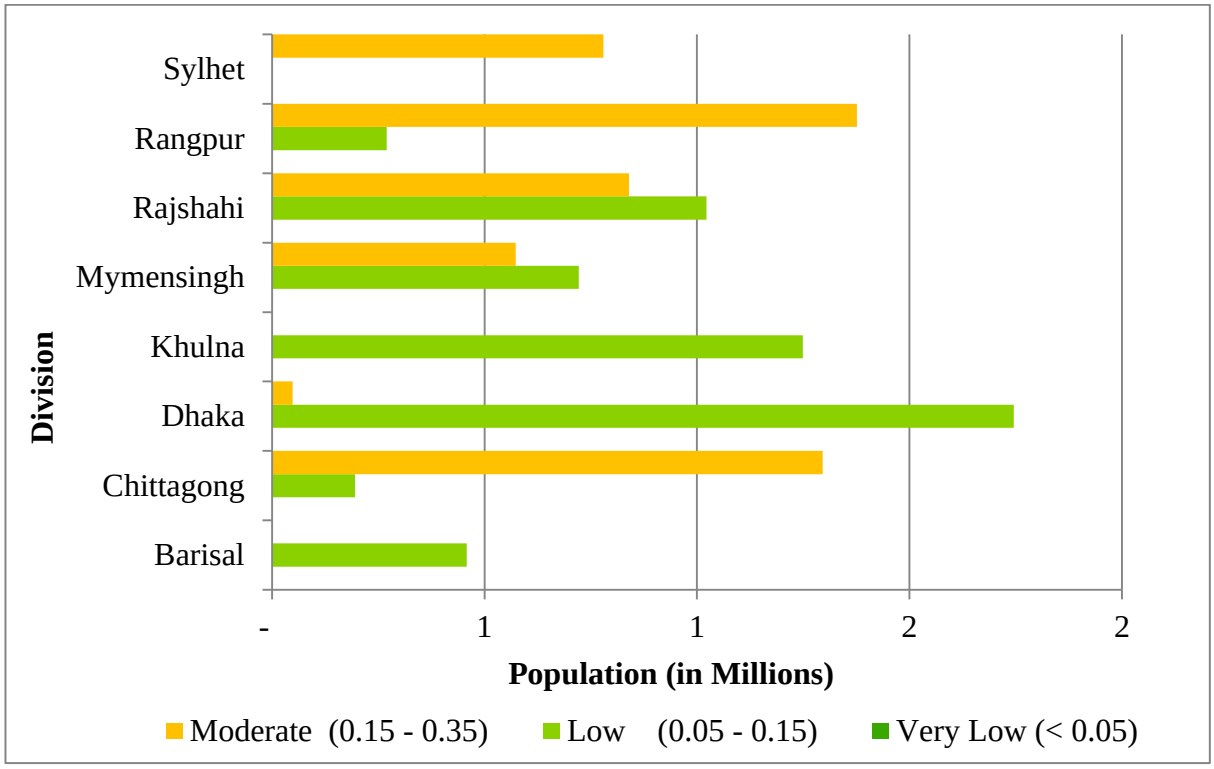

Figure 2.11: Employed (Agriculture) Population exposed to different intensity of earthquake at division level

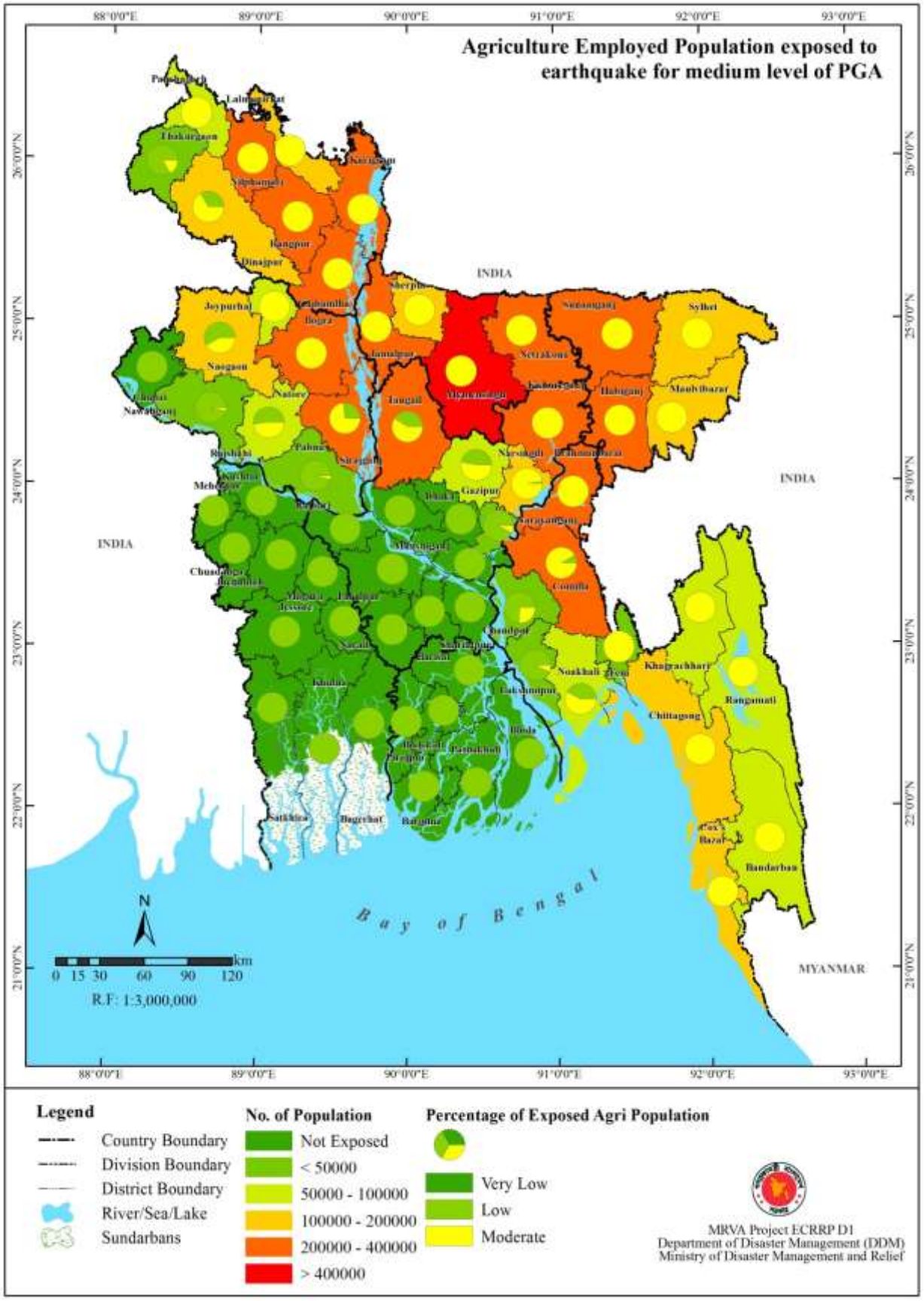

Figure 2.12: Employed (Agriculture) Population exposed to moderate level of earthquake at district level

Table 2.7: Employed (Industry) Population exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	33,435	-
Chittagong	-	29,418	195,084
Dhaka	-	727,818	4,204
Khulna	-	102,288	-
Mymensingh	-	50,291	29,834
Rajshahi	64	108,147	88,925
Rangpur	-	13,196	67,347
Sylhet	-	-	86,912
Country total	64	1,064,593	472,306

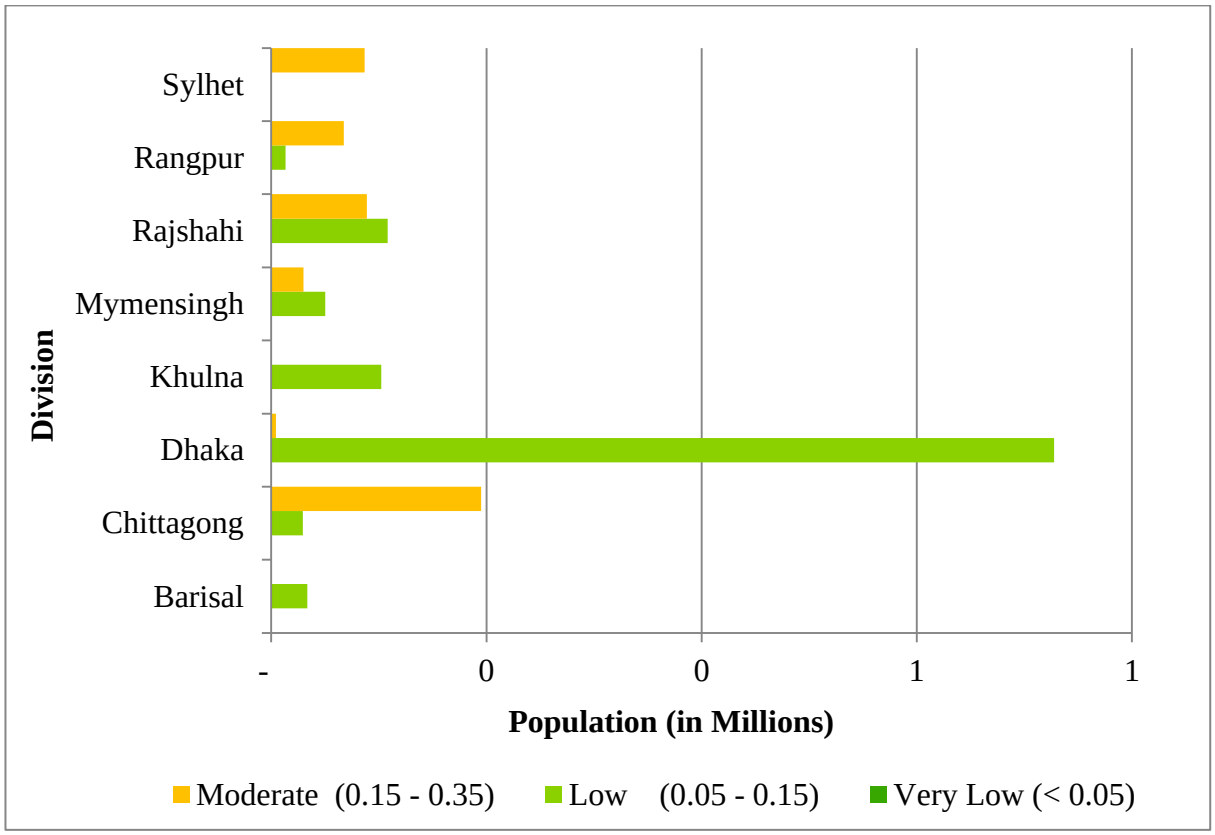

Figure 2.13: Employed (Industry) Population exposed to different intensity of earthquake at division level

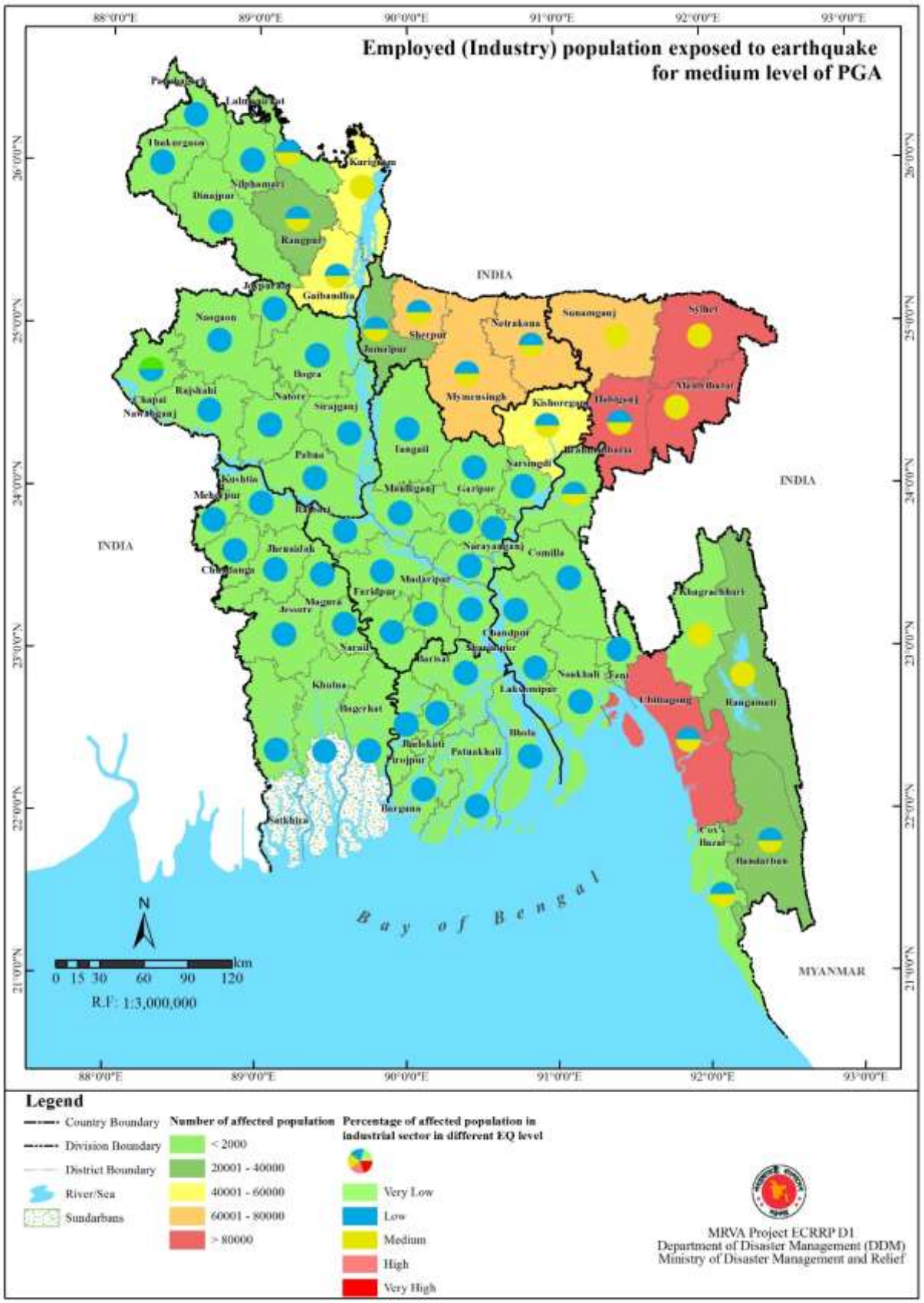

Figure 2.14: Employed (Industry) Population exposed to moderate level of earthquake at district level

2.1.1.5 Education

Details of population with education are given in section 1.1.5 of volume III of this report, Literate Population (male) exposed to earthquake is given in table 2.8 and figure 2.15. Literate Population (female) exposed to earthquake is given in table 2.9 and figure 2.16.

Table 2.8: Literate Population (male) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2,350,620	-
Chittagong	-	981,609	6,509,421
Dhaka	-	11,253,371	101,951
Khulna	-	4,370,286	-
Mymensingh	-	1,377,422	952,983
Rajshahi	1,518	2,560,607	2,105,489
Rangpur	-	653,040	3,332,885
Sylhet	-	-	2,310,720
Total	1,518	23,546,955	15,313,449

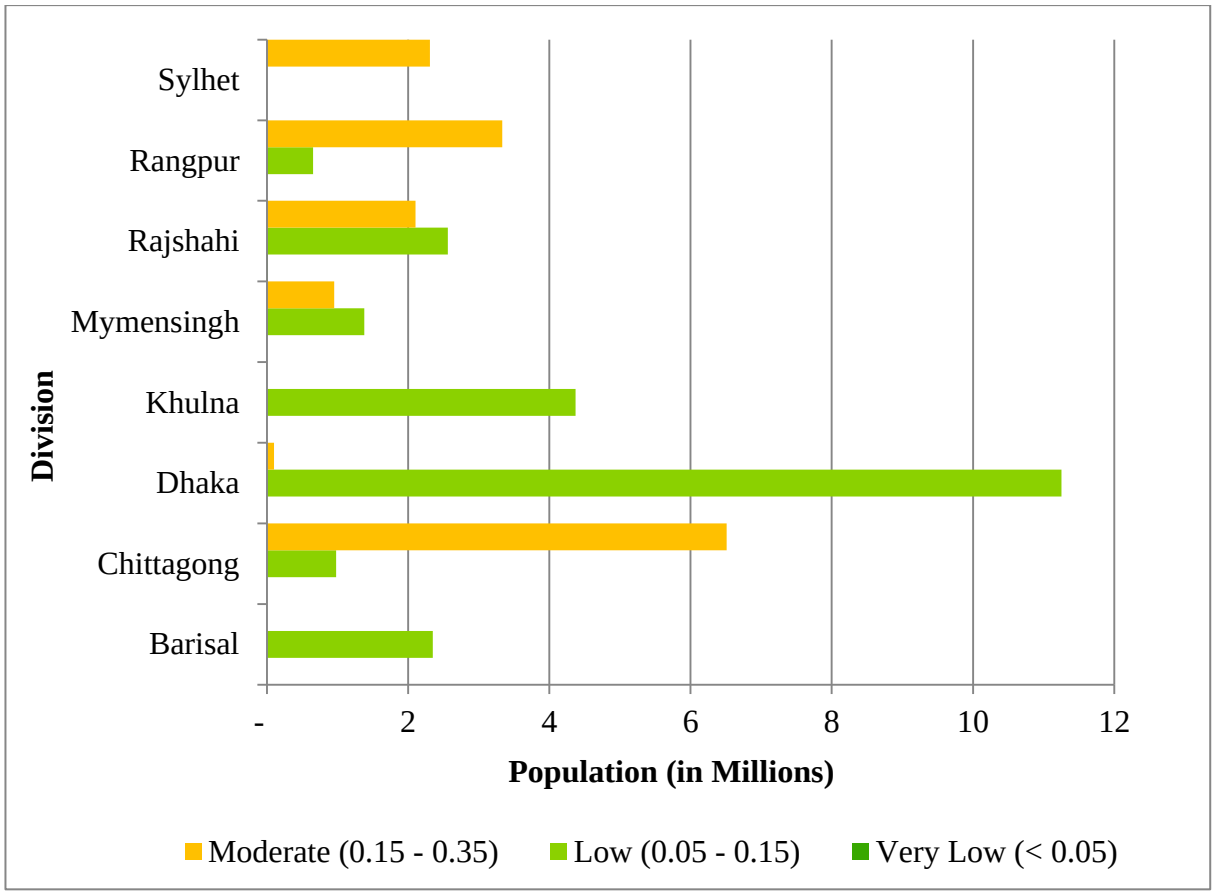

Figure 2.15: Literate Population (male) exposed to different intensity of earthquake at division level

Table 2.9: Literate Population (female) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2,362,869	-
Chittagong	-	976,095	6,472,856
Dhaka	-	9,606,095	102,281
Khulna	-	3,982,786	-
Mymensingh	-	1,289,084	882,218
Rajshahi	1,367	2,305,794	1,895,966
Rangpur	-	567,283	2,895,214
Sylhet	-	-	2,138,539
Total	1,367	21,090,006	14,387,074

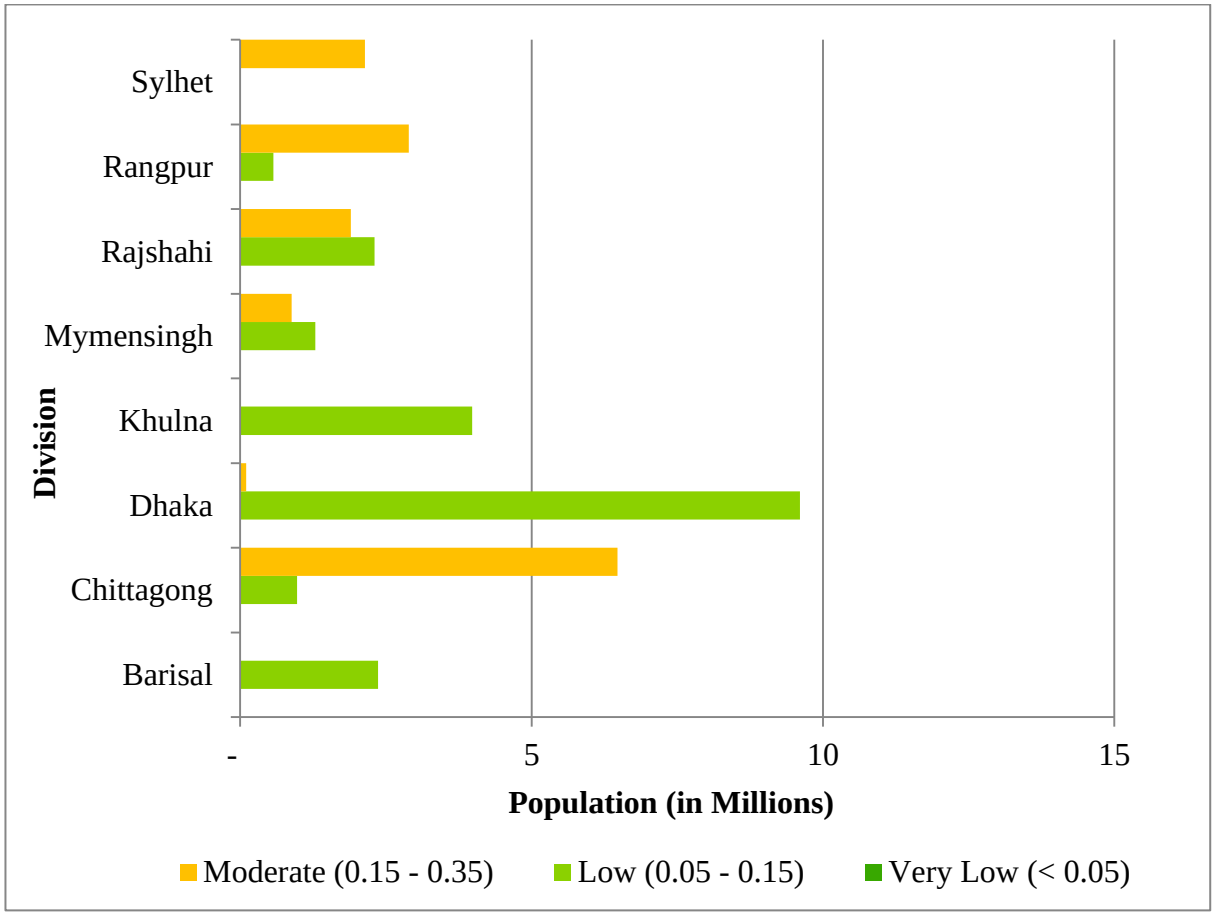

Figure 2.16: Literate Population (female) exposed to different intensity of earthquake at division level

2.1.1.6 Disability

Details of population with disability are given in section 1.1.6 (Volume –III of this report). Disabilities of population mentioned are Speech, Vision, Hearing, Physical, Mental and Autism. Population with disability of Vision exposed to earthquake at division level is given table 2.10 and figure 2.17. Population with disability of Physical exposed to earthquake at division level is given table 2.11 and figure 2.18. Population with disability of Mental exposed to earthquake at division level is given table 2.12 and figure 2.19. Population with disability of Autism exposed to earthquake at division level is given table 2.13 and figure 2.20. Distribution of population with disability in moderate earthquake level is given in figure 2.21.

Table 2.10: Disable Population (Vision) exposed to earthquake at division level

Division	PGA Value / Population			
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)	
Barisal	-	25,342	-	
Chittagong	-	8,670	57,493	
Dhaka	-	73,965	1,498	
Khulna	-	43,752	-	
Mymensingh	-	15,054	12,809	
Rajshahi	19	32,164	26,447	
Rangpur	-	8,444	43,098	
Sylhet	-	-	28,764	
	Total	19	207,391	170,109

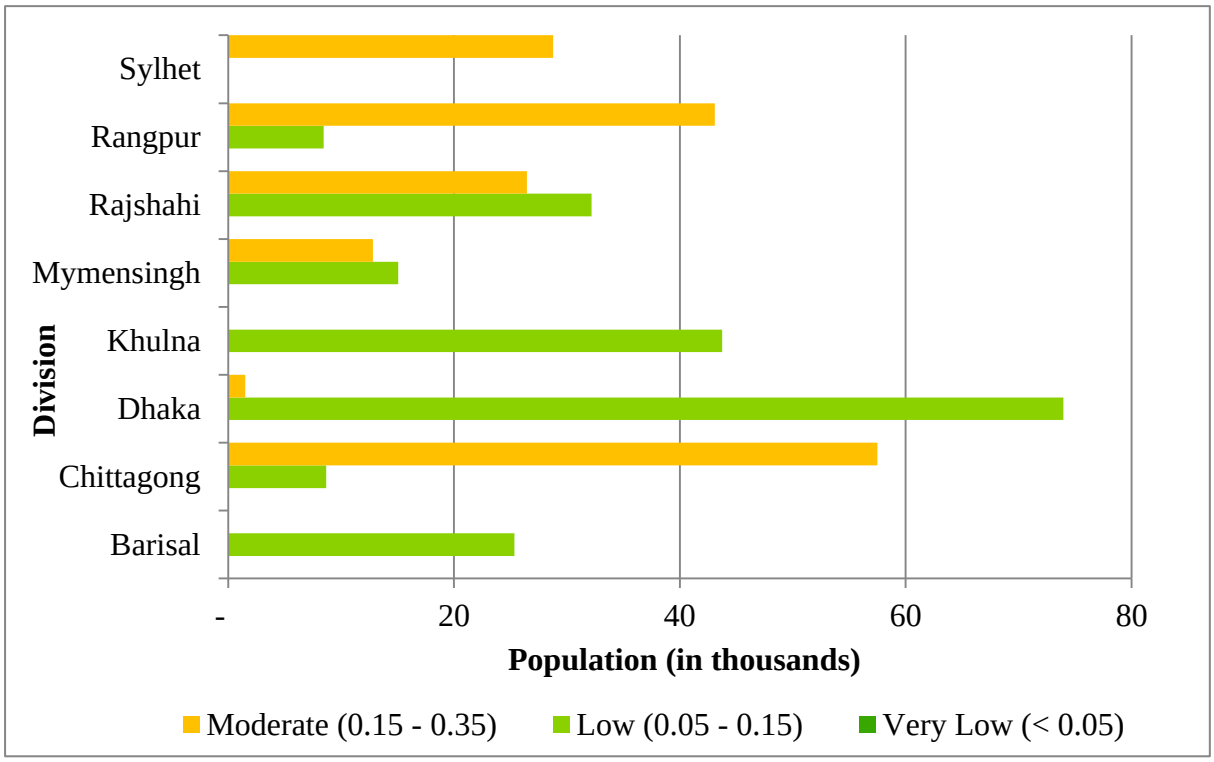

Figure 2.17: Disable Population (Vision) exposed to different intensity of earthquake at division level

Table 2.11: Disable Population (Physical) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	56,549	-
Chittagong	-	20,271	134,423
Dhaka	-	148,593	2,997
Khulna	-	103,922	-
Mymensingh	-	32,287	24,025
Rajshahi	37	61,820	50,832
Rangpur	-	16,372	83,558
Sylhet	-	-	51,470
Total	37	439,813	347,305

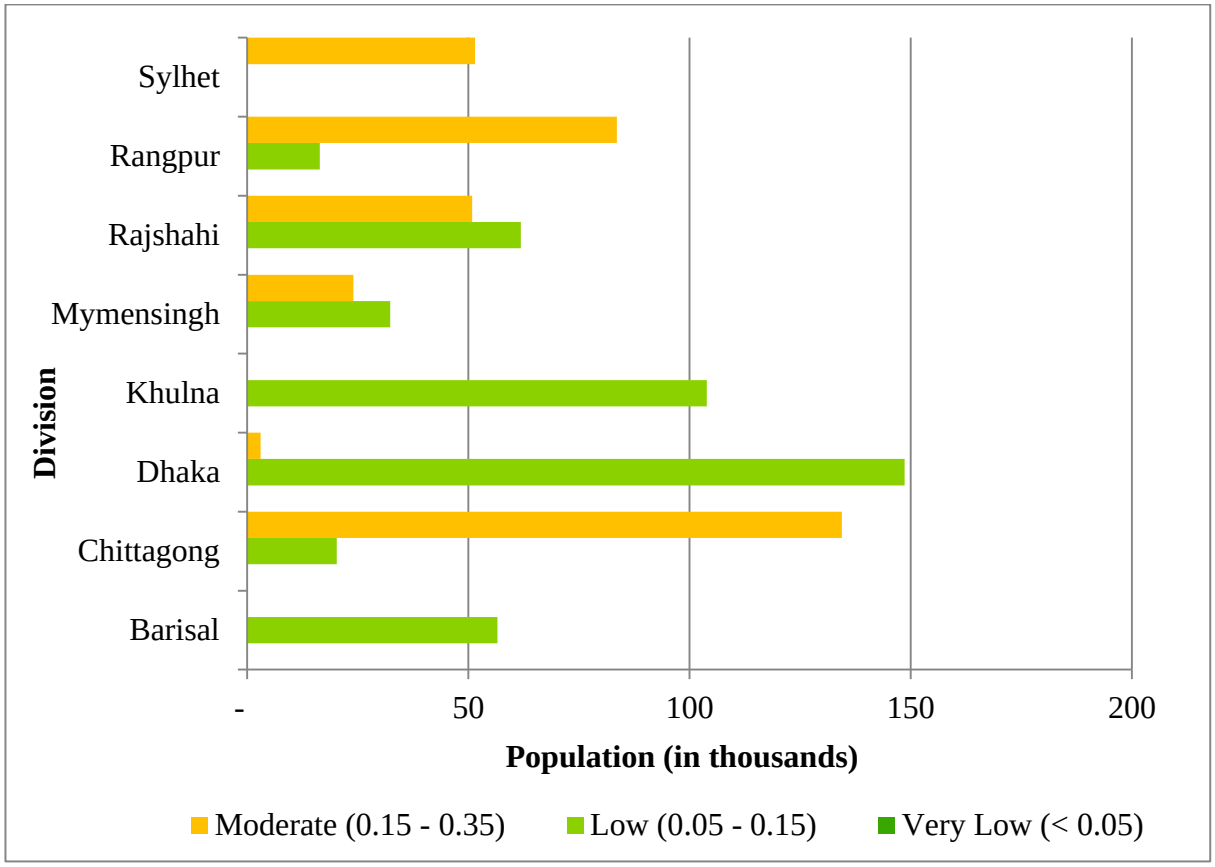

Figure 2.18: Disable Population (Physical) exposed to different intensity of earthquake at division level

Table 2.12: Disable Population (Mental) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	14,876	-
Chittagong	-	6,748	44,746
Dhaka	-	51,248	999
Khulna	-	31,376	-
Mymensingh	-	12,485	7,268
Rajshahi	12	20,281	16,676
Rangpur	-	5,173	26,402
Sylhet	-	-	19,820
Total	12	142,187	115,911

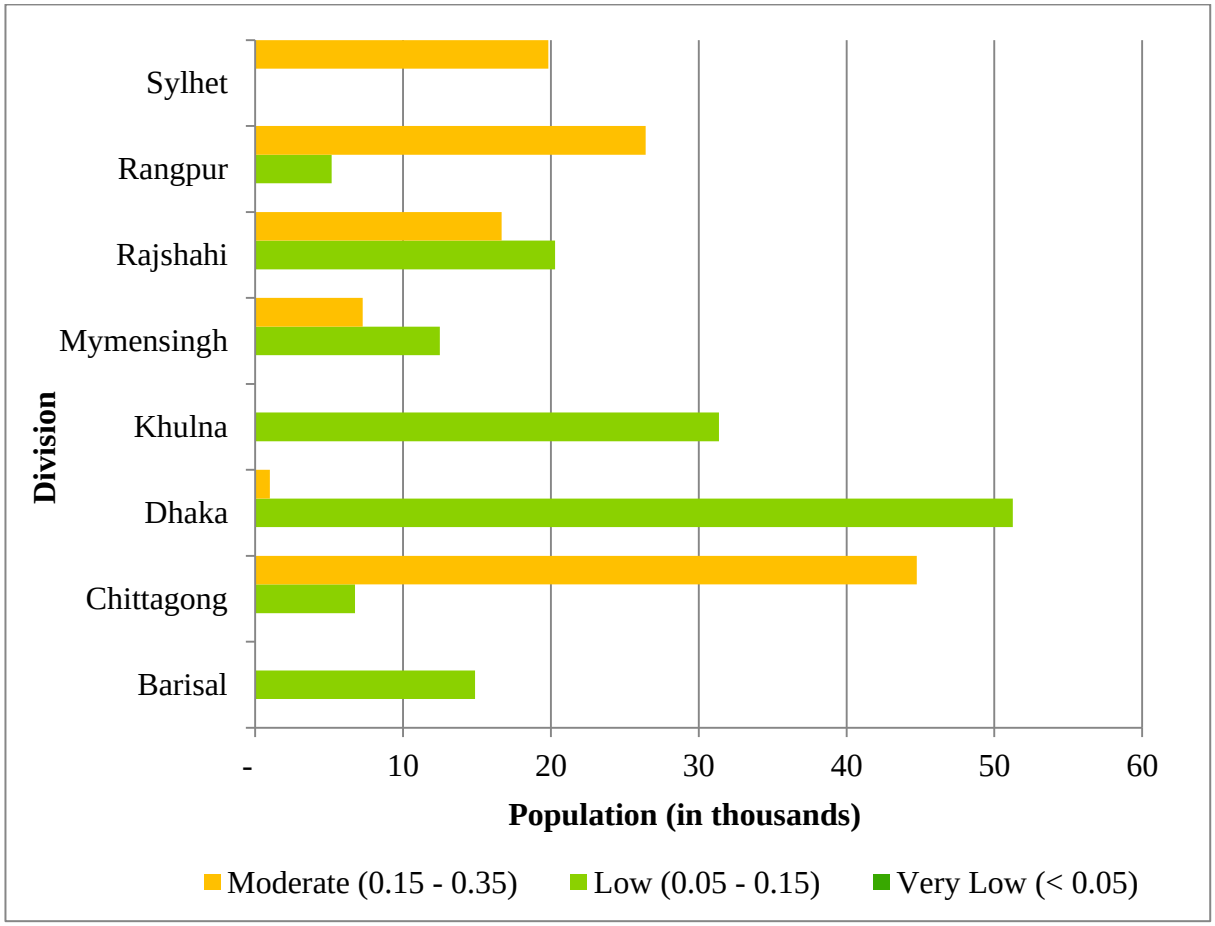

Figure 2.19: Disable Population (Mental) exposed to different intensity of earthquake at division level

Table 2.13: Disable Population (Autism) exposed to earthquake at division level

Division	PGA Value / Population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	8,326	-
Chittagong	-	3,724	24,697
Dhaka	-	35,935	499
Khulna	-	15,688	-
Mymensingh	-	6,388	4,603
Rajshahi	6	10,141	8,338
Rangpur	-	2,586	13,201
Sylhet	-	-	9,910
Total	6	82,788	61,248

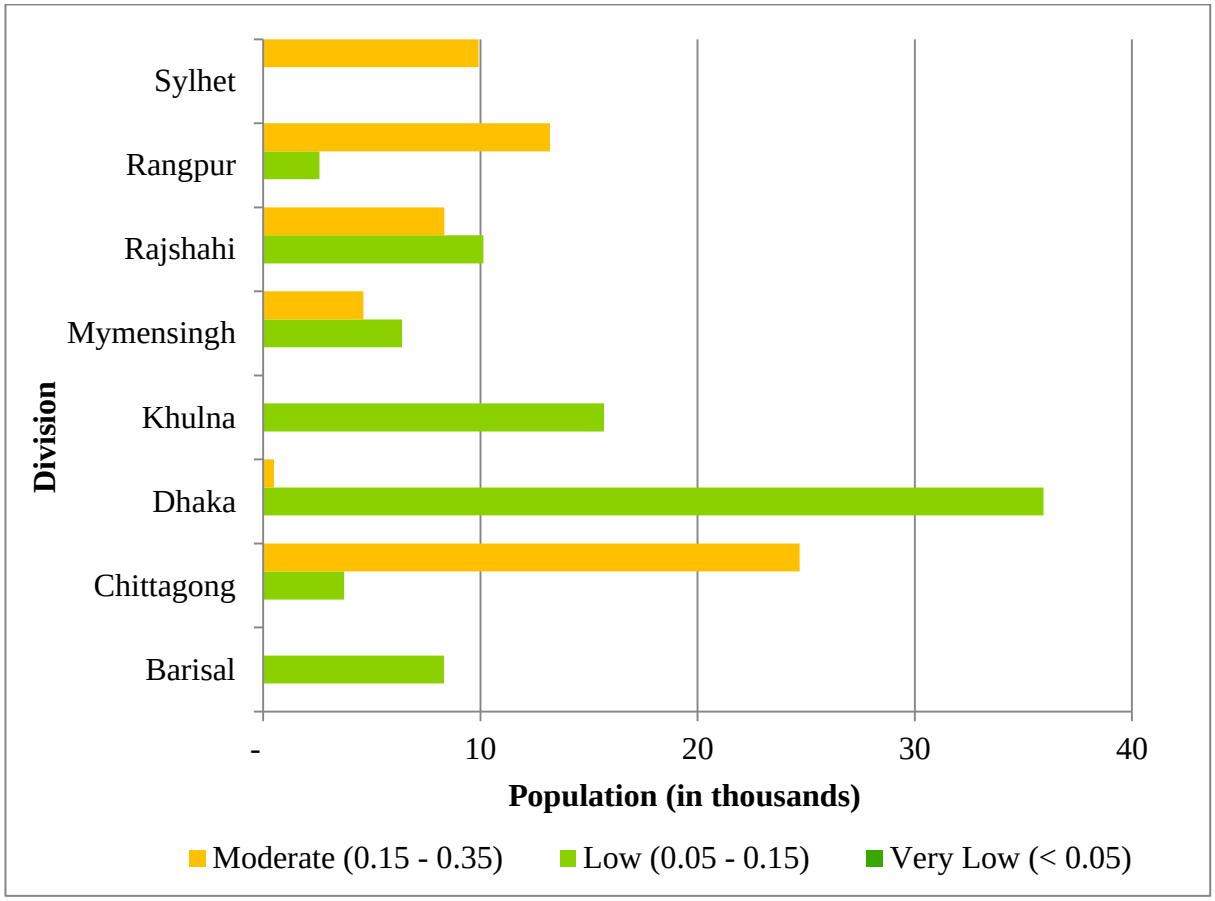

Figure 2.20: Disable Population (Autism) exposed to different intensity of earthquake at division level

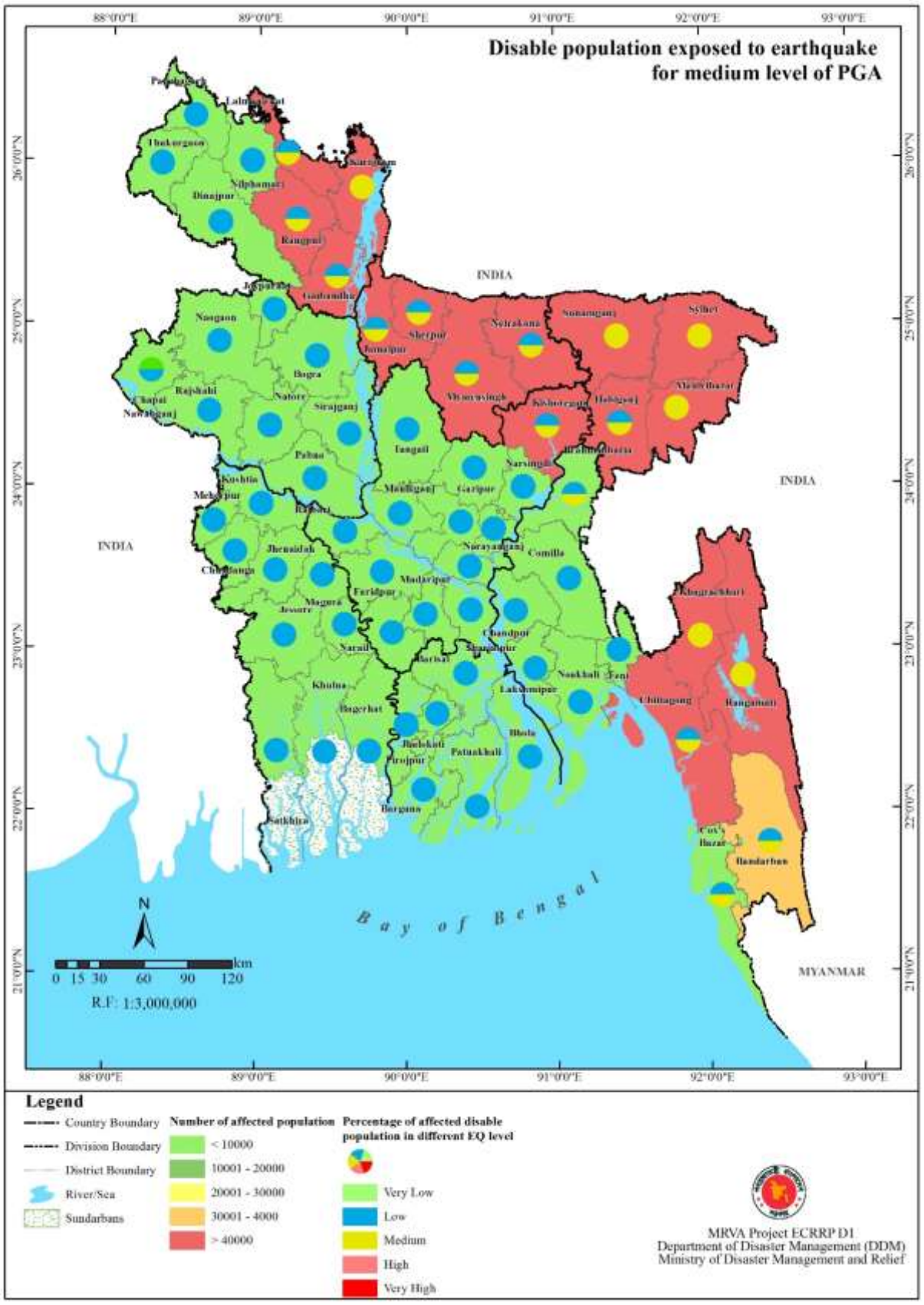

Figure 2.21: Disable Population exposed to moderate earthquake level at district level

2.1.1.7 Poverty

The exposure of population in poverty (extreme poor) to earthquake at division level is provided in table 2.14 and figure 2.22. At district level shown in figure 2.23.

Table 2.14: Number of extreme poor population exposed to earthquake at division level

Division	PGA Value / extreme poor population		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2,129,399	-
Chittagong	-	496,032	3,289,373
Dhaka	-	5,772,483	34,798
Khulna	-	2,585,800	-
Mymensingh	-	790,027	912,849
Rajshahi	860	1,450,103	1,192,364
Rangpur	-	656,921	3,352,695
Sylhet	-	-	2,002,879
Total	860	13,880,765	10,784,958

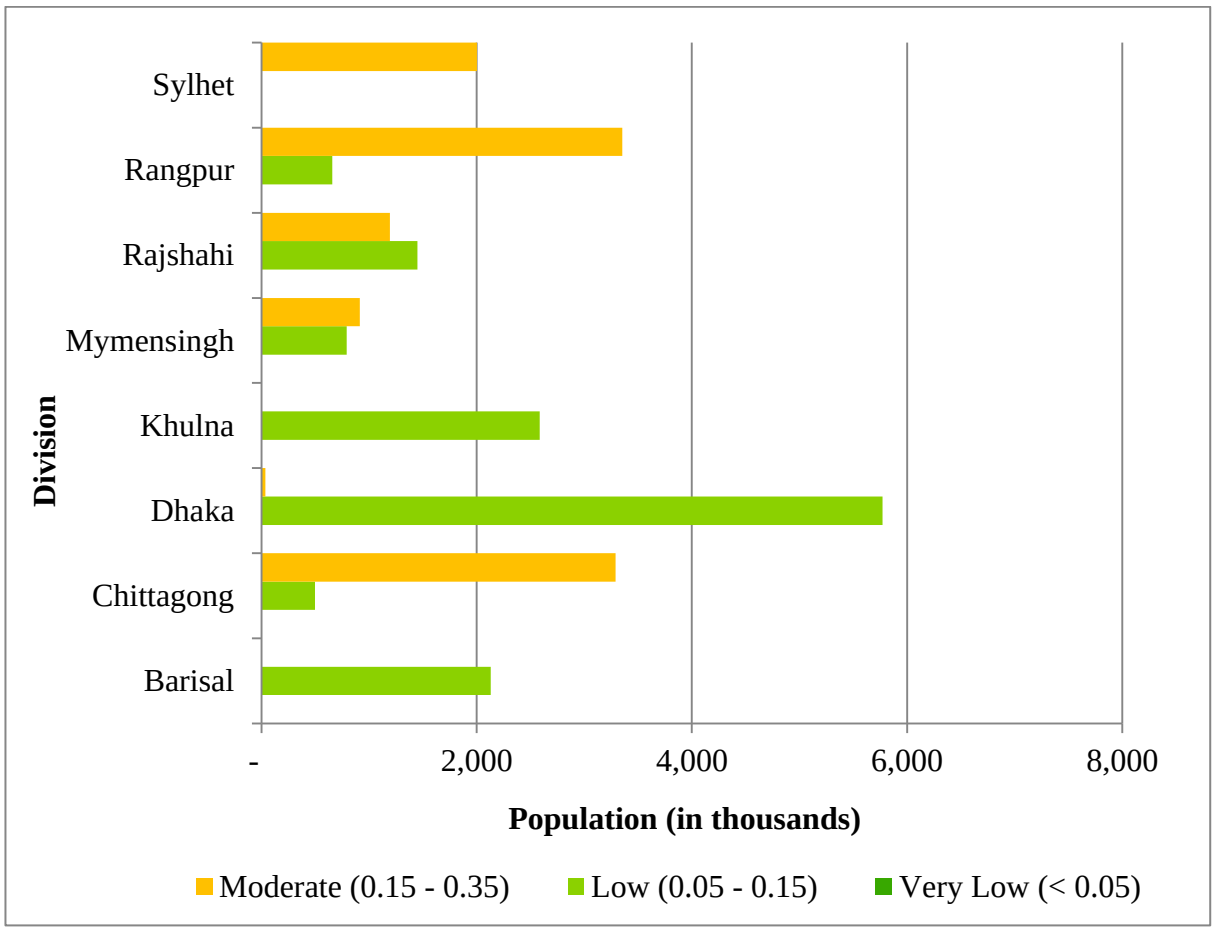

Figure 2.22: Number of extreme poor population exposed to different intensity of earthquake at division level

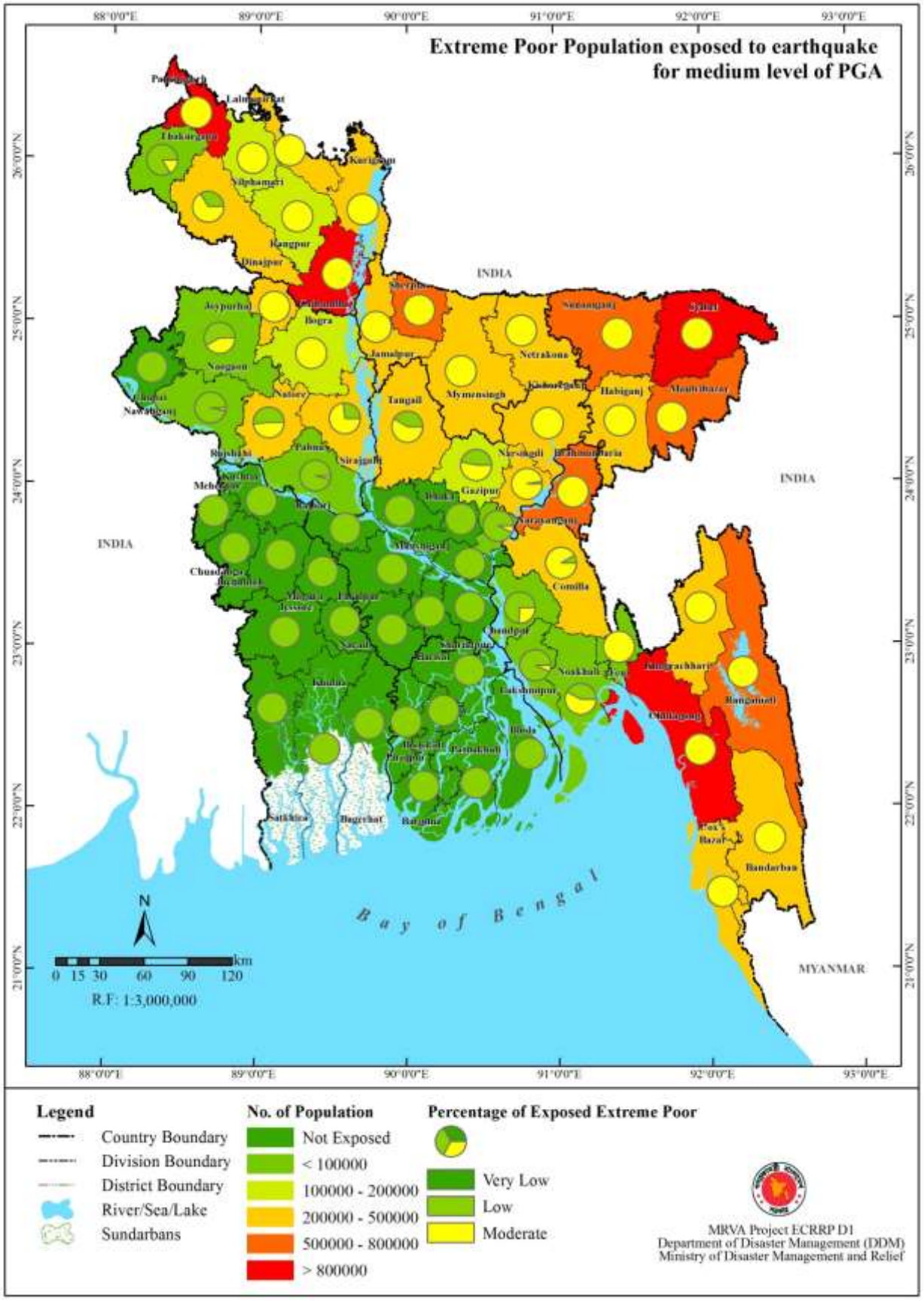

Figure 2.23: Number of extreme poor population exposed to earthquake for medium level of PGA at district level

The exposure of population in poverty (poor) to earthquake at division level is provided in table 2.15 and figure 2.24. At district level shown in figure 2.25.

Table 2.15: Number of poor population exposed to earthquake at division level

Division	PGA Value / household structures		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	3,196,923	-
Chittagong	-	968,924	6,425,300
Dhaka	-	9,828,871	69,796
Khulna	-	5,010,278	-
Mymensingh	-	1,582,185	1,580,175
Rajshahi	1,649	2,782,578	2,288,007
Rangpur	-	1,087,082	5,548,086
Sylhet	-	-	2,491,027
Total	1,649	24,456,841	18,402,391

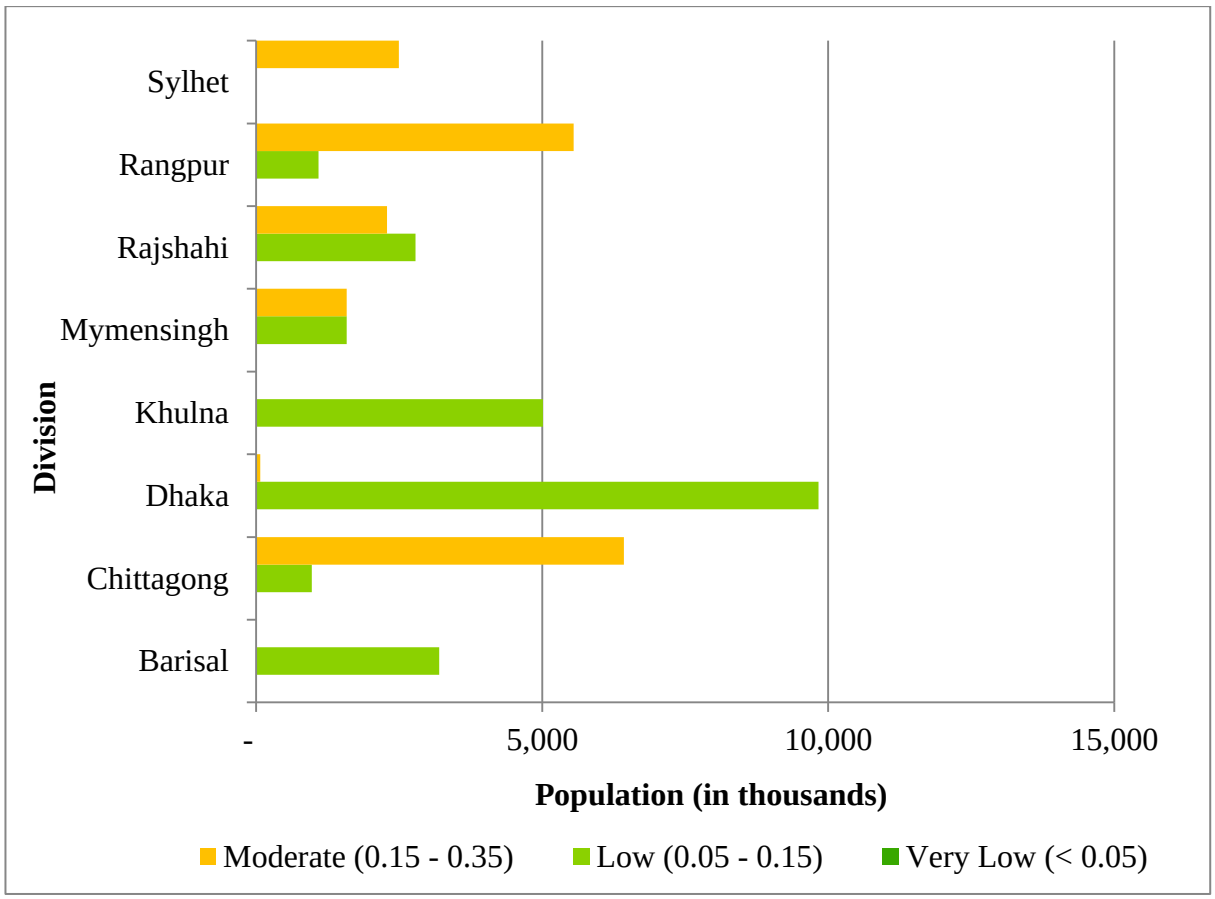

Figure 2.24: Number of poor population exposed to different intensity of earthquake at division level

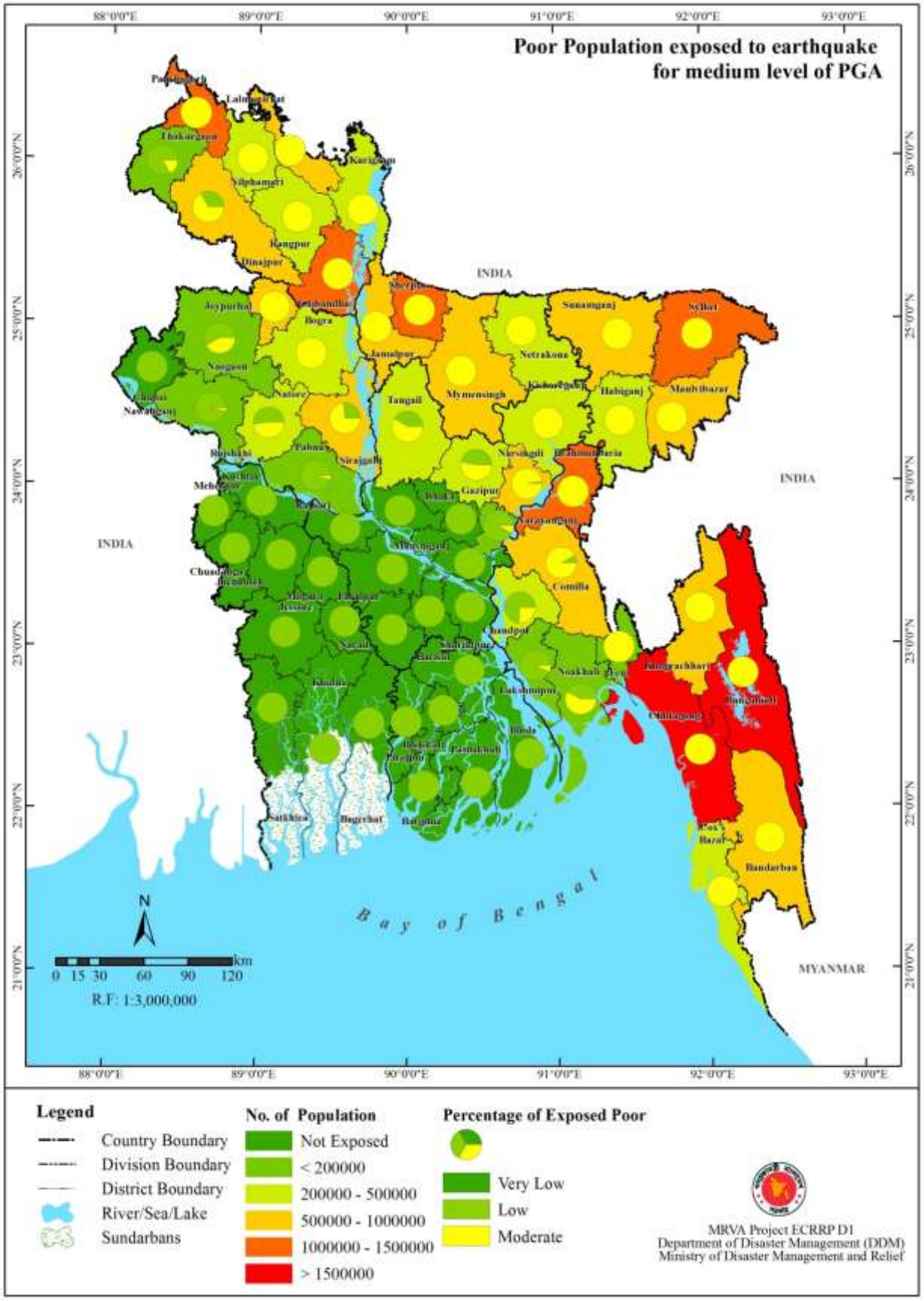

Figure 2.25: Number of poor population exposed to earthquake for medium level of PGA at district level

2.1.2 Housing

As mentioned in section 1.2.1 of volume III of this report, household structure types are Pucca, Semi-Pucca, Katcha, Jhupri. Exposure of the household structures of each category to earthquake is assessed by combining earthquake hazard map and household structure maps. Number of Pucca household structures in each earthquake category at division level is given in table 2.16, figure 2.26 and at district level shown in figure 2.27. Number of semi-Pucca household structures in each earthquake category at division level is given in table 2.17, figure 2.28 and at district level shown in figure 2.29. Number of Katcha household structures in each earthquake category at division level is given in table 2.18, figure 2.30 and at district level shown in figure 2.31. Number of Jhupri household structures in each earthquake category at division level is given in table 2.19 and figure 2.31 and at district level shown in figure 2.32.

Table 2.16: Number of Pucca household structures exposed to earthquake at division level

Division	PGA Value / household structures		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	77,994	-
Chittagong	-	95,036	630,221
Dhaka	-	1,670,840	3,013
Khulna	-	509,340	-
Mymensingh	-	43,752	21,420
Rajshahi	100	168,518	138,566
Rangpur	-	18,162	92,690
Sylhet	-	-	223,352
Total	100	2,583,641	1,109,262

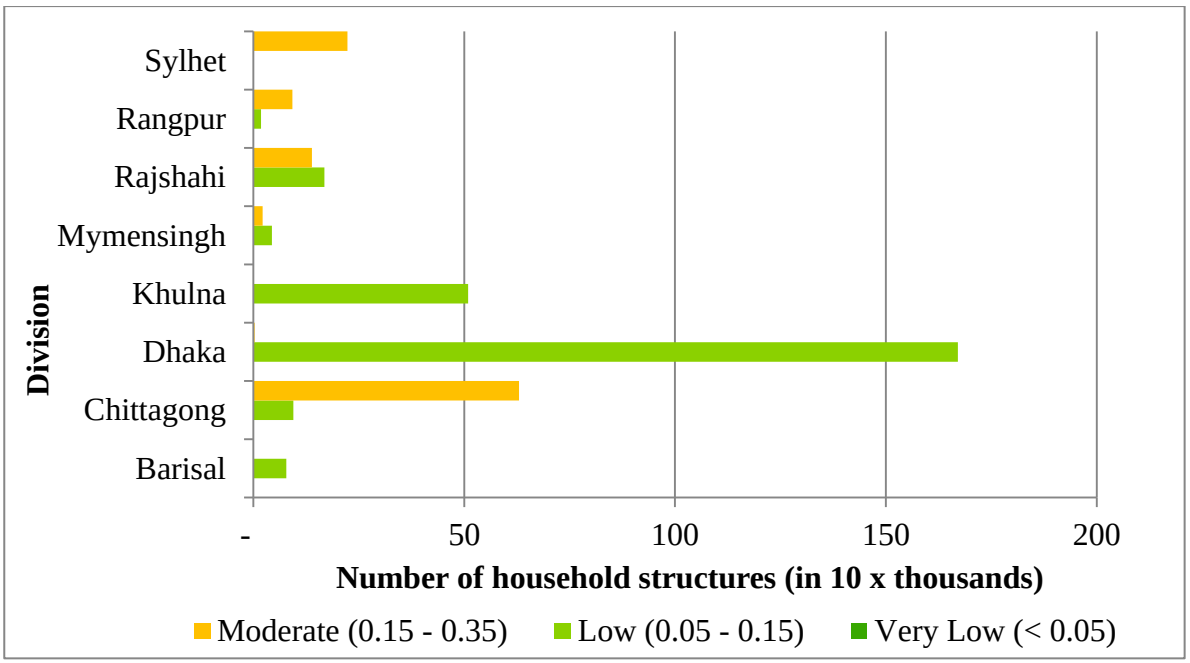

Figure 2.26: Number of Pucca household structures exposed to different intensity of earthquake at division level

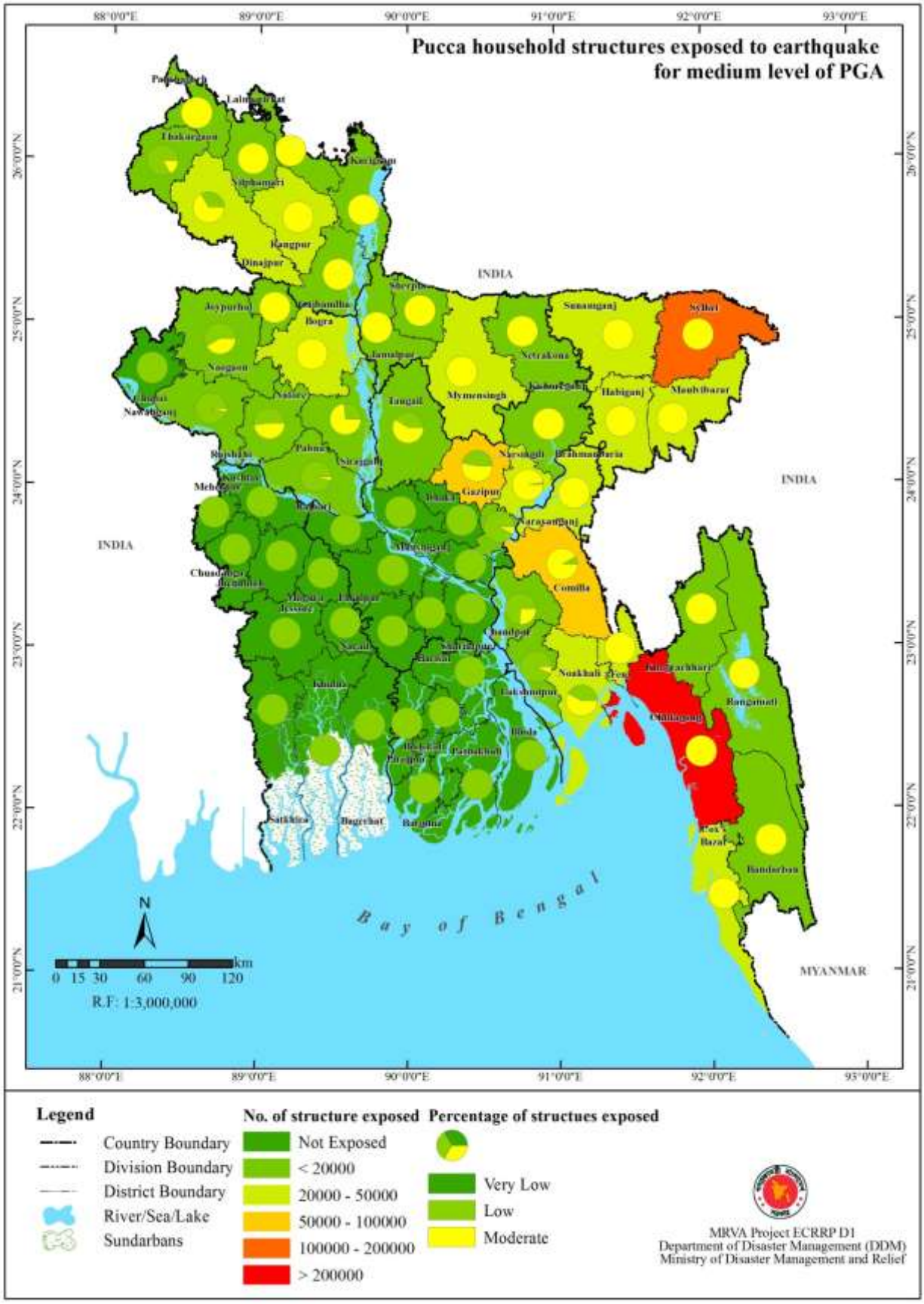

Figure 2.27: Number of Pucca household structures exposed to earthquake for medium level of PGA at district level

Table 2.17: Number of semi-Pucca household structures exposed to earthquake at division level

Division	PGA Value / household structures		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	152,933	-
Chittagong	-	103,977	689,513
Dhaka	-	2,152,295	12,374
Khulna	-	1,023,972	-
Mymensingh	-	157,742	100,403
Rajshahi	314	529,658	435,517
Rangpur	-	92,445	471,804
Sylhet	-	-	414,934
Total	314	4,213,022	2,124,545

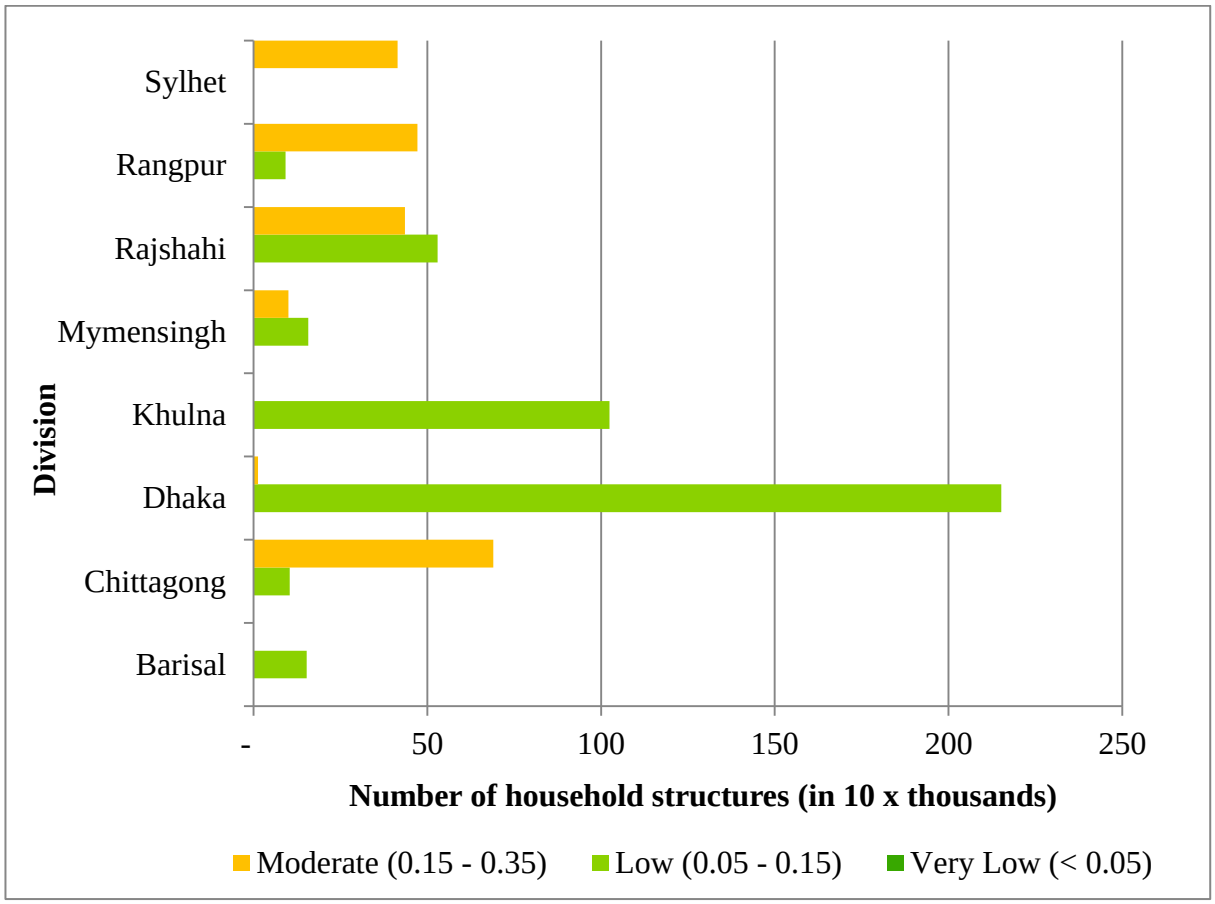

Figure 2.28: Number of semi-pucca household structures exposed to different intensity of earthquake at division level

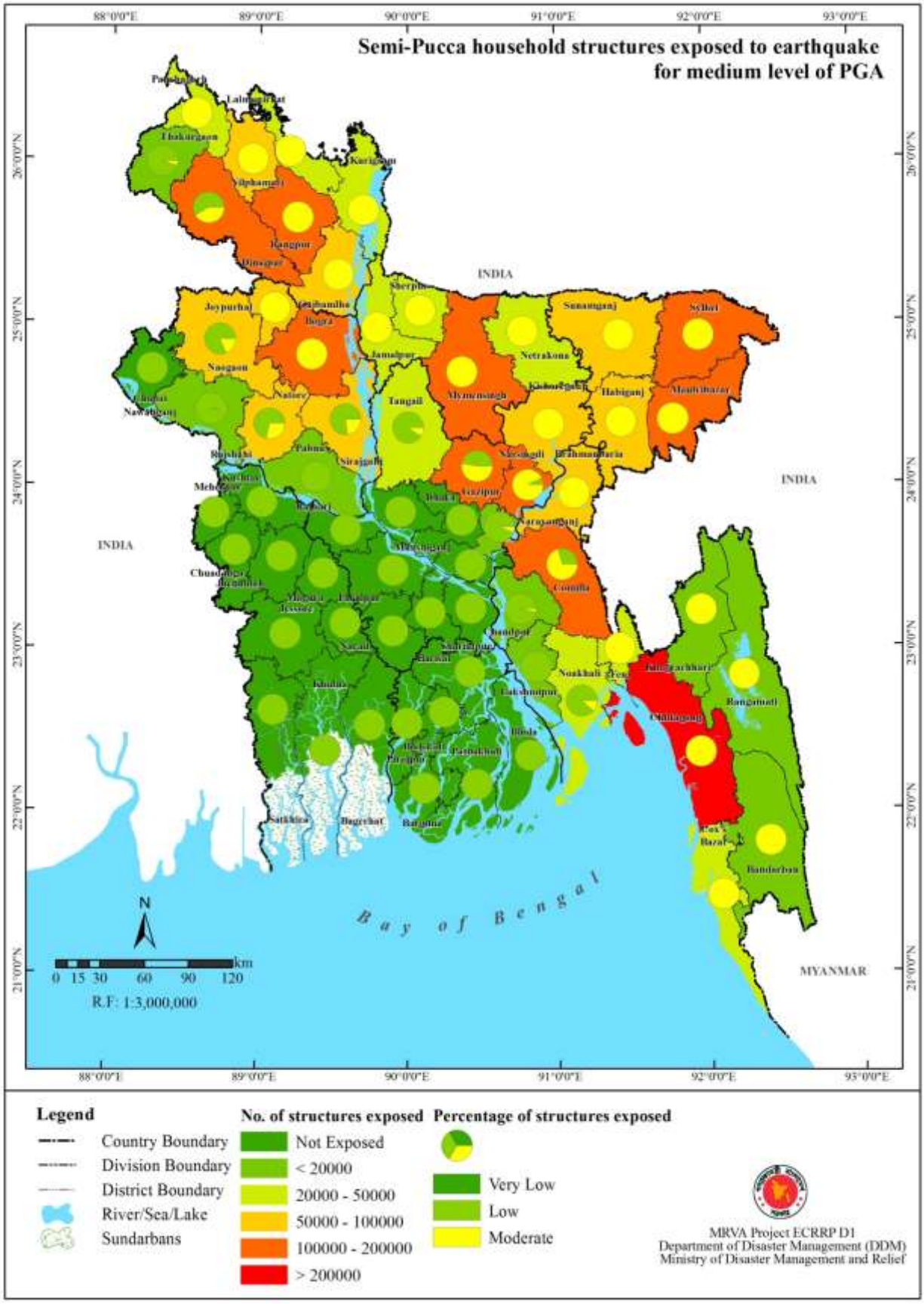

Figure 2.29: Number of semi-pucca household structures exposed to earthquake for medium level of PGA at district level

Table 2.18: Number of Kutcha household structures exposed to earthquake at division level

Division	PGA Value / household structures		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	1,572,238	-
Chittagong	-	508,696	3,373,353
Dhaka	-	4,251,042	90,492
Khulna	-	2,095,162	-
Mymensingh	-	1,233,570	883,048
Rajshahi	1,003	1,692,606	1,391,765
Rangpur	-	495,594	2,529,334
Sylhet	-	-	1,099,584
Total	1,003	11,848,907	9,367,577

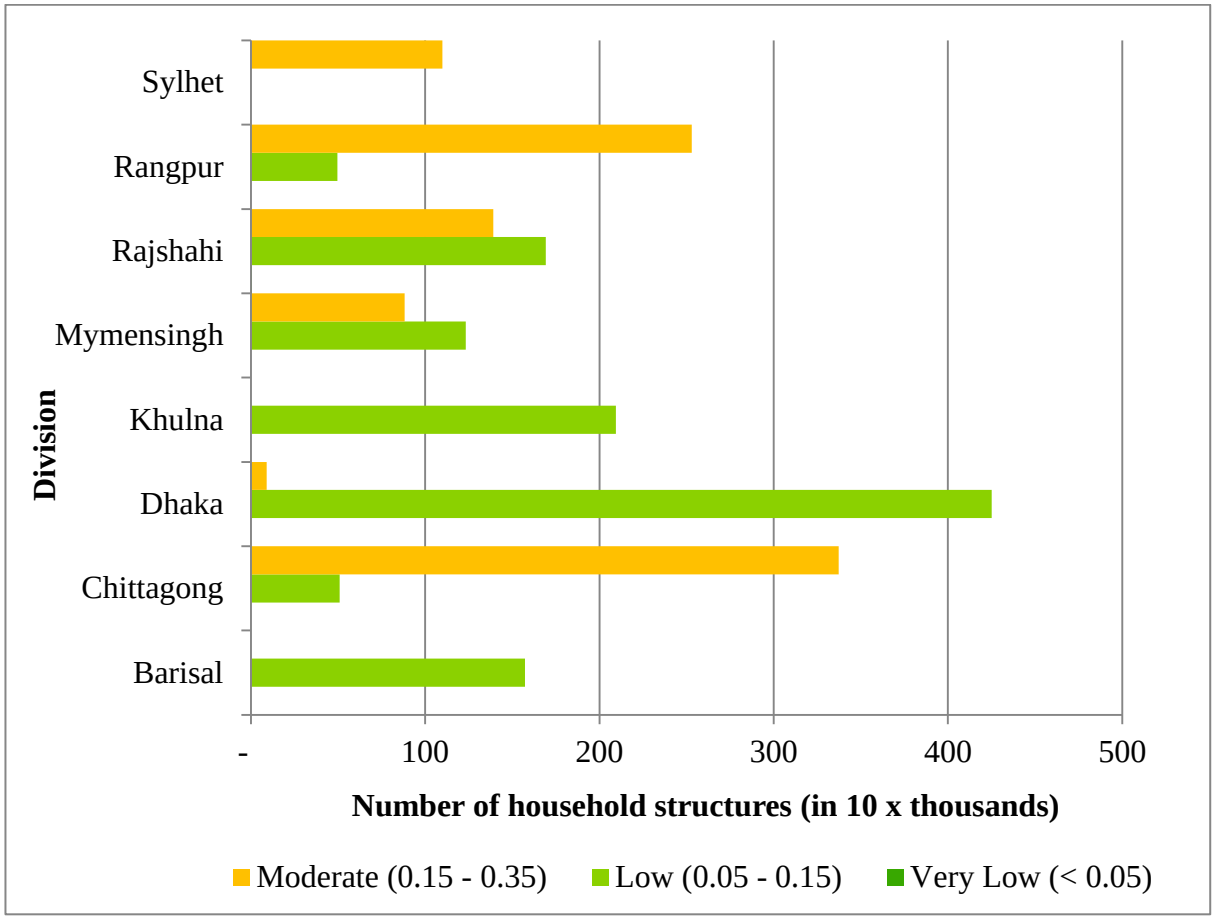

Figure 2.30: Number of Kutcha household structures exposed to different intensity of earthquake at division level

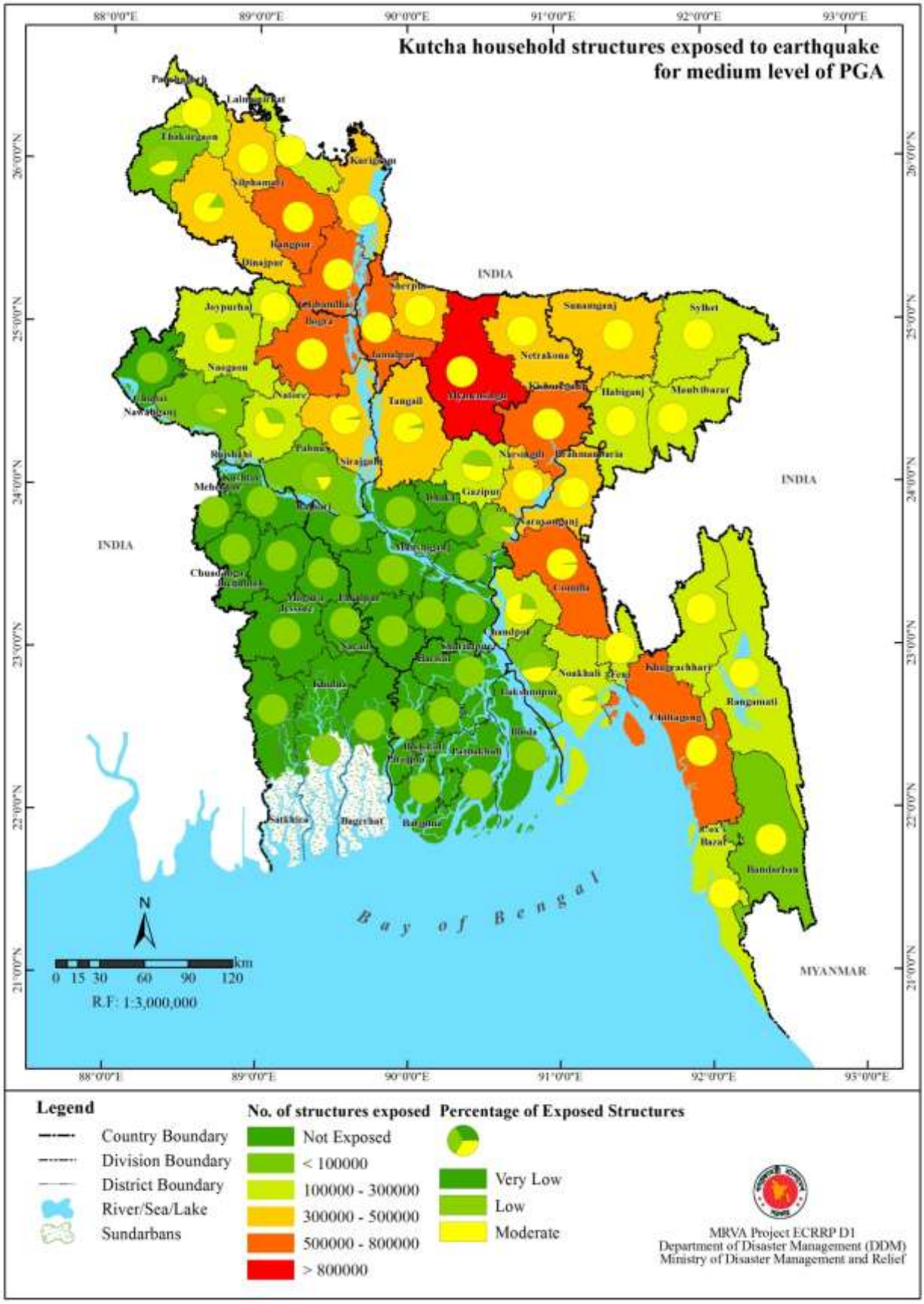

Figure 2.31: Number of kutcha household structures exposed to earthquake for medium level of PGA at district level

Table 2.19: Number of Jhupri household structures exposed to earthquake at division level

Division	PGA Value / household structures		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	59,673	-
Chittagong	-	29,551	195,964
Dhaka	-	128,147	1,722
Khulna	-	111,309	-
Mymensingh	-	46,890	52,567
Rajshahi	42	70,647	58,091
Rangpur	-	19,273	98,363
Sylhet	-	-	53,020
Total	42	465,491	459,727

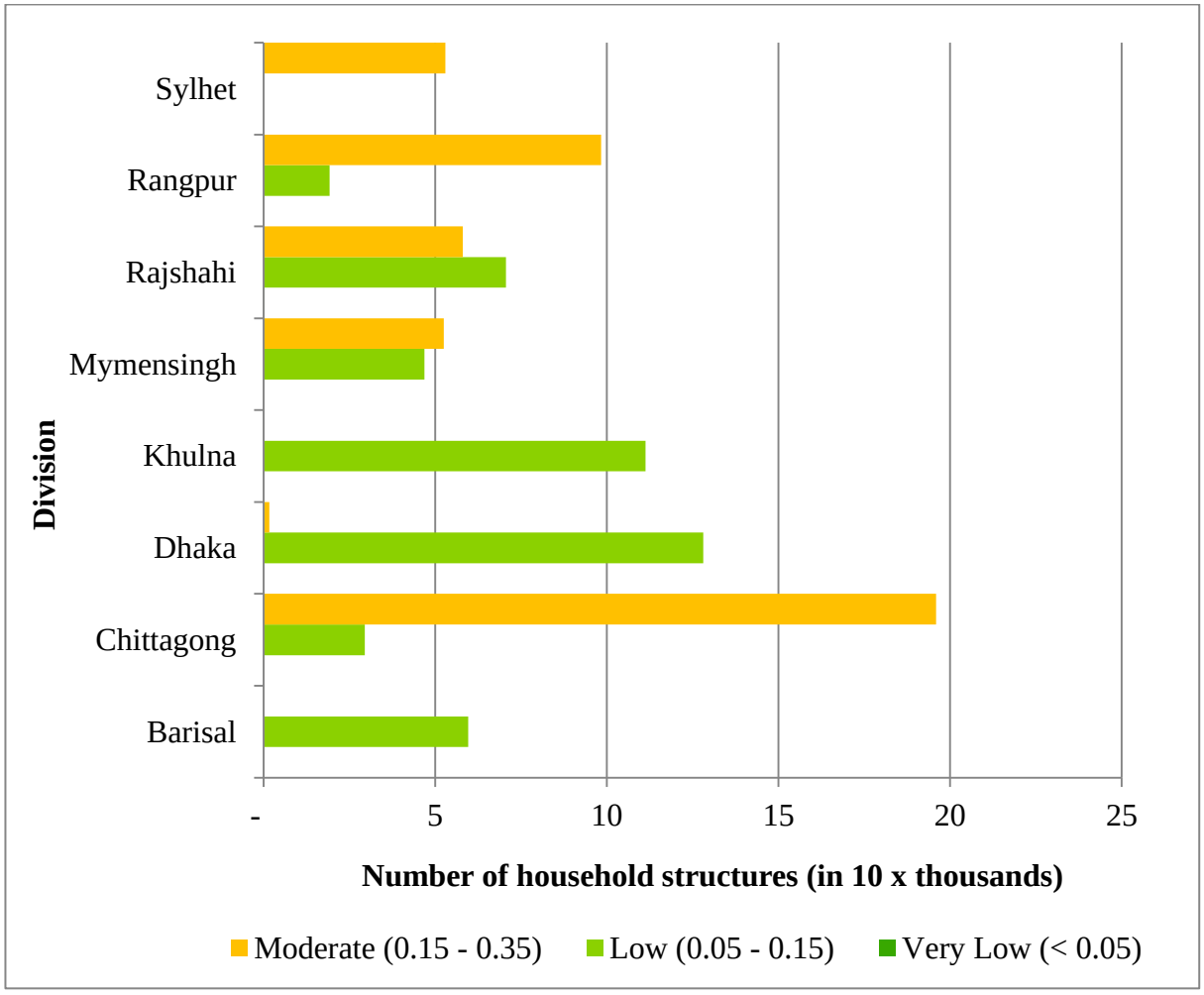

Figure 2.32: Number of Jhupri household structures exposed to different intensity of earthquake at division level

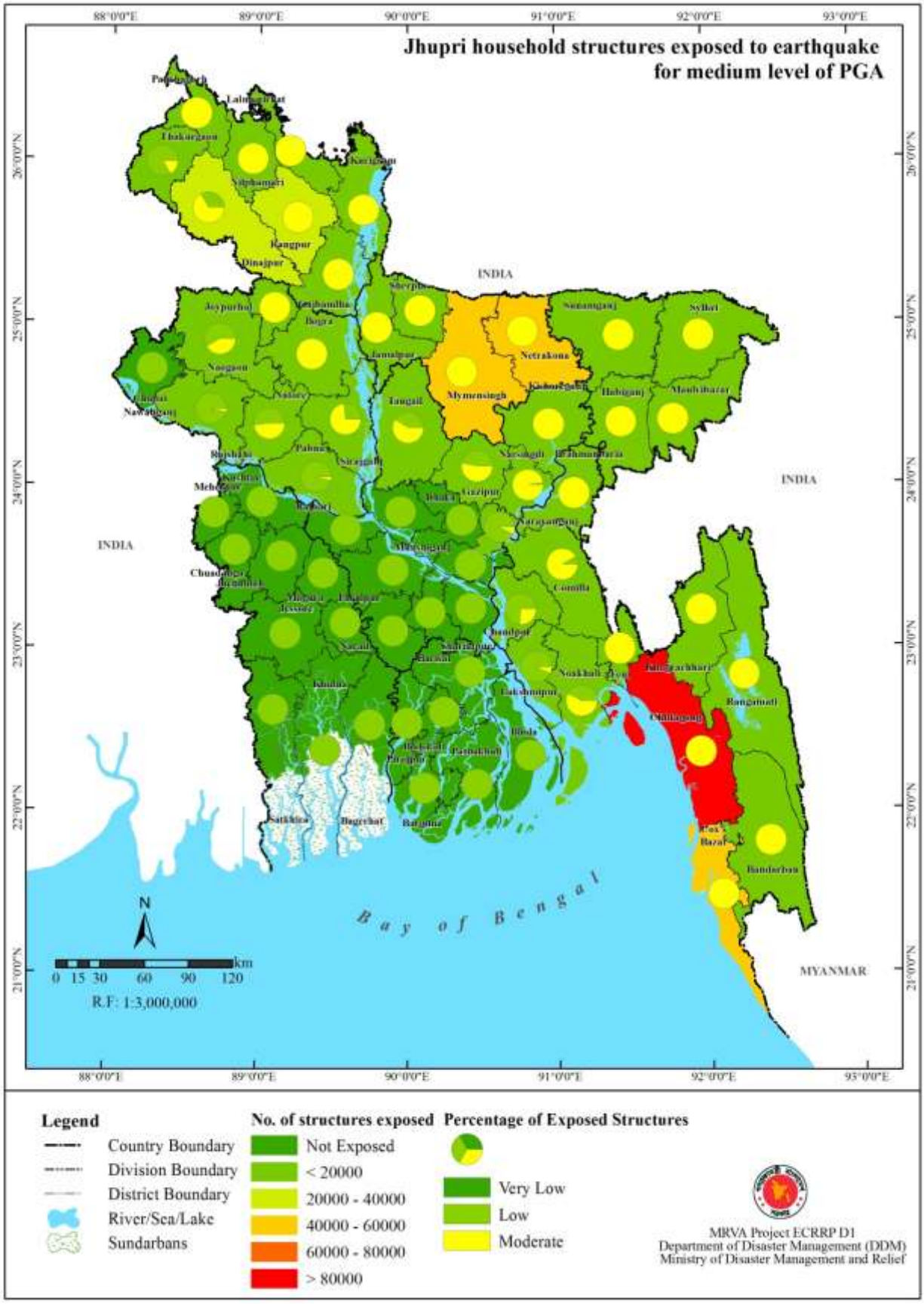

Figure 2.33: Number of jhupri household structures exposed to earthquake for medium level of PGA at district level

2.1.3 Livelihood

Components considered in livelihood are agriculture and Industries.

2.1.3.1 Agriculture

As mentioned earlier in para 1.2.1, agriculture is not considered for assessing risk due to earthquake hazard.

2.1.3.2 Industries

The different types of industries (Food Godowns, Mill factory, Gas Field, Cold Storage, Cottage Industries, Rice/Oil/Grain mills) existing in the database are assessed for their exposure to earthquake.

The number of food godowns exposed to earthquake at division level is given in table 2.20 and figure 2.34.

Table 2.20: Number of food godowns exposed to earthquake at division level

Division	PGA Value / food godowns		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	64	-
Chittagong	-	8	109
Dhaka	-	112	42
Khulna	-	72	-
Mymensingh	-	-	61
Rajshahi	-	49	46
Rangpur	-	28	86
Sylhet	-	-	58
Total	-	333	402

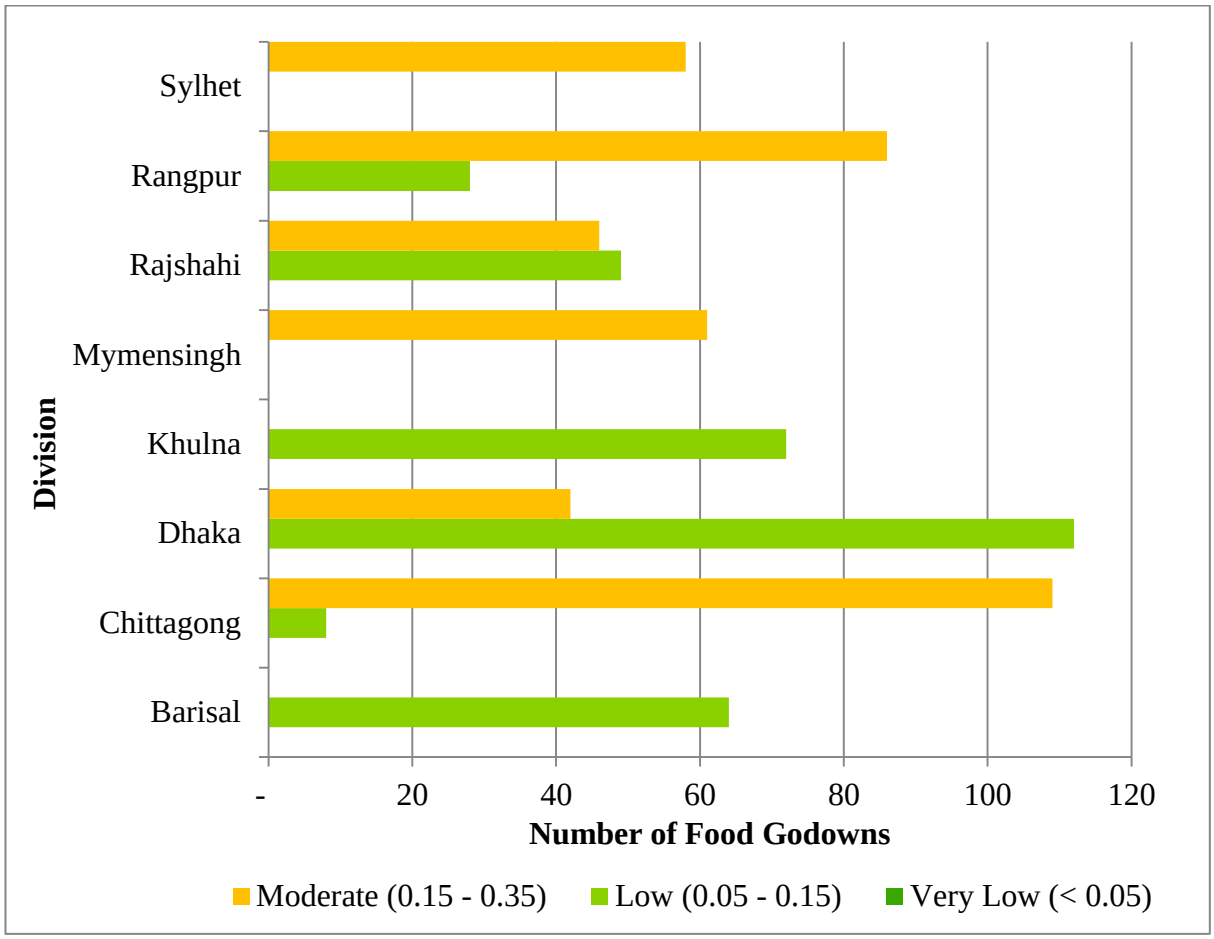

Figure 2.34: Number of food godowns exposed to different intensity of earthquake at division level

The number of Mills existing in different earthquake hazard levels at division level is given in table 2.21 and figure 2.35.

Table 2.21: Number of Mills exposed to earthquake at division level

Division	PGA Value / Mills		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	6	-
Chittagong	-	3	24
Dhaka	-	28	5
Khulna	-	24	-
Mymensingh	-	-	2
Rajshahi	-	15	8
Rangpur	-	-	10
Sylhet	-	-	6
Total	-	76	55

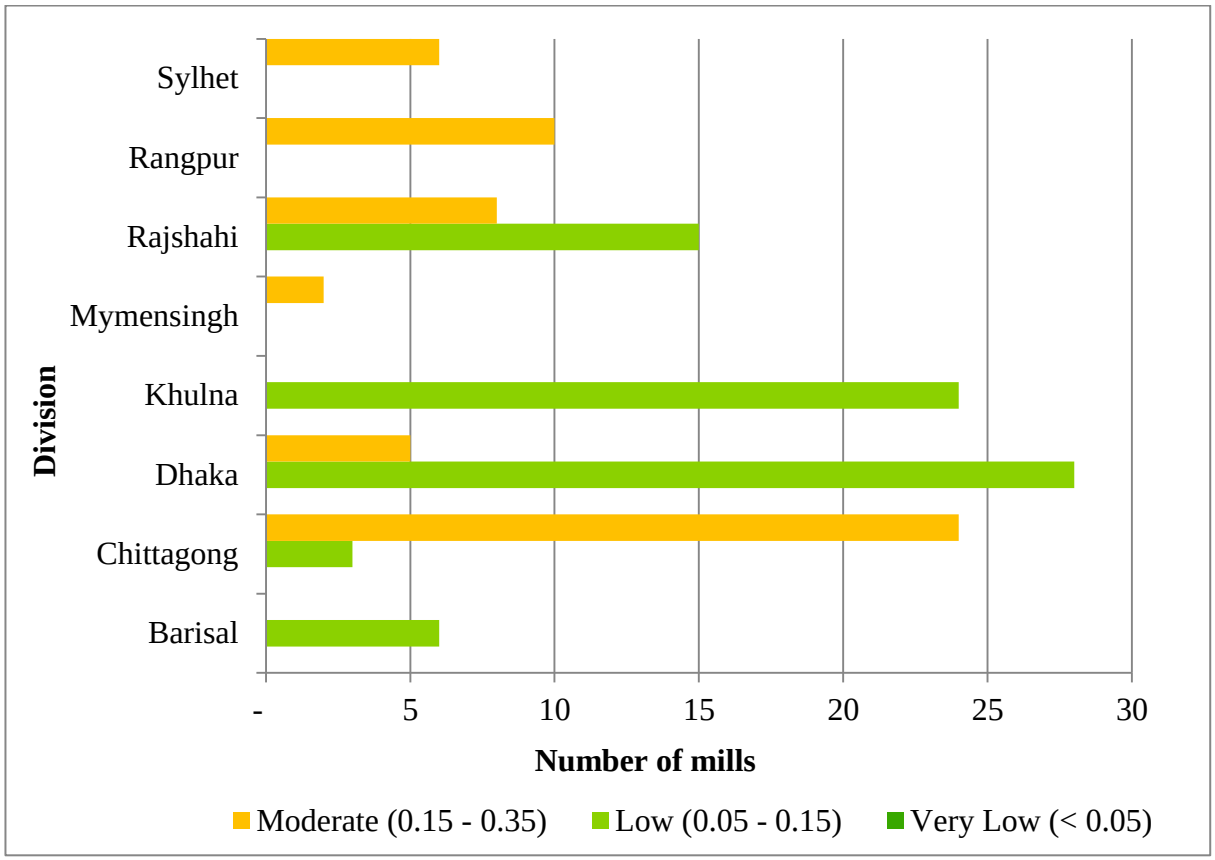

Figure 2.35: Number of Mills exposed to different intensity of earthquake at division level

The number of Gas Fields existing in different earthquake hazard levels at division level is given in table 2.22.

Table 2.22: Number of Gas Fields exposed to earthquake at division level

Division	PGA Value / Gas Fields		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	-	7
Dhaka	-	-	4
Khulna	-	2	-
Mymensingh	-	-	-
Rajshahi	-	-	-
Rangpur	-	-	-
Sylhet	-	-	3
Total	-	2	14

The number of Cold Storage existing in different earthquake hazard levels at division level is given in table 2.23.

Table 2.23: Number of Cold Storage exposed to earthquake at division level

Division	PGA Value / Cold Storage		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	1	1
Dhaka	-	1	-
Khulna	-	-	-
Mymensingh	-	-	1
Rajshahi	-	-	5
Rangpur	-	-	-
Sylhet	-	-	1
Total	-	2	8

The number of Cottage Industry existing in different earthquake hazard levels at division level is given in table 2.24 and figure 2.36.

Table 2.24: Number of Cottage Industry exposed to earthquake at division level

Division	PGA Value / Cottage Industry		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	1	2
Dhaka	-	35	14
Khulna	-	1	-
Mymensingh	-	-	-
Rajshahi	-	2	1
Rangpur	-	-	-
Sylhet	-	-	1
Total	-	39	18

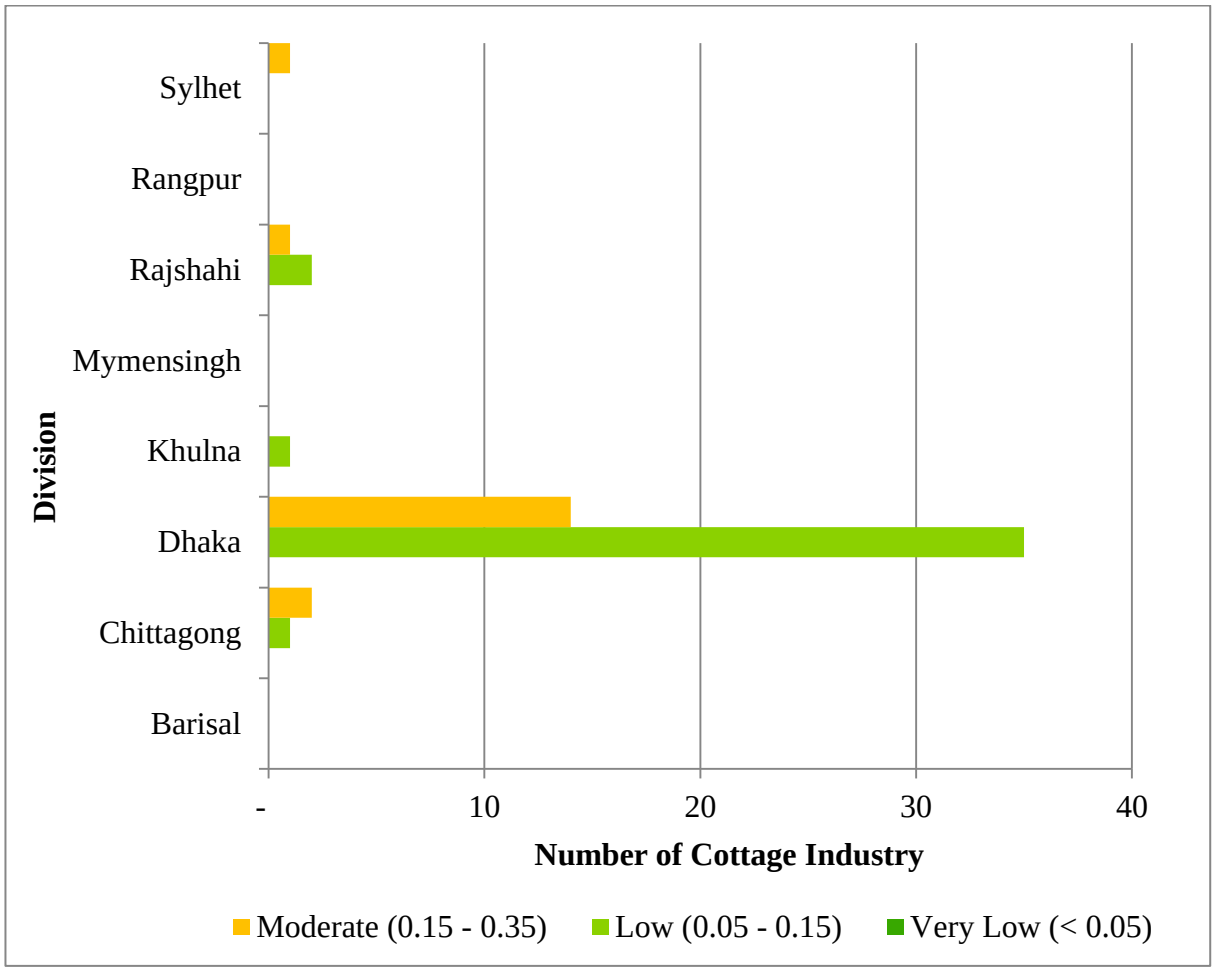

Figure 2.36: Number of Cottage Industry exposed to different intensity of earthquake at division level

The number of Rice/Oil/Grain Mill existing in different earthquake hazard levels at division level is given in table 2.25 and figure 2.37.

Table 2.25: Number of Rice/Oil/Grain Mill exposed to earthquake at division level

Division	PGA Value / Rice/Oil/Grain Mill		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	21	-
Dhaka	-	1	-
Khulna	-	-	-
Mymensingh	-	-	-
Rajshahi	-	-	-
Rangpur	-	-	4
Sylhet	-	-	5
Total	-	22	9

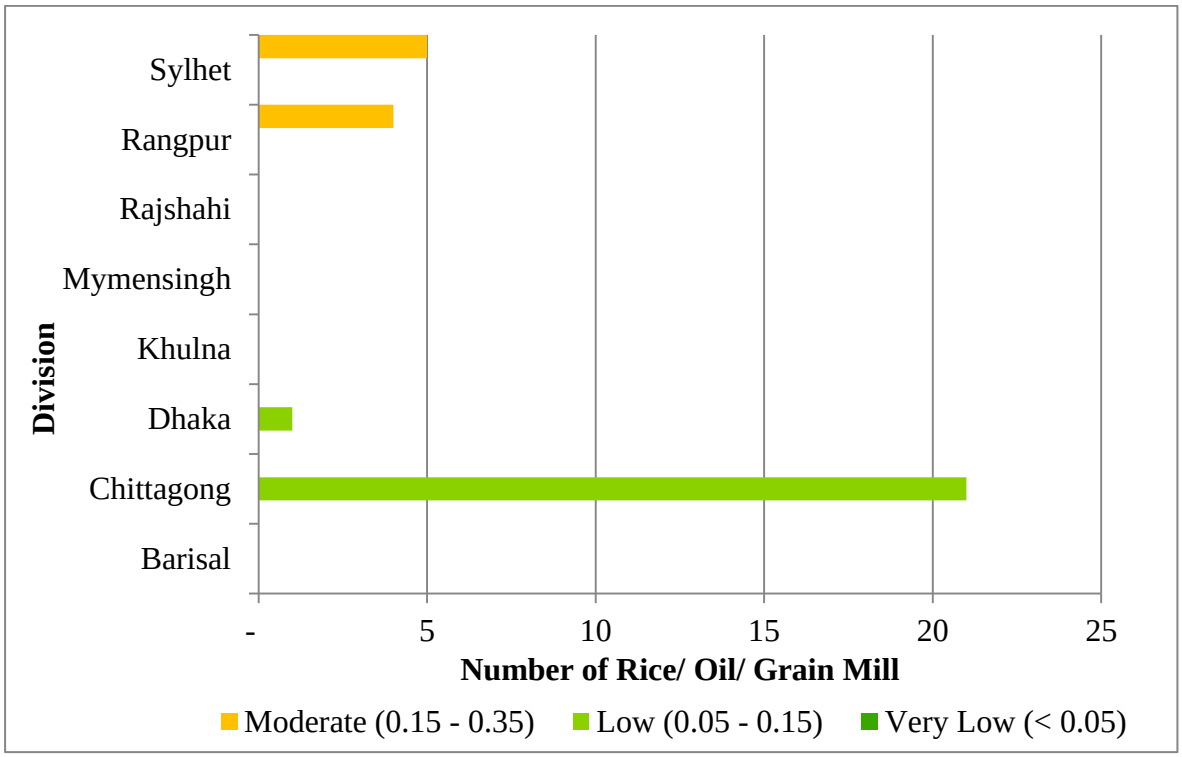

Figure 2.37: Number of Rice/Oil/Grain Mill exposed to different intensity of earthquake at division level

2.1.4 Critical Facilities

2.1.4.1 Health care facilities

Combining earthquake hazard map and Health care facility map will provide existing hospitals and family welfare centers in earthquake prone areas.

The number of hospitals existing in different earthquake hazard levels at division level is given in table 2.26 and figure 2.38. Hospitals existing in different earthquake zones at district level are shown in figure 2.39.

Table 2.26: Number of hospitals exposed to earthquake at division level

Division	PGA Value / hospitals		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	36	-
Chittagong	-	8	87
Dhaka	-	101	1
Khulna	-	66	-
Mymensingh	-	12	12
Rajshahi	-	23	30
Rangpur	-	7	31
Sylhet	-	-	34
Total	-	253	195

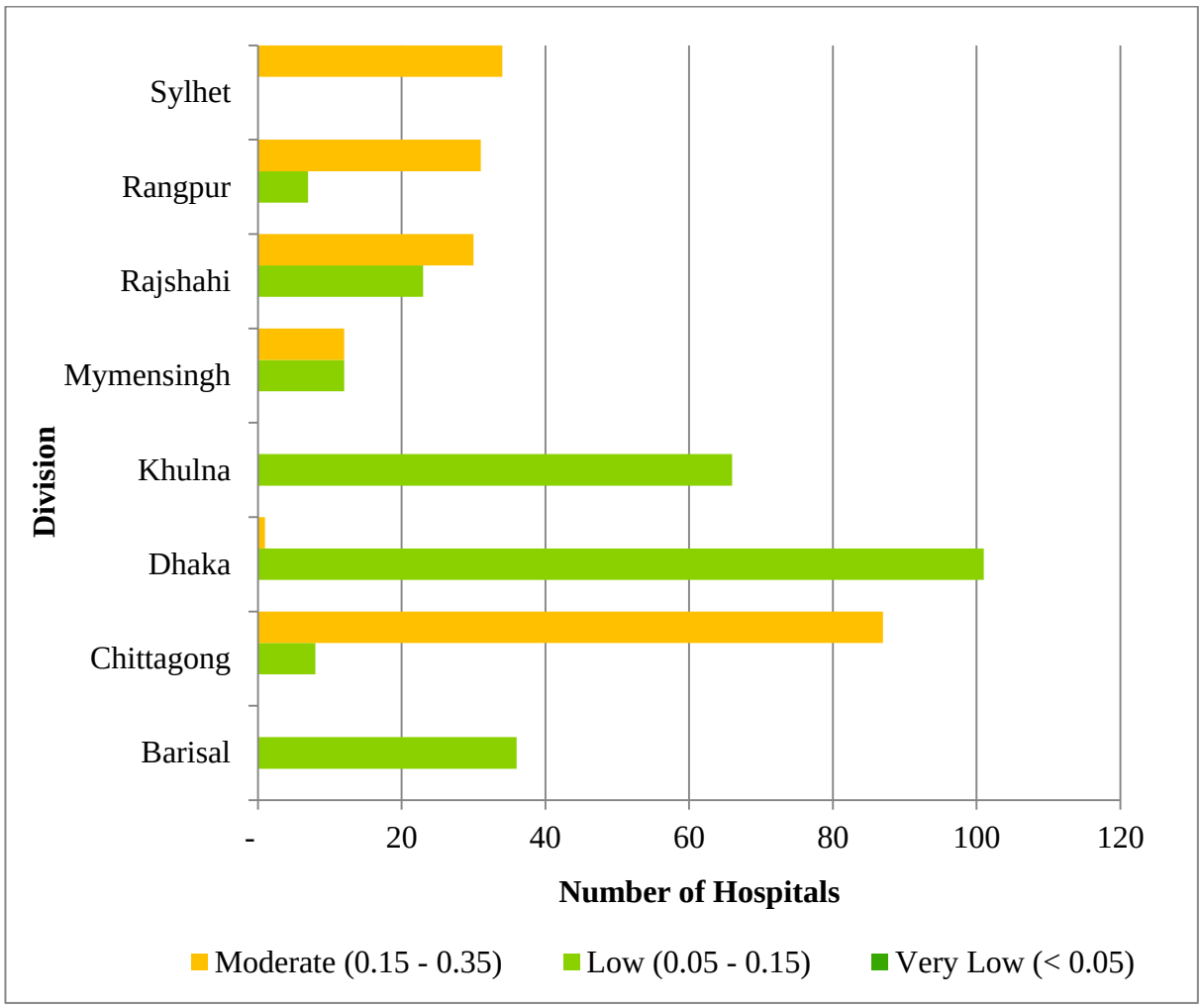

Figure 2.38: Number of hospitals exposed to different intensity of earthquake at division level

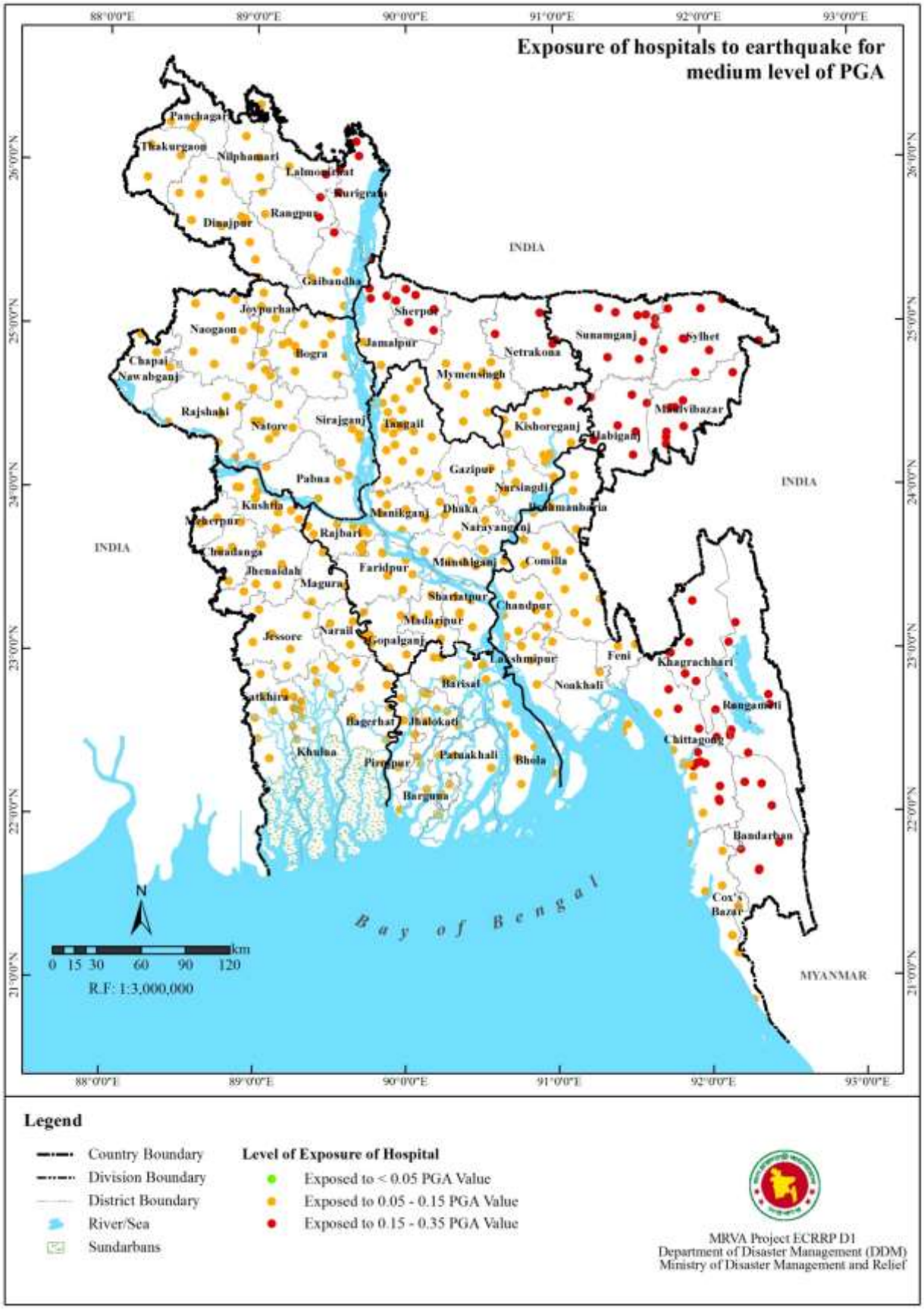

Figure 2.39: Exposure of hospitals to earthquake at district level

The number of Family Welfare centres existing in different earthquake hazard levels at division level is given in table 2.27 and figure 2.40. Family Welfare centres existing in different earthquake zones at district level is shown in figure 2.41.

Table 2.27: Number of Family Welfare centres exposed to earthquake at division level

Division	PGA Value / Family Welfare centers		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	207	-
Chittagong	-	61	291
Dhaka	-	625	1
Khulna	-	342	-
Mymensingh	-	113	66
Rajshahi	-	204	187
Rangpur	-	55	309
Sylhet	-	-	154
Total	-	1,607	1,008

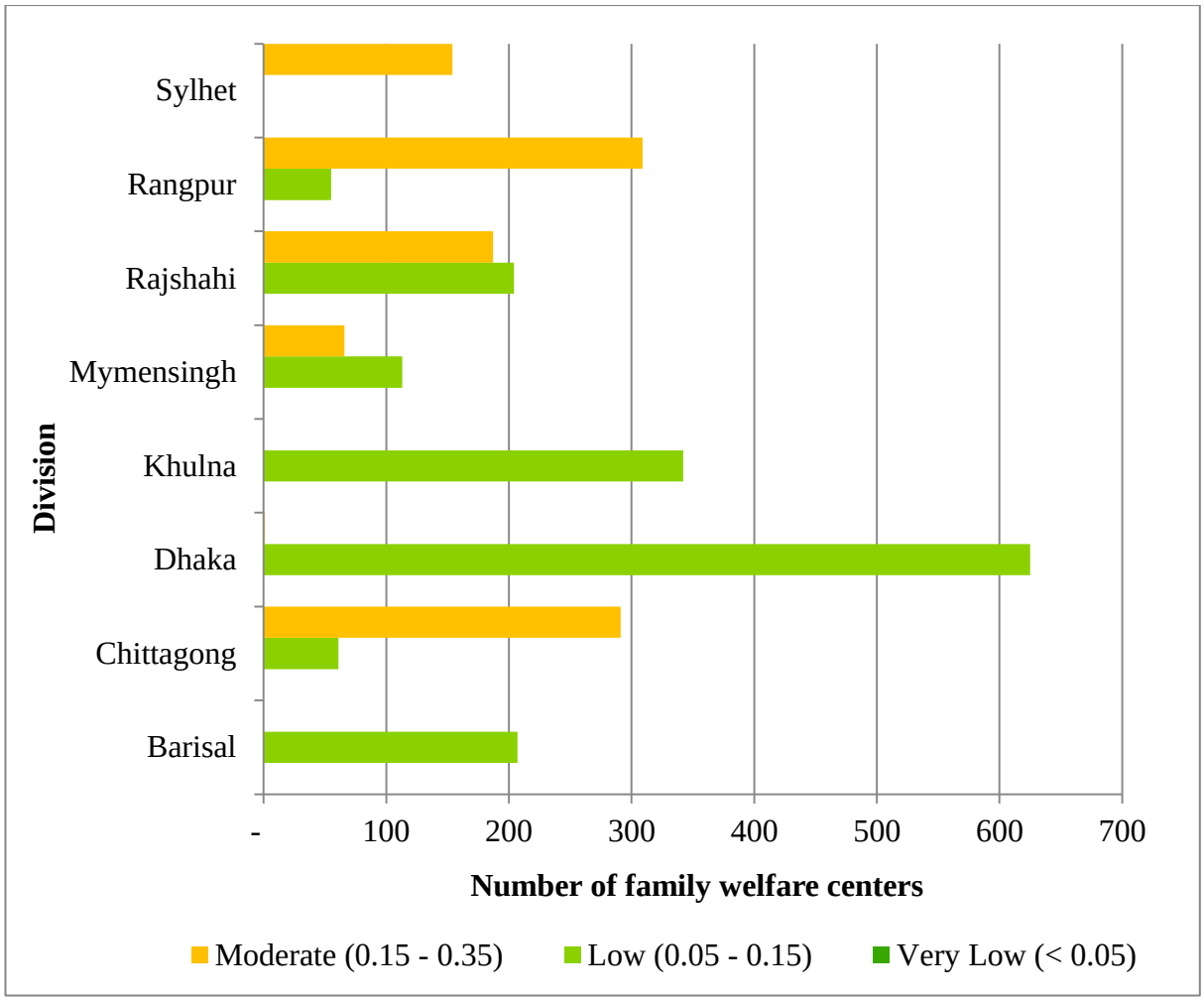

Figure 2.40: Number of Family Welfare centers exposed to different intensity of `earthquake at division level

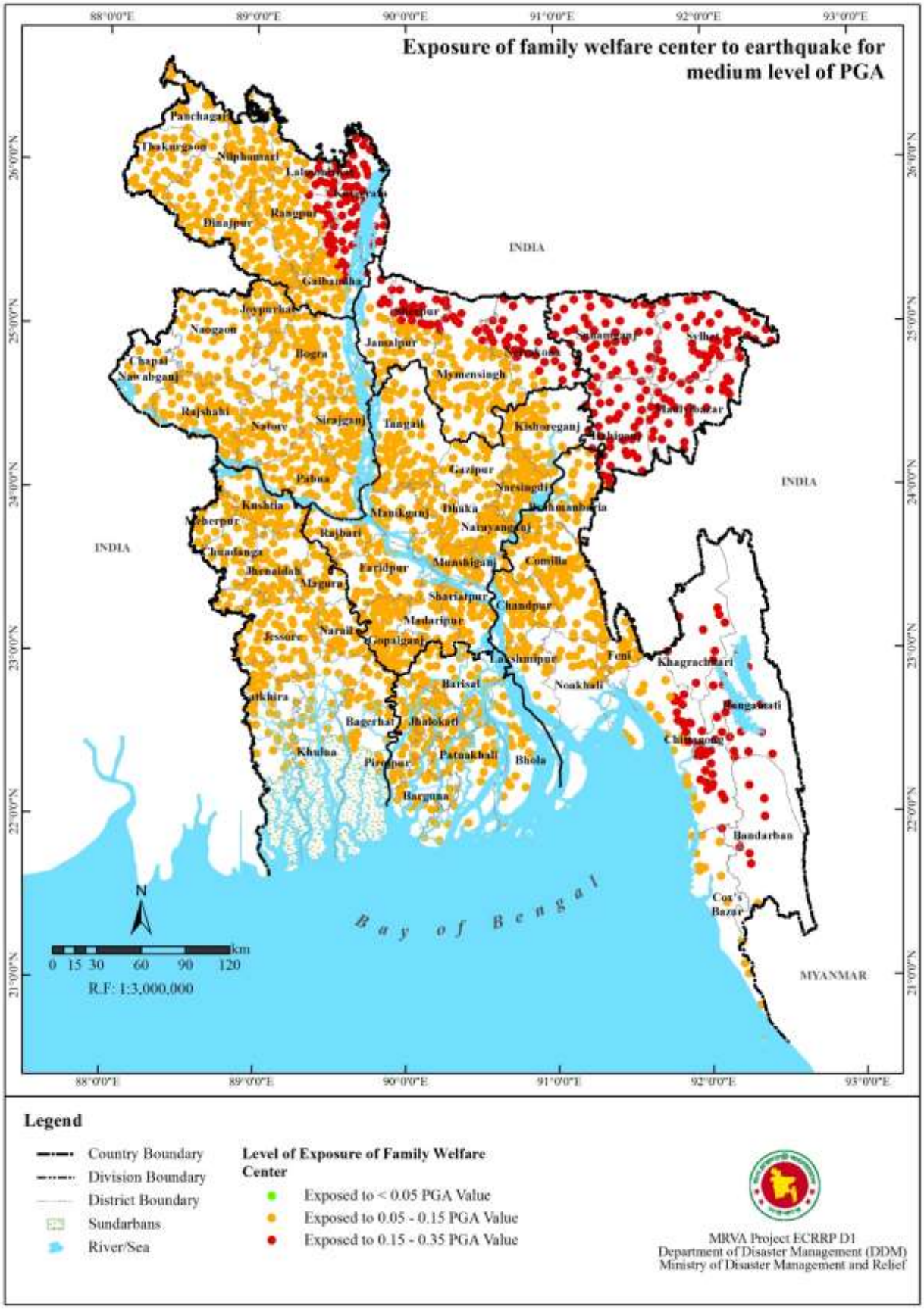

Figure 2.41: Exposure of family welfare center to earthquake at district level

2.1.4.2 Educational Institutions

Educational institutions database consists of categories of educational institutions as University,

College, High School, Madrasa, Primary Schools. Combining earthquake hazard map and Educational institutions map will provide existing Educational institutions in earthquake prone areas.

The number of High Schools existing in different earthquake hazard levels at division level is given in table 2.28 and figure 2.42. High Schools existing in different earthquake zones at district level is shown in figure 2.43.

Table 2.28: Number of High Schools exposed to earthquake at division level

Division	PGA Value / High Schools		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	835	-
Chittagong	-	207	1,039
Dhaka	-	1472	10
Khulna	-	1,048	-
Mymensingh	-	342	181
Rajshahi	-	502	450
Rangpur	-	140	779
Sylhet	-	-	427
Total	-	4,546	2,886

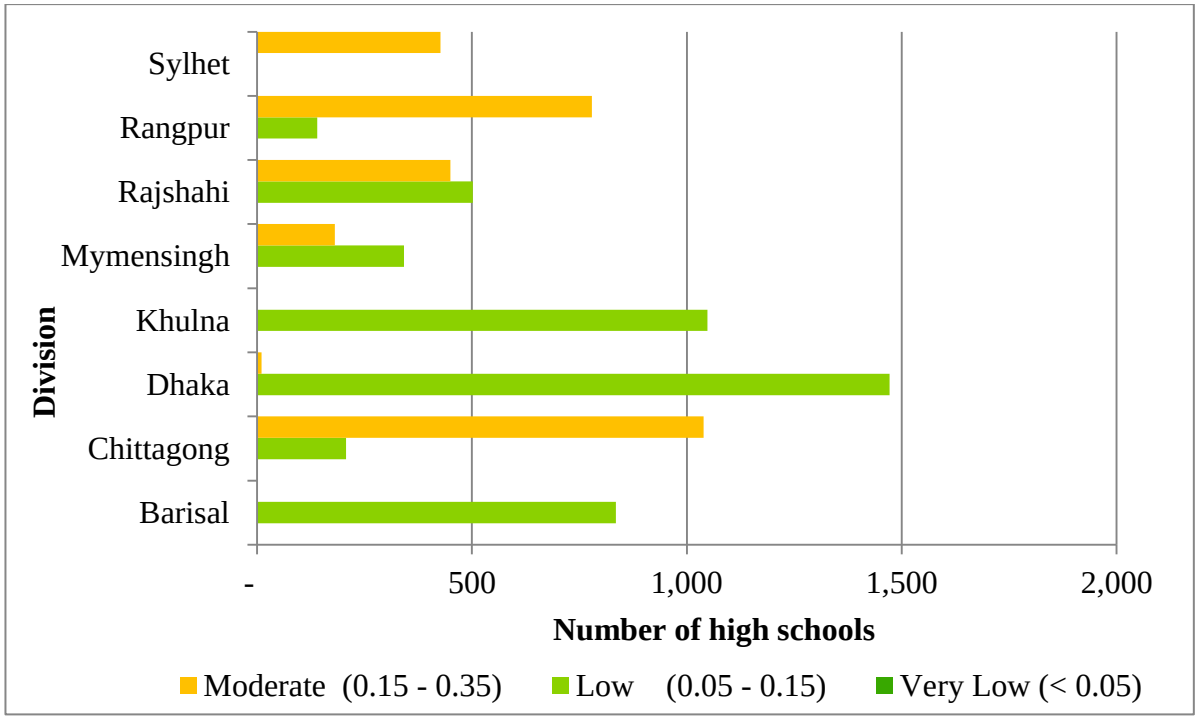

Figure 2.42: Number of High Schools exposed to different intensity of earthquake at division level

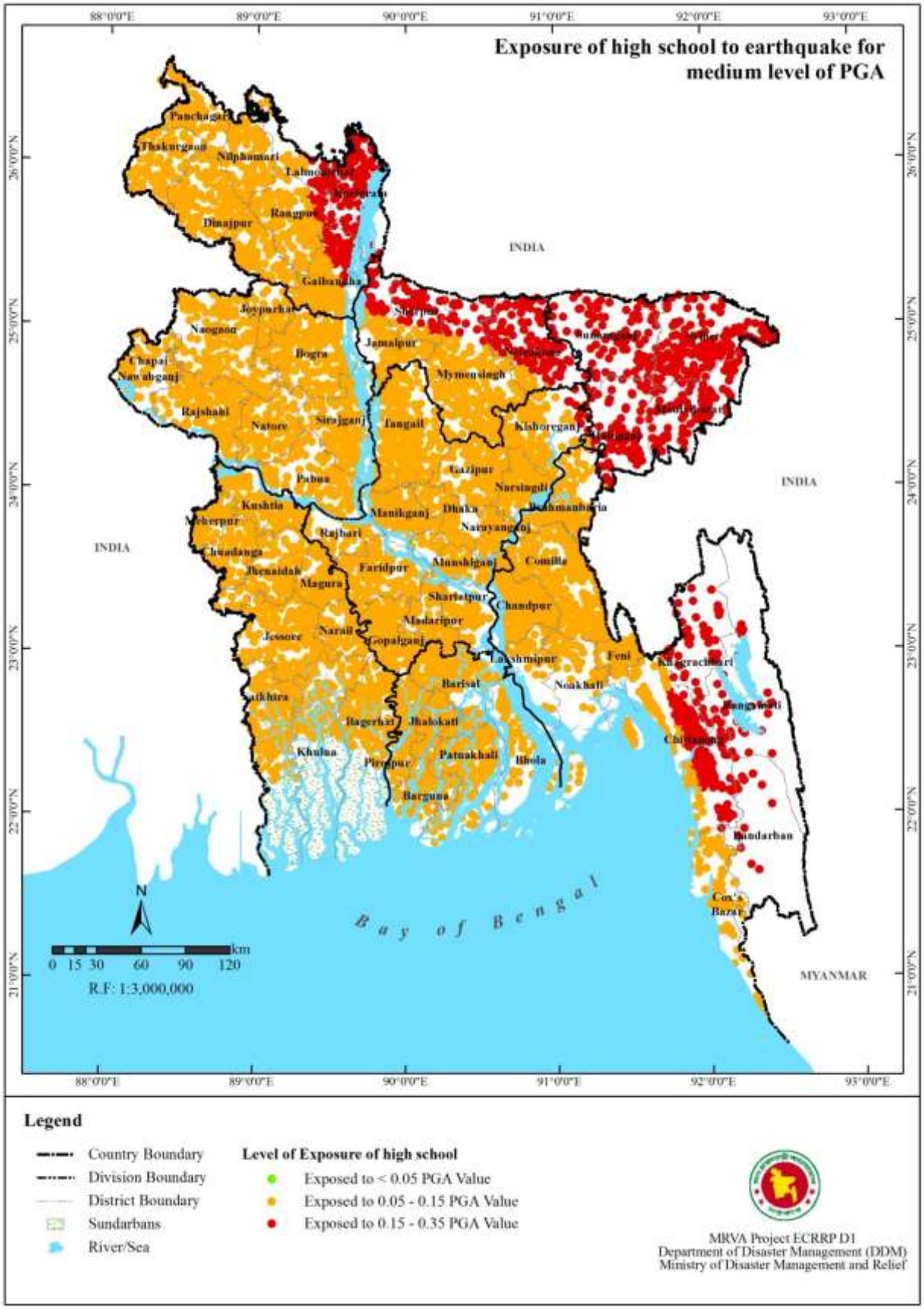

Figure 2.43: Exposure of High Schools to earthquake at district level

The number of Madrasa existing in different earthquake hazard levels at division level is given in table 2.29 and figure 2.44. Madrasa existing in different earthquake zones at district level is shown in figure 2.45.

Table 2.29: Number of Madrasa exposed to earthquake at division level

Division	PGA Value / Madrasa		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	315	-
Chittagong	-	105	570
Dhaka	-	871	5
Khulna	-	507	-
Mymensingh	-	188	143
Rajshahi	-	359	304
Rangpur	-	72	458
Sylhet	-	-	419
Total	-	2,417	1,899

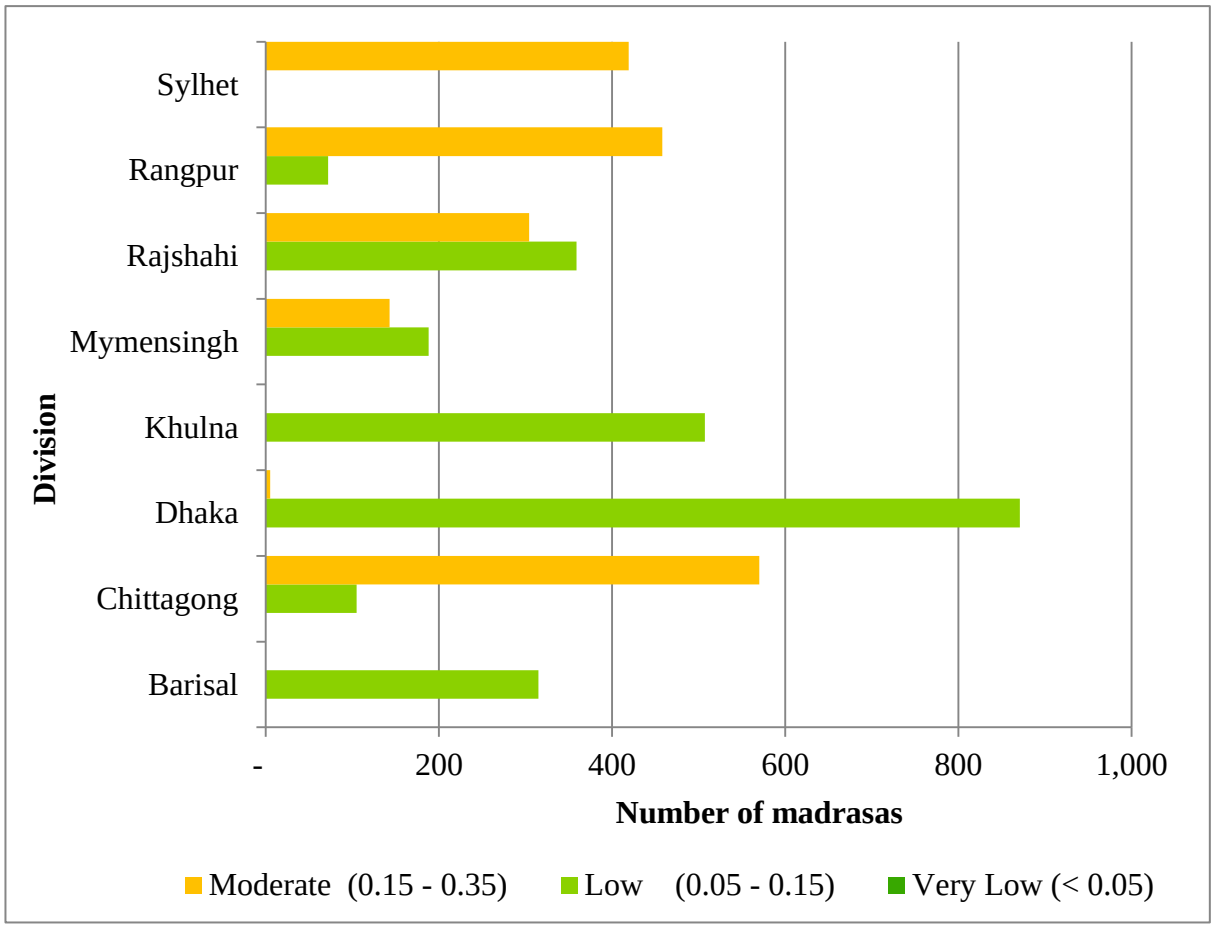

Figure 2.44: Number of Madrasa exposed to different intensity of earthquake at division level

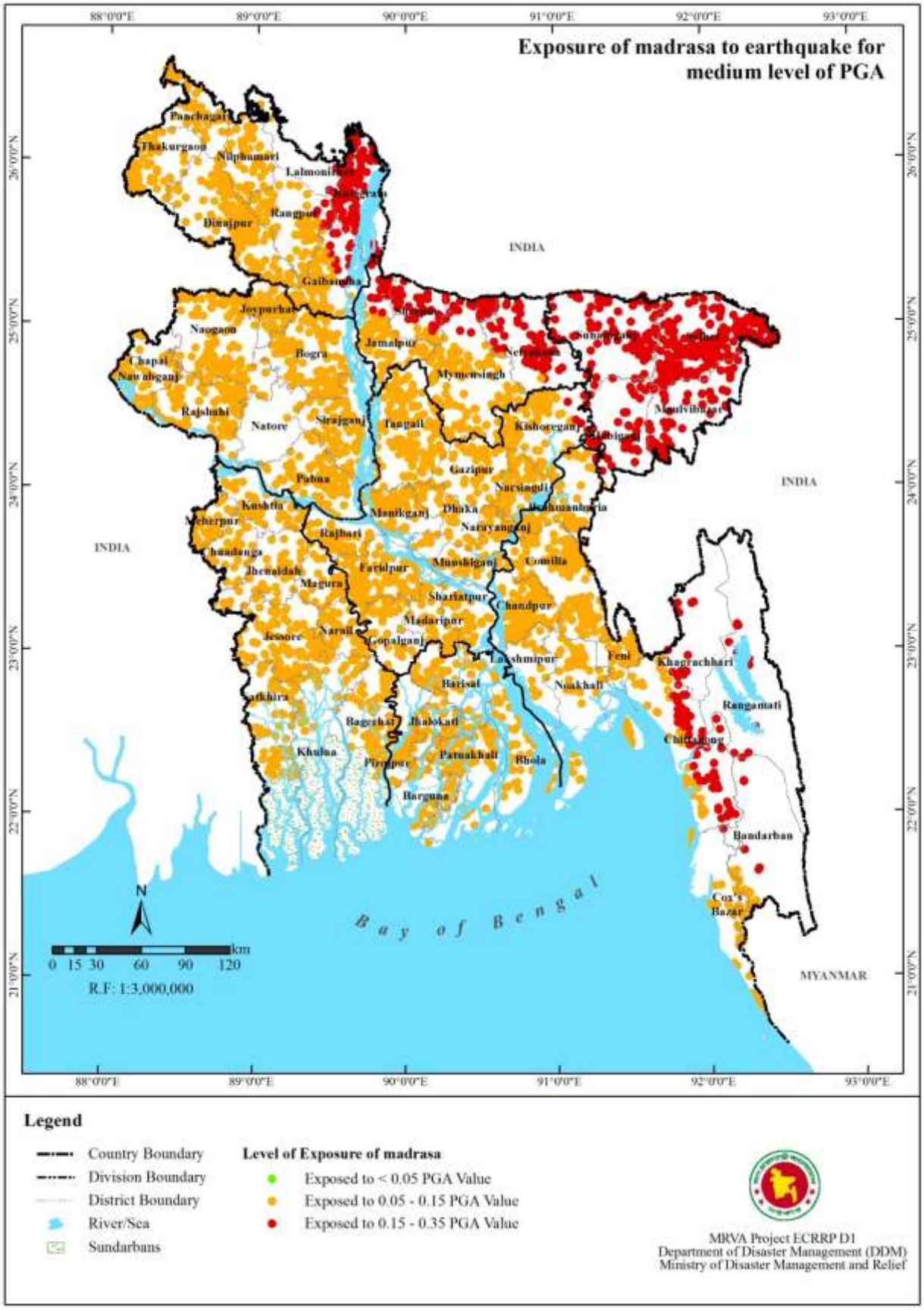

Figure 2.45: Exposure of madrasas to earthquake at district level

The number of Primary School existing in different earthquake hazard levels at division level is given in table 2.30 and figure 2.46. Primary School s existing in different earthquake zones at district level is shown in figure 2.47.

Table 2.30: Number of Primary Schools exposed to earthquake at division level

Division	PGA Value / Primary Schools		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2,257	-
Chittagong	-	952	5,369
Dhaka	-	7,529	70
Khulna	-	4,191	-
Mymensingh	-	1,567	1,088
Rajshahi	-	2,212	2,110
Rangpur	-	663	3,336
Sylhet	-	-	3,219
Total	-	19,371	15,192

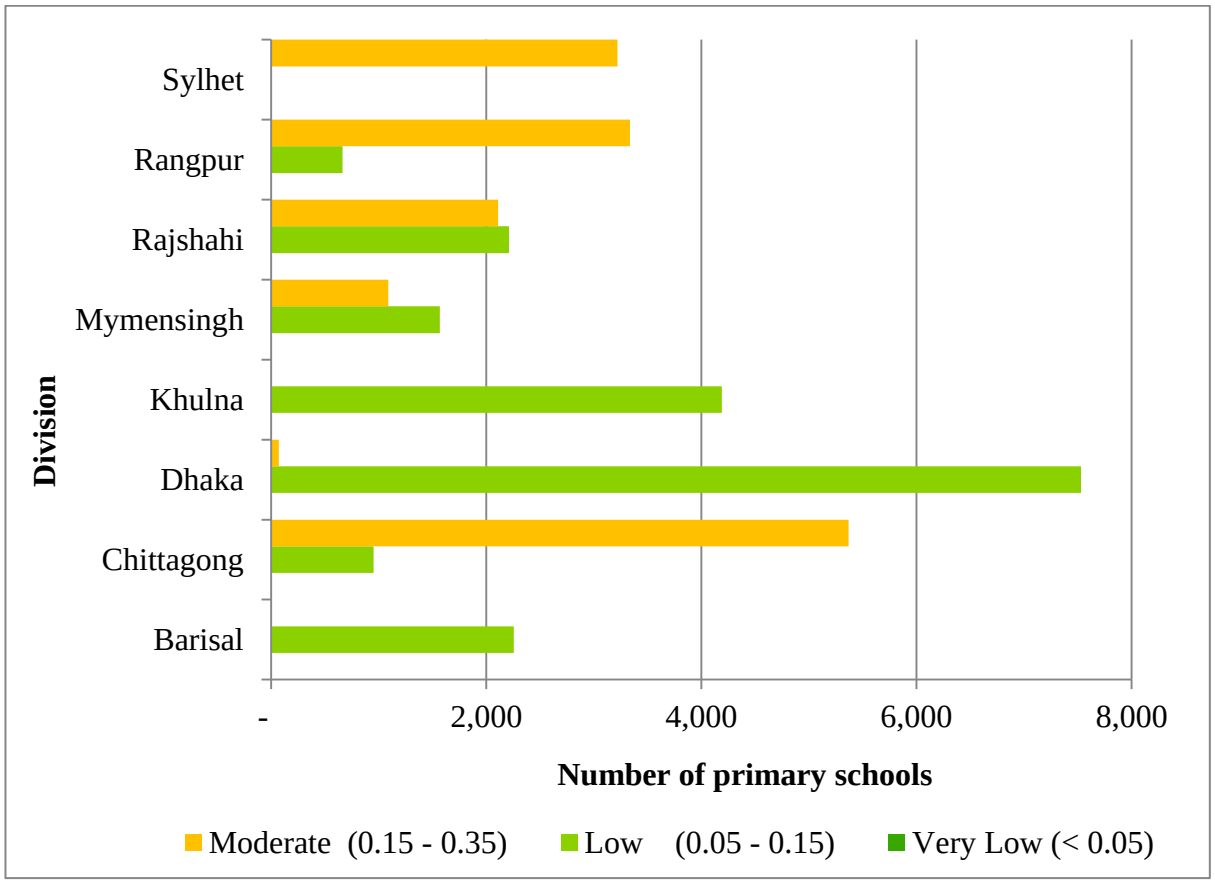

Figure 2.46: Number of Primary School exposed to different intensity of earthquake at division level

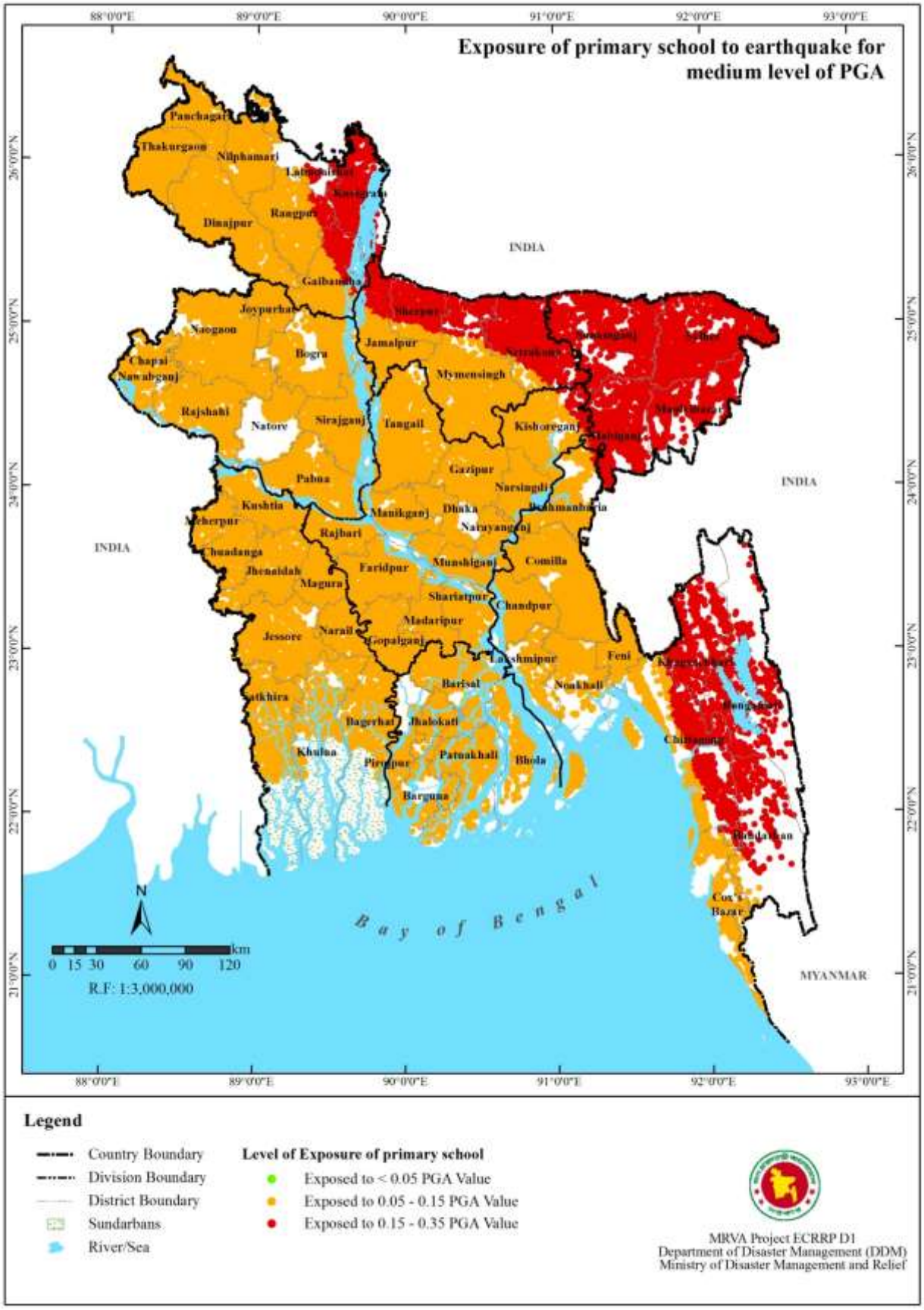

Figure 2.47: Exposure of Primary Schools to earthquake at district level

2.1.4.3 First Responders

Fire stations

The number of Fire stations existing in different earthquake hazard levels at division level is given in table 2.31 and figure 2.48. Fire stations existing in different earthquake zones at district level are shown in figure 2.49.

Table 2.31: Number of Fire stations exposed to earthquake at division level

Division	PGA Value / Fire stations		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	8	-
Chittagong	-	2	22
Dhaka	-	29	-
Khulna	-	16	-
Mymensingh	-	5	1
Rajshahi	-	11	8
Rangpur	-	4	7
Sylhet	-	-	8
Total	-	75	46

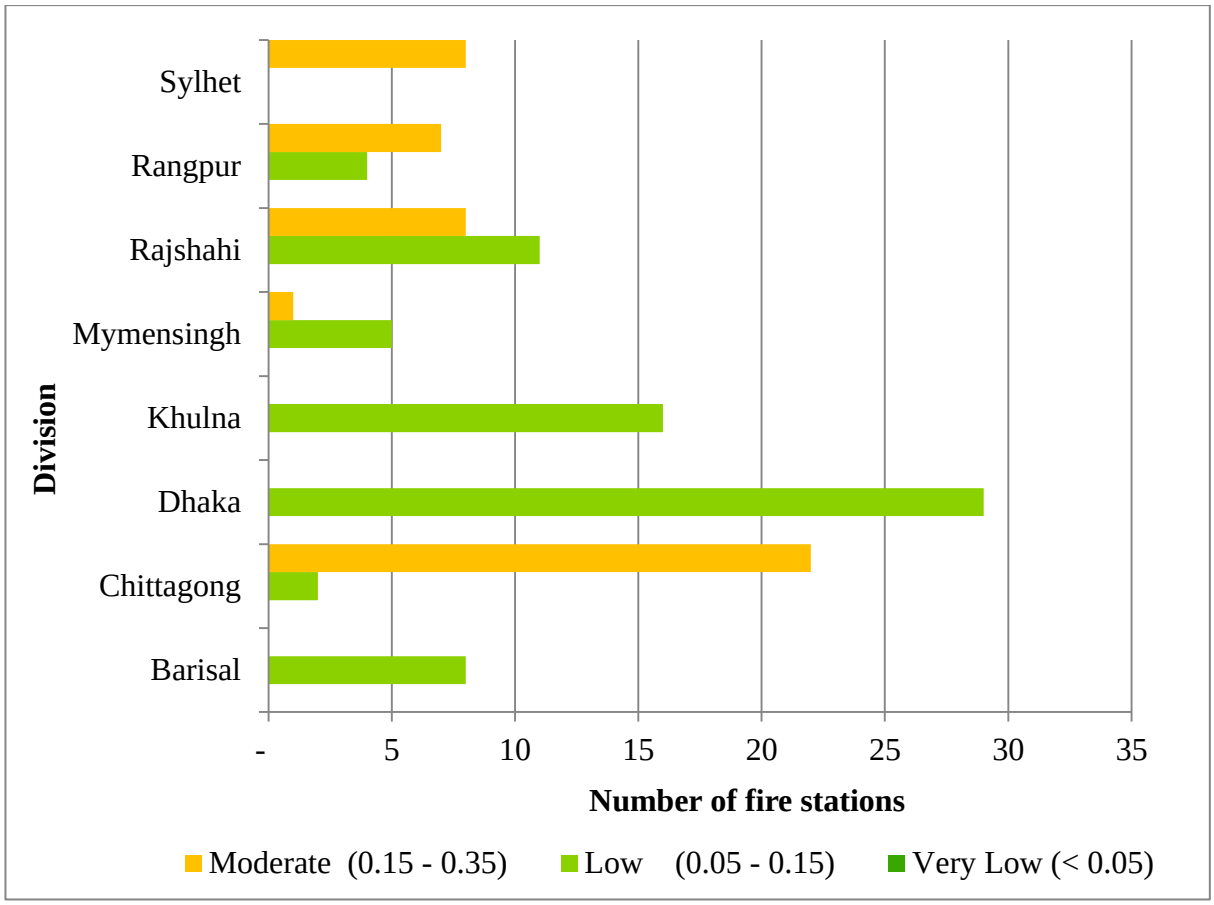

Figure 2.48: Number of Fire stations exposed to different intensity of earthquake at division level

Figure 2.49: Exposure of Fire stations to earthquake at district level

Police stations

The number of Police stations existing in different earthquake hazard levels at division level is given in table 2.32 and figure 2.50. Police stations existing in different earthquake zones at district level are shown in figure 2.51.

Table 2.32: Number of Police stations exposed to earthquake at division level

Division	PGA Value / Police stations		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	569	-
Chittagong	-	272	2,437
Dhaka	-	2,580	64
Khulna	-	3,063	-
Mymensingh	-	725	577
Rajshahi	-	1,271	942
Rangpur	-	178	1,213
Sylhet	-	-	1,586
Total	-	8,658	6,819

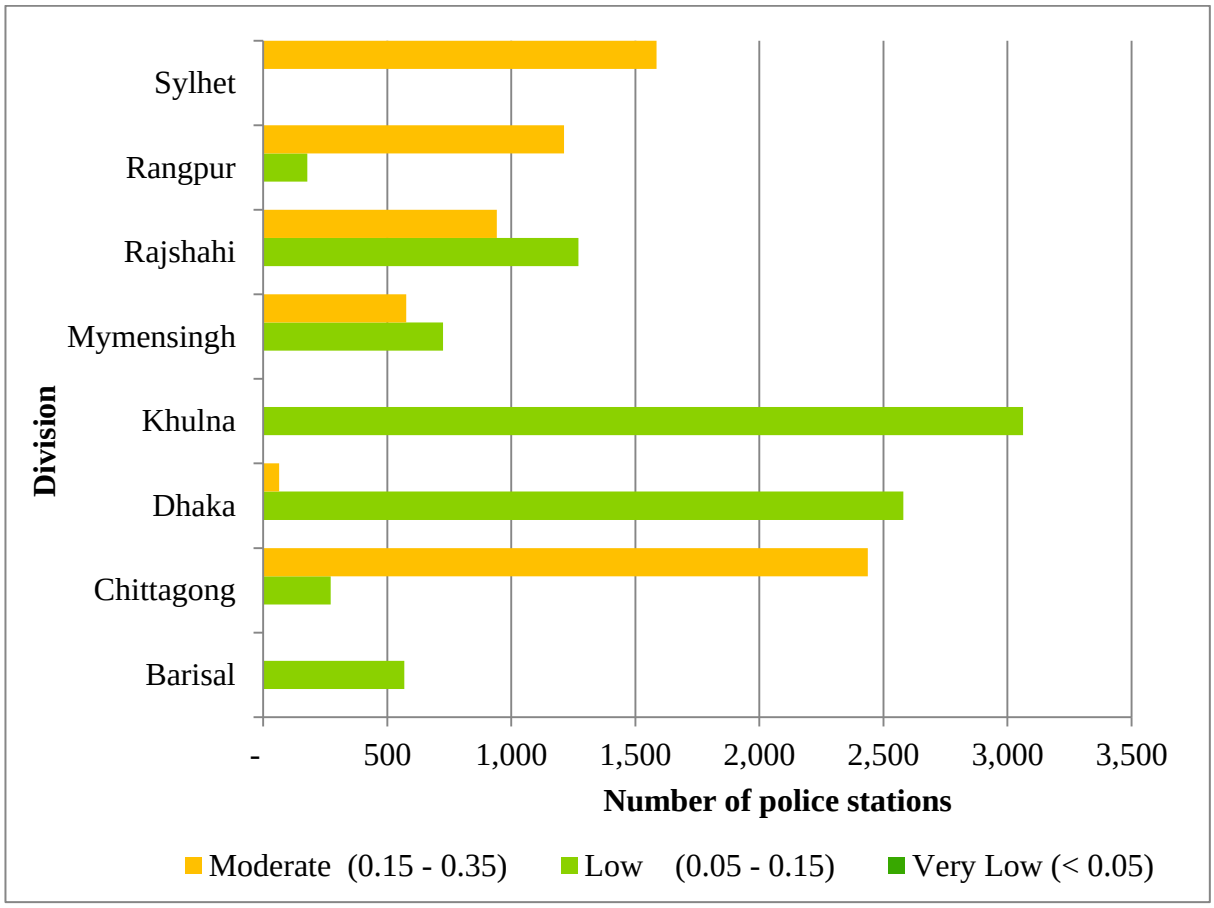

Figure 2.50: Number of Police stations exposed to different intensity of earthquake at division level

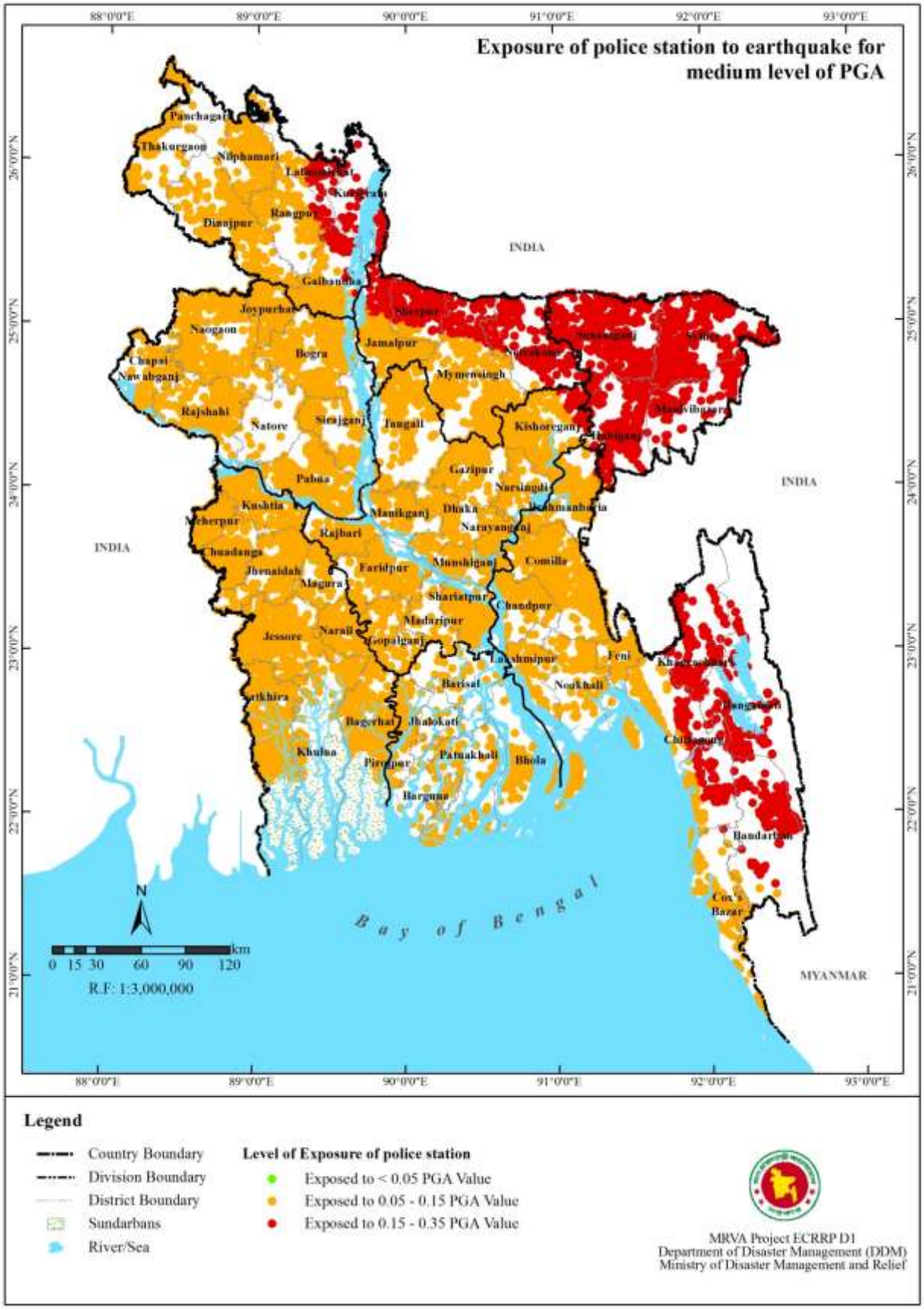

Figure 2.51: Exposure of Police stations to earthquake at district level

2.1.4.4 Cyclone Shelters `

The number of Cyclone Shelters existing in different earthquake hazard levels at division level is given in table 2.33 and figure 2.52. Cyclone Shelters existing in different earthquake zones at district level is shown in figure 2.53.

Table 2.33: Number of Cyclone Shelters exposed to earthquake at division level

Division	PGA Value / Cyclone shelters		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	1,426	-
Chittagong	-	277	1,221
Dhaka	-	236	-
Khulna	-	451	-
Total	-	2,390	1,221

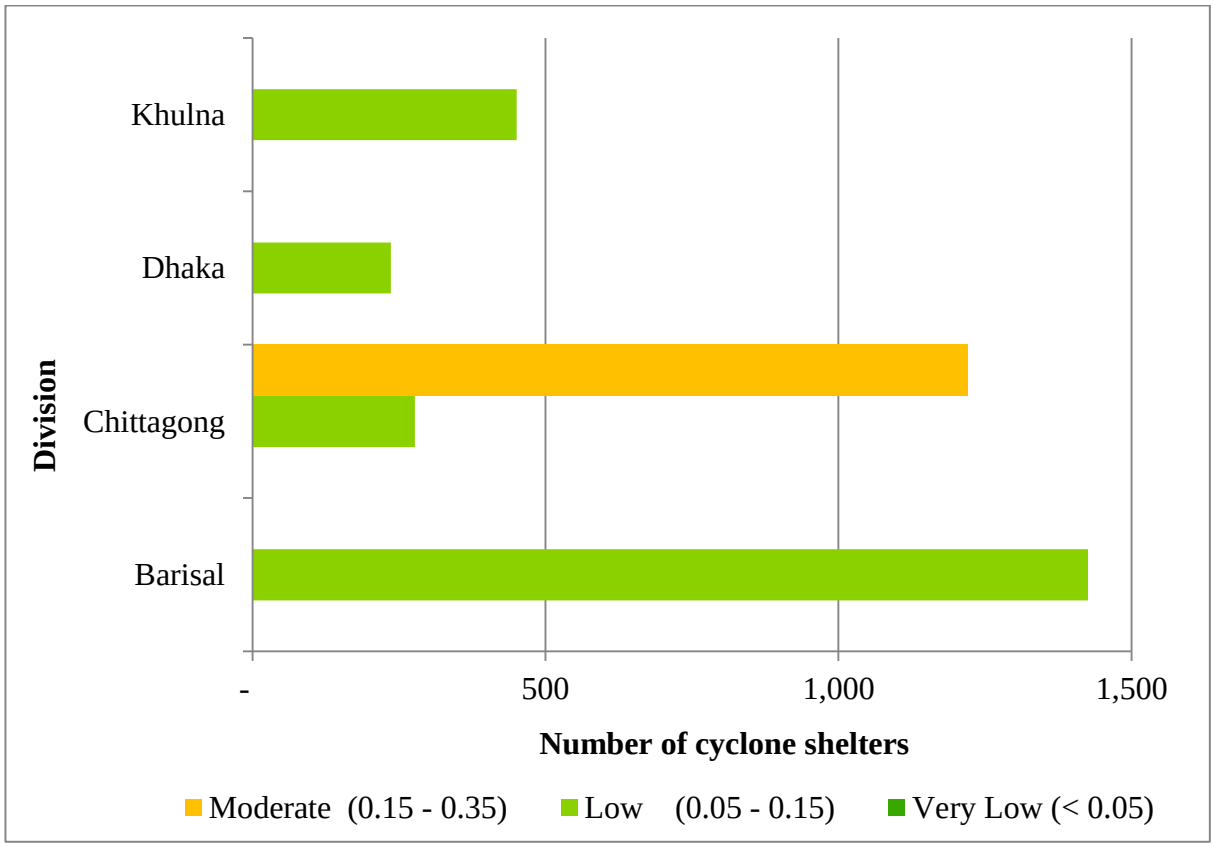

Figure 2.52: Number of Cyclone Shelters exposed to different intensity of earthquake at division level

Figure 2.53: Exposure of cyclone shelters to earthquake at district level

2.1.5 Infrastructure

2.1.5.1 Road

The type of roads existing in the database are National Highway, Regional Highway, Municipal road, Upazila road, Union road and Village roads. Combining earthquake hazard map and road network map will give exposure of types of roads to earthquake.

The length of National Highway exposed to earthquake at division level is given in table 2.34 and figure 2.54.

Table 2.34: Length of National Highway exposed to earthquake at division level

Division	PGA Value / road length (km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	159.22	-
Chittagong	-	9.12	668.08
Dhaka	-	837.57	-
Khulna	-	568.52	-
Mymensingh	-	95.39	39.71
Rajshahi	-	365.17	248.04
Rangpur	-	24.44	379.08
Sylhet	-	-	247.67
Total	-	2,059.42	1,582.58

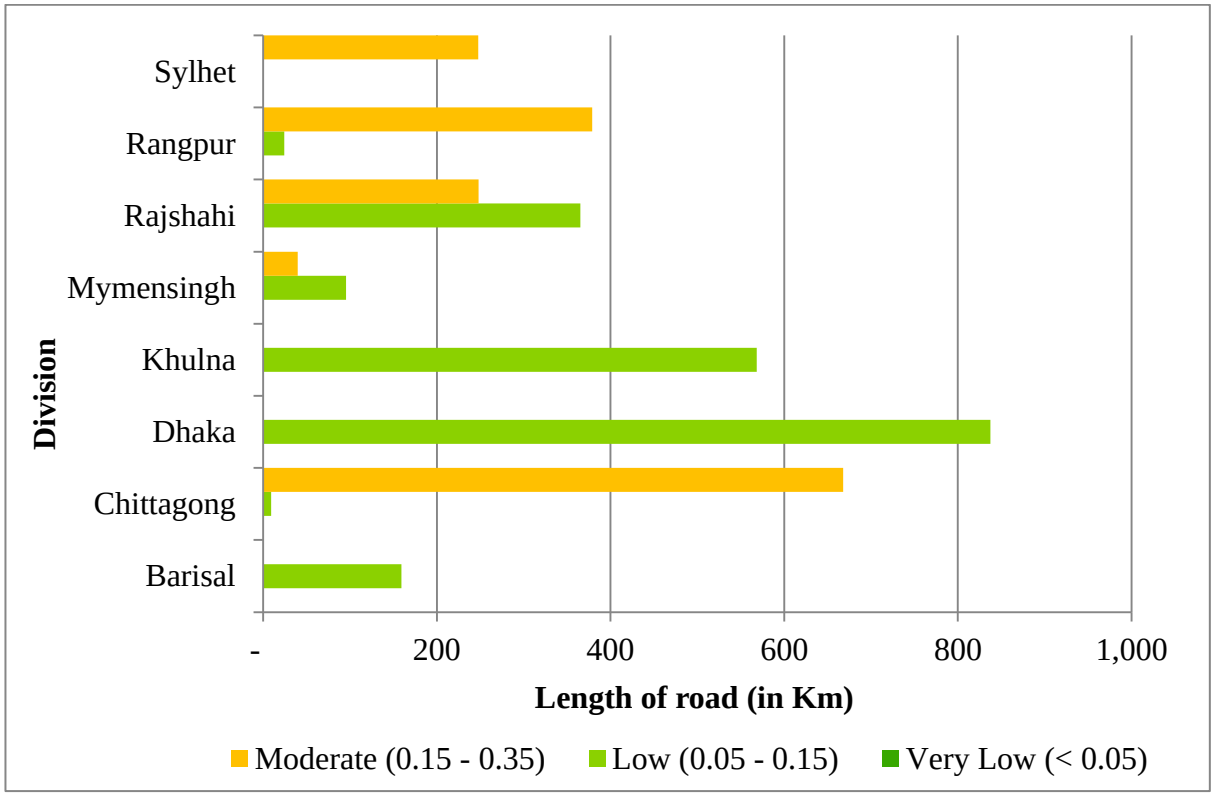

Figure 2.54: Length of National Highway exposed to different intensity of earthquake at division level

The length of Regional Highway existing in different earthquake hazard levels at division level is given in table 2.35 and figure 2.55.

Table 2.35: Length of Regional Highway exposed to earthquake at division level

Division	PGA Value / road length (Km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	812.90	-
Chittagong	-	341.33	2,339.74
Dhaka	-	1,666.91	1,727.68
Khulna	-	1,257.40	-
Mymensingh	-	591.89	504.90
Rajshahi	-	956.02	796.68
Rangpur	-	258.61	1,135.41
Sylhet	-	-	855.79
Total	-	5,885.06	7,360.20

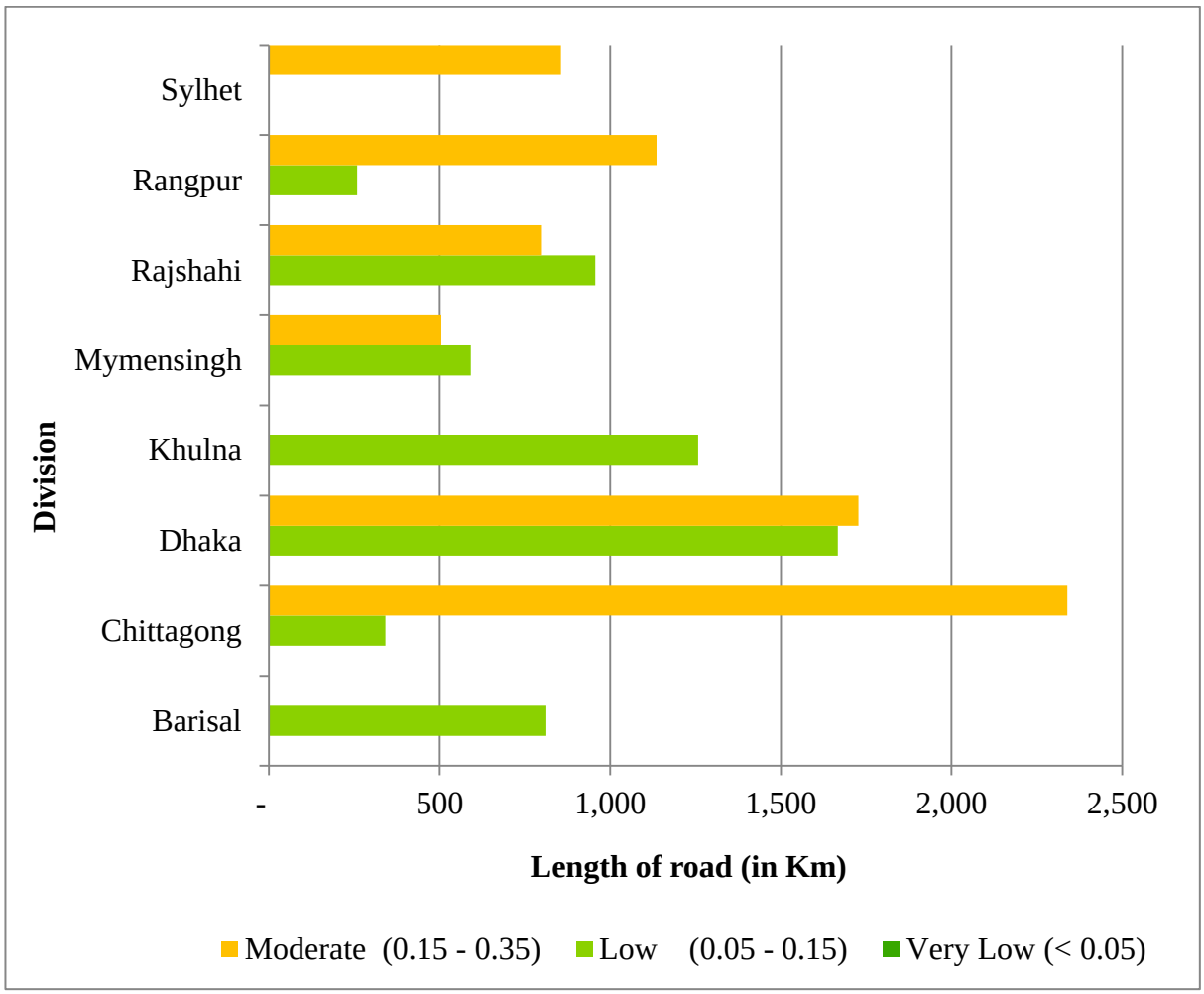

Figure 2.55: Length of Regional Highway exposed to different intensity of earthquake at division level

The length of Upazila Road existing in different earthquake hazard levels at division level is given in table 2.36 and figure 2.56.

Table 2.36: Length of Upazila Road exposed to earthquake at division level

Division	PGA Value / road length (Km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2,921.77	-
Chittagong	-	753.79	4,433.90
Dhaka	-	5,879.46	74.75
Khulna	-	5,531.51	-
Mymensingh	-	1,368.79	1,243.22
Rajshahi	-	2,867.75	2,574.69
Rangpur	-	770.44	3,731.95
Sylhet	-	-	2,356.43
Total	-	20,093.52	14,414.94

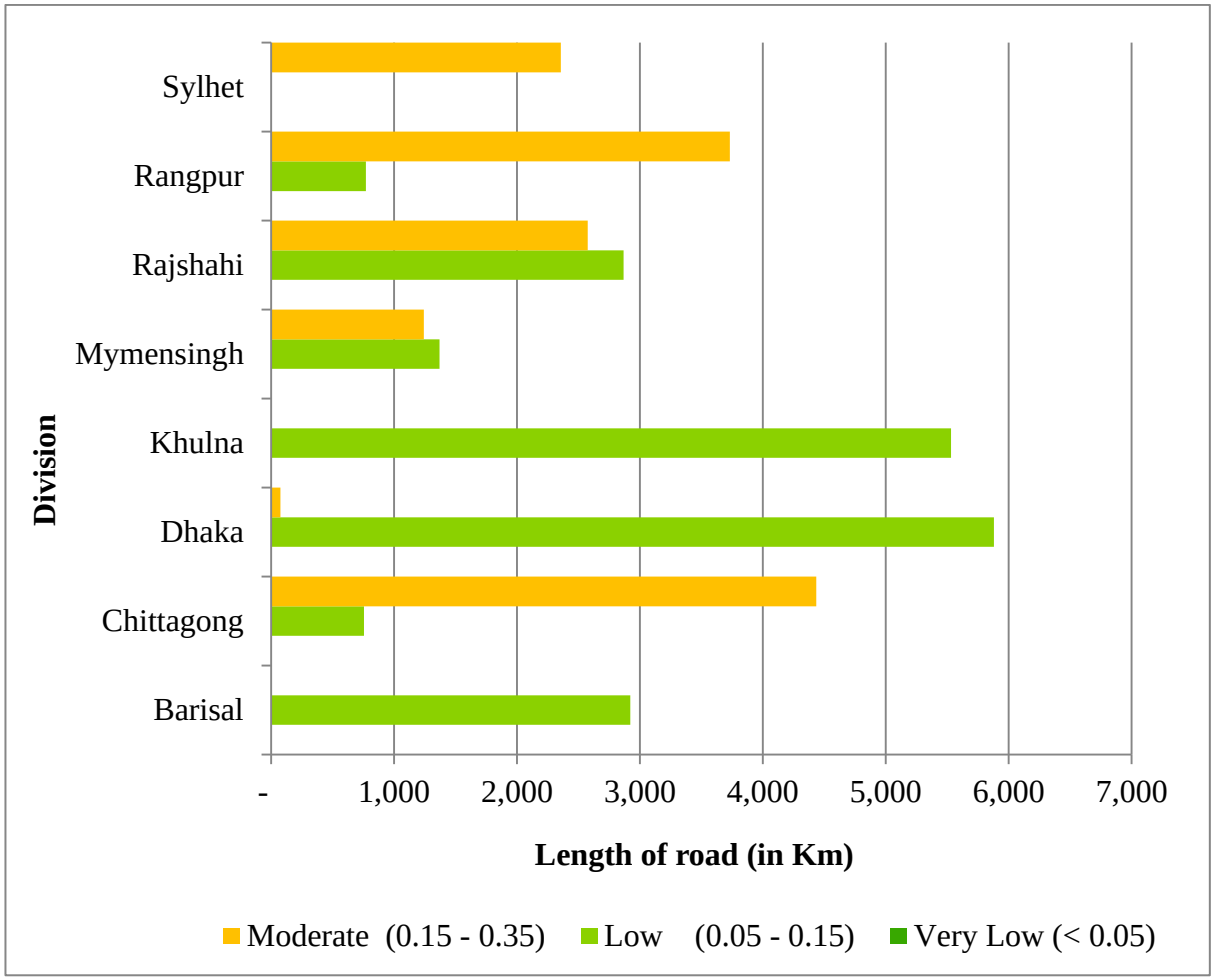

Figure 2.56: Length of Upazila Road exposed to different intensity of earthquake at division level

The length of Union Road existing in different earthquake hazard levels at division level is given in table 2.37 and figure 2.57.

Table 2.37: Length of Union Road exposed to earthquake at division level

Division	PGA Value / road length (Km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	3,845.85	-
Chittagong	-	973.03	5,539.61
Dhaka	-	6,607.55	70.08
Khulna	-	4,582.21	-
Mymensingh	-	1,950.13	1,431.84
Rajshahi	-	3,051.61	2,670.61
Rangpur	-	1,025.98	4,733.55
Sylhet	-	-	2,407.76
Total	-	22,036.35	16,853.45

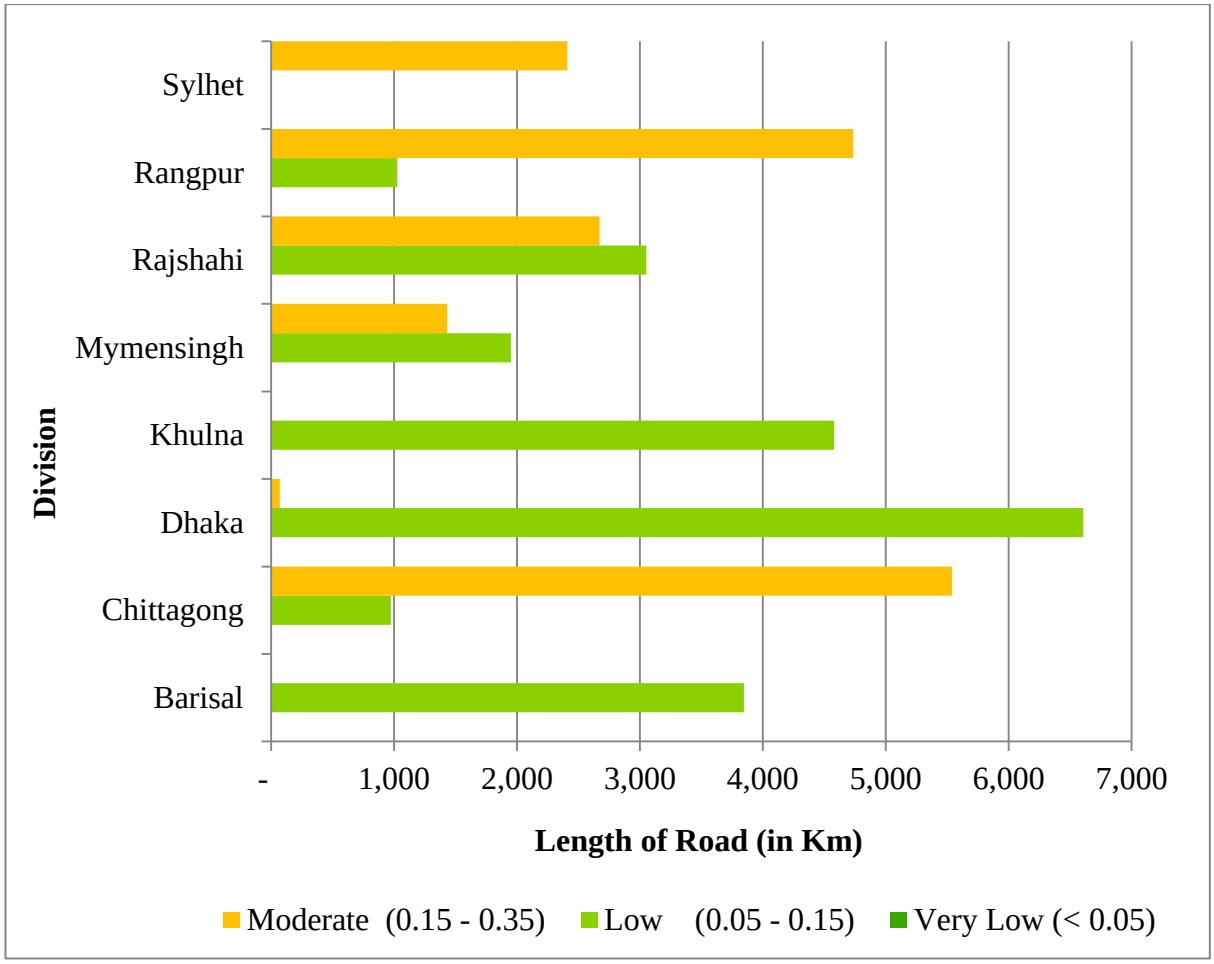

Figure 2.57: Length of Union Road exposed to different intensity of earthquake at division level

The length of Village Road existing in different earthquake hazard levels at division level is given in table 2.38 and figure 2.58.

Table 2.38: Length of Village Road exposed to earthquake at division level

Division	PGA Value / road length (Km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	14,705.98	-
Chittagong	-	4,037.82	23,489.08
Dhaka	-	22,000.37	245.62
Khulna	-	20,591.93	-
Mymensingh	-	6,244.29	4,642.47
Rajshahi	0.25	8,819.75	6,805.14
Rangpur	-	2,890.06	14,002.12
Sylhet	-	-	8,834.78
Total	0.25	79,290.20	58,019.22

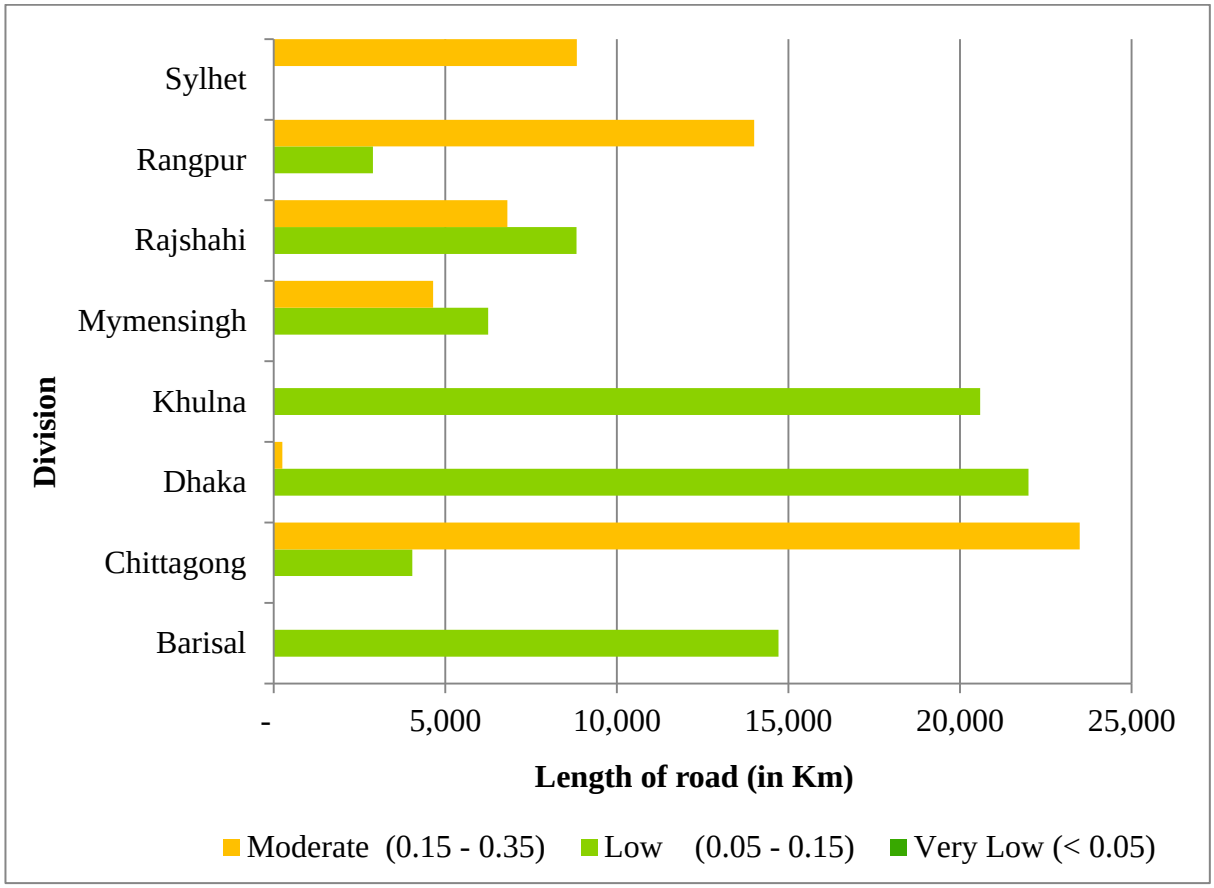

Figure 2.58 : Length of Village Road exposed to different intensity of earthquake at division level

The map different types of roads exposed to earthquake district level are shown in figure 2.59.

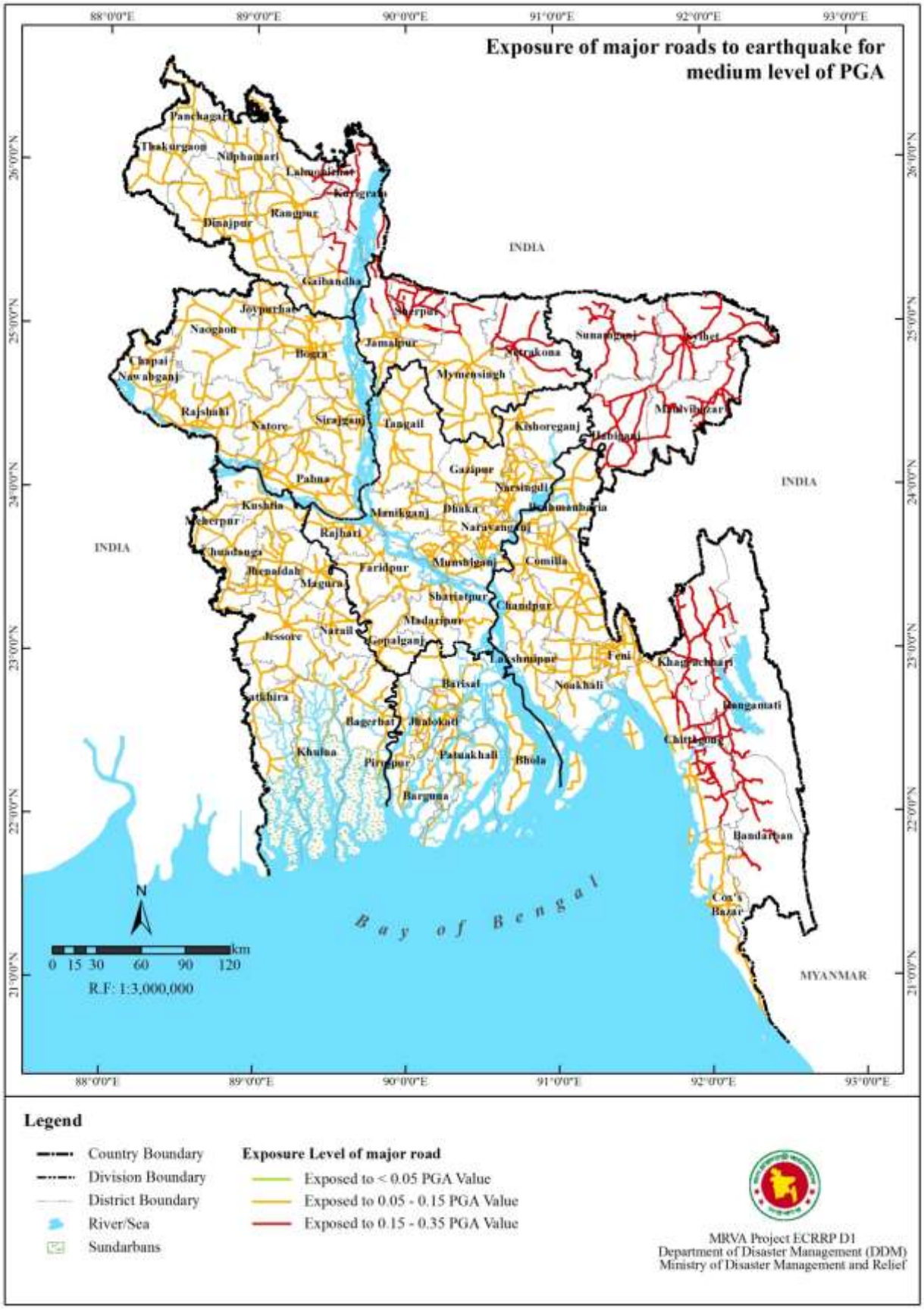

Figure 2.59: Exposure of Road network to earthquake at district level

2.1.5.2 Bridge

Combining earthquake hazard map and bridge map will give exposure of bridges exposed to earthquake.

The number of bridges exposed to earthquake at division level is given in table 2.39 and figure 2.60. The number of bridges exposed to earthquake at district level is shown in figure 2.61.

Table 2.39: Number of bridges exposed to earthquake hazard at division level

Division	PGA Value / Number of bridges		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	912	
Chittagong	-	9	2,385
Dhaka	-	15,344	282
Khulna	-	3,280	
Mymensingh	-	2,593	5,191
Rajshahi	-	1,148	219
Rangpur	-	112	1,105
Sylhet	-		10,417
Total	-	23,398	19,599

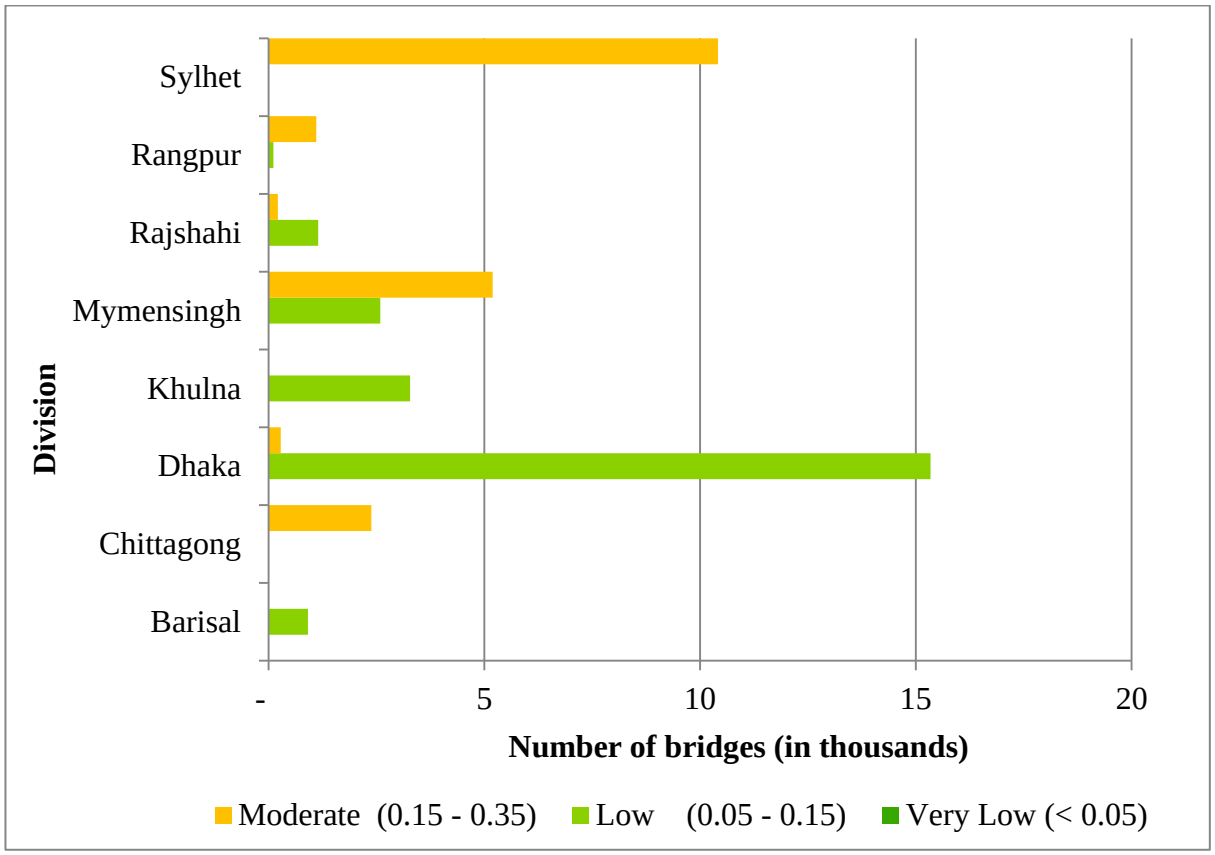

Figure 2.60: Number of bridges exposed to different intensity of earthquake hazard at division level

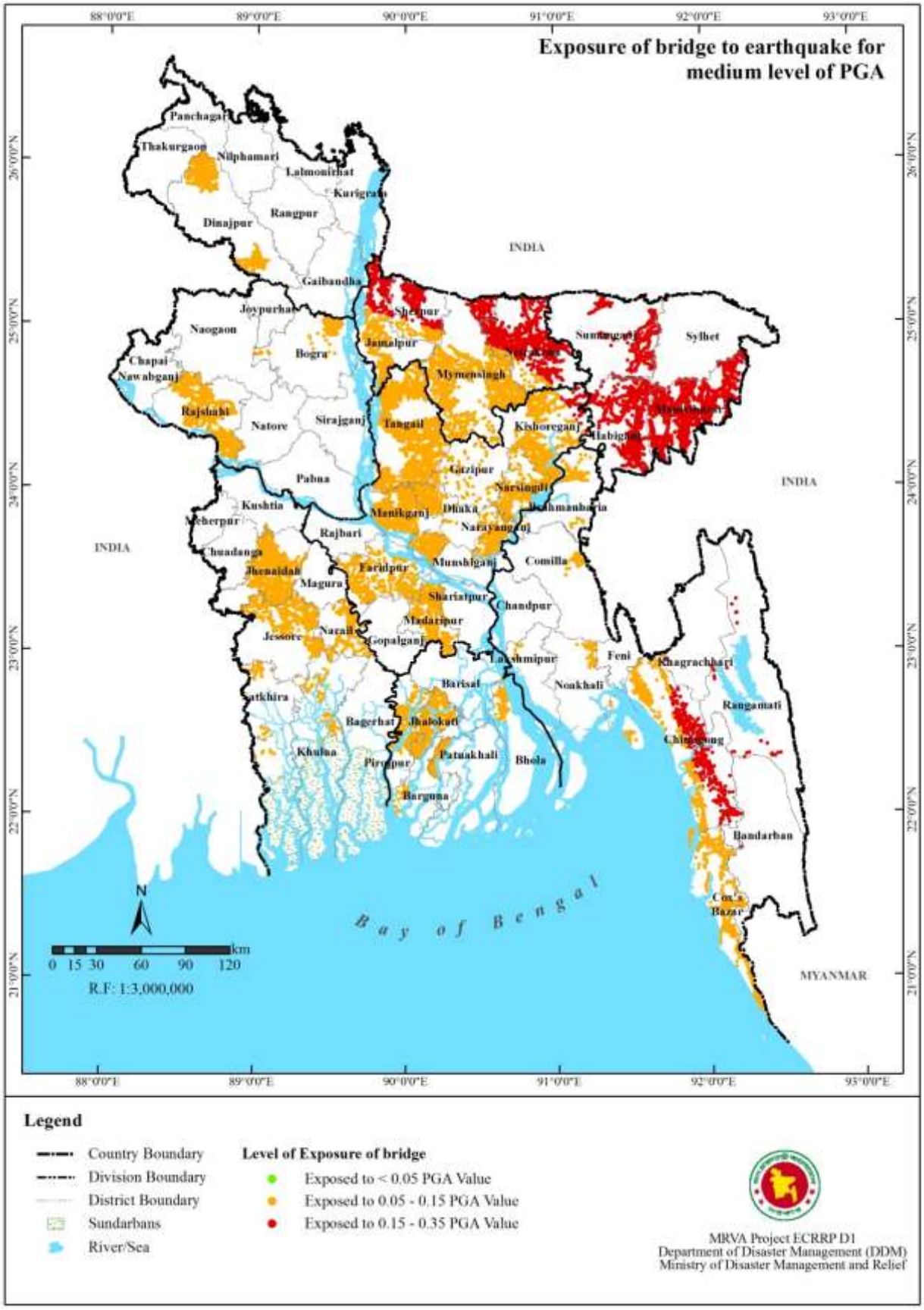

Figure 2.61: Exposure of bridges to earthquake at district level

2.1.5.3 Railway

Combining earthquake hazard map and railway network map will give provide the length of railway network (broad gauge and narrow gauge) exposed to earthquake.

The length of railway network (Broad gauge) exposed to earthquake at division level is given in table 2.40 and figure 2.62.

Table 2.40: Length of the railway (Broad gauge) exposed to earthquake at division level

Division	PGA Value / railway length (Km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	-	-
Dhaka	-	232.65	0
Khulna	-	287.90	-
Mymensingh	-	0	0
Rajshahi	-	220.06	136.45
Rangpur	-	-	118.46
Sylhet	-	-	-
Total	-	740.61	254.91

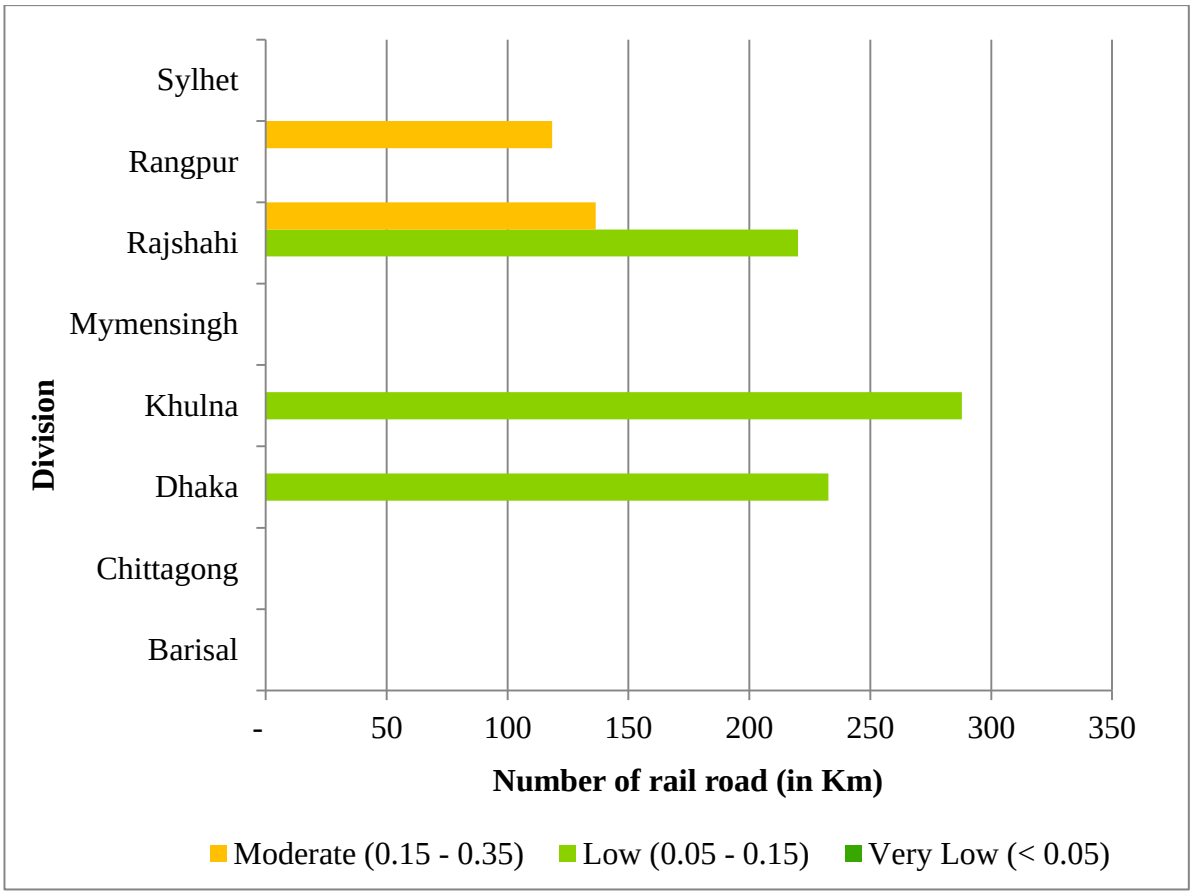

Figure 2.62: Length of the railway (Broad gauge) exposed to different intensity of earthquake at division level

The length of railway network (Narrow Gauge) existing in different earthquake hazard levels at division level is given in table 2.41 and figure 2.63.

Table 2.41: Length of the railway (Narrow Gauge) exposed to earthquake at division level

Division	PGA Value / railway length (Km)		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	36.29	421.55
Dhaka	-	235.30	0
Khulna	-	-	-
Mymensingh	-	236.83	79.48
Rajshahi	-	-	68.33
Rangpur	-	101.06	360.85
Sylhet	-	-	280.17
Total	-	609.49	1,210.37

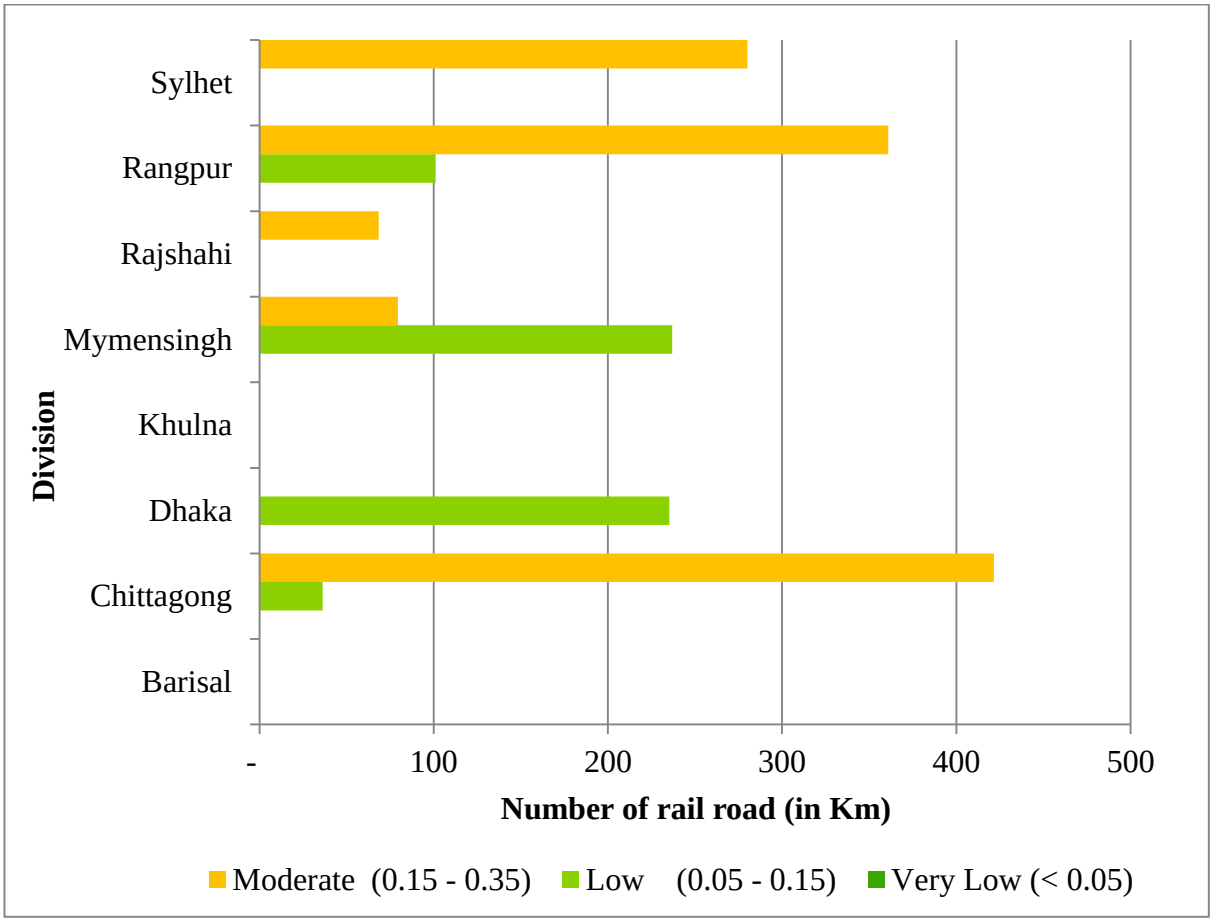

Figure 2.63: Length of the railway (Narrow Gauge) exposed to different intensity of earthquake at division level

The railway network exposed to earthquake at district level is shown in figure 2.64.

Figure 2.64: Exposure of railway network to earthquake at district level

2.1.5.4 Air, Sea and River Ports

Combining earthquake hazard map and Air, Sea and River ports map will provide the number of ports exposed to earthquake hazard levels.

The number of Airports exposed to earthquake at division level is given in table 2.42.

Table 2.42: Number of Airports exposed to earthquake at division level

Division	PGA Value / Air ports		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2	-
Chittagong	-	-	3
Dhaka	-	2	-
Khulna	-	1	-
Mymensingh	-	-	-
Rajshahi	-	2	1
Rangpur	-	1	2
Sylhet	-	-	2
Total	-	8	8

The number of Sea ports existing in different earthquake hazard levels at division level is given in table 2.43.

Table 2.43: Number of Sea ports exposed to earthquake at division level

Division	PGA Value / Sea ports		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	-	-
Chittagong	-	-	1
Dhaka	-	-	-
Khulna	-	1	-
Mymensingh	-	-	-
Rajshahi	-	-	-
Rangpur	-	-	-
Sylhet	-	-	-
Total	-	1	1

The number of River ports existing in different earthquake hazard levels at division level is given in table 2.44.

Table 2.44: Number of River ports exposed to earthquake at division level

Division	PGA Value / River pots		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	2	-
Chittagong	-	-	-
Dhaka	-	1	-
Khulna	-	-	-
Mymensingh	-	-	-
Rajshahi	-	-	-
Rangpur	-	-	-
Sylhet	-	-	-
Total	-	3	-

2.1.5.5 Power

Combining earthquake hazard map and Power sector (Power stations, Power sub-stations) map will provide the number of power stations, Power sub-stations exposed to earthquake.

The number of Power stations exposed to earthquake at division level is given in table 2.45 and figure 2.65.

Table 2.45: Number of Power stations exposed to earthquake at division level

Division	PGA Value / Power stations		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	1	-
Chittagong	-	1	4
Dhaka	-	2	2
Khulna	-	2	
Mymensingh	-		
Rajshahi	-	1	-
Rangpur	-	1	3
Sylhet	-	-	3
Total	-	8	12

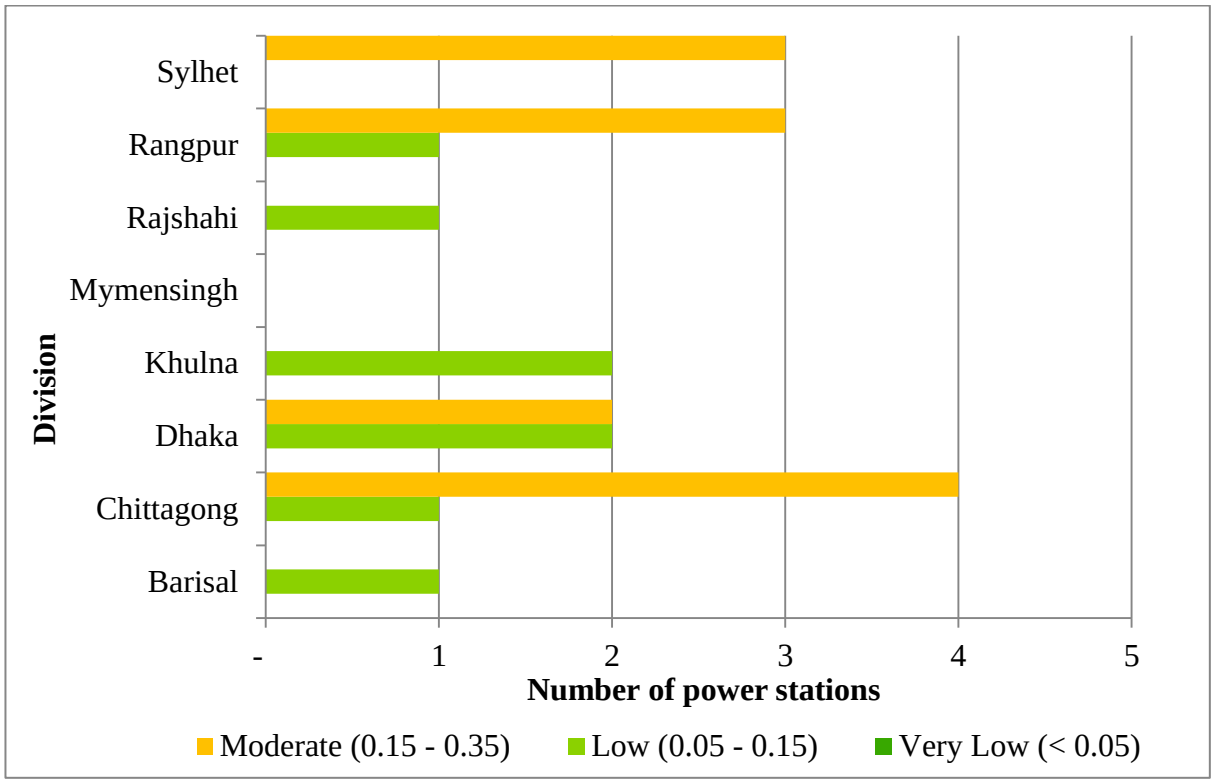

Figure 2.65: Number of Power stations exposed to different intensity of earthquake at division level

Power stations exposed to earthquake at district level are shown in figure 2.66.

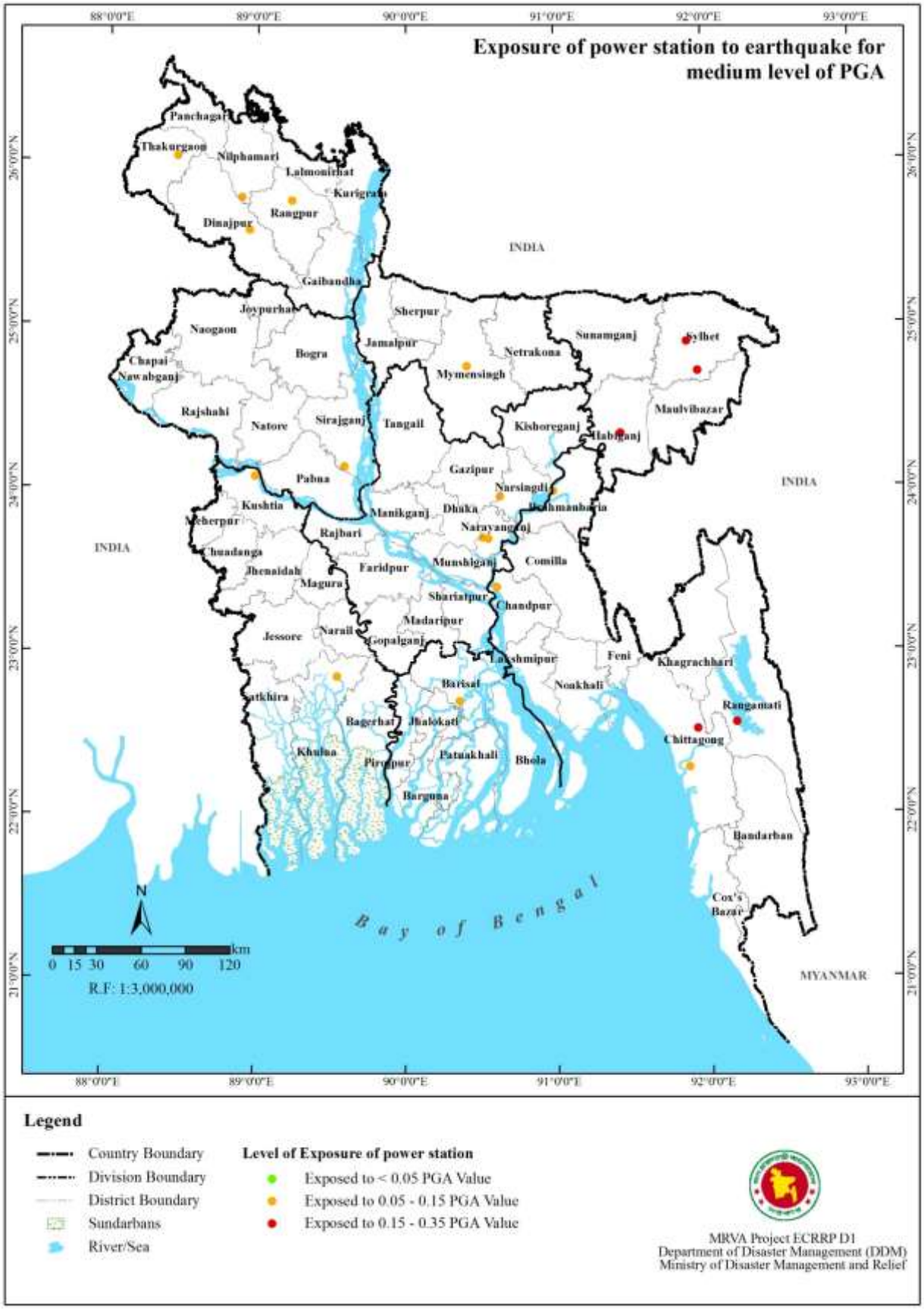

Figure 2.66: Exposure of Power stations to earthquake at district level

The number of Power Sub Stations existing in different earthquake hazard levels at division level is given in table 2.46 and figure 2.67.

Table 2.46: Number of Power sub-stations exposed to earthquake at division level

Division	PGA Value / Power sub-stations		
	Very Low (< 0.05)	Low (0.05 - 0.15)	Moderate (0.15 - 0.35)
Barisal	-	3	-
Chittagong	-	1	12
Dhaka	-	17	2
Khulna	-	11	-
Mymensingh	-	-	2
Rajshahi	-	6	4
Rangpur	-	-	4
Sylhet	-	-	3
Total	-	38	27

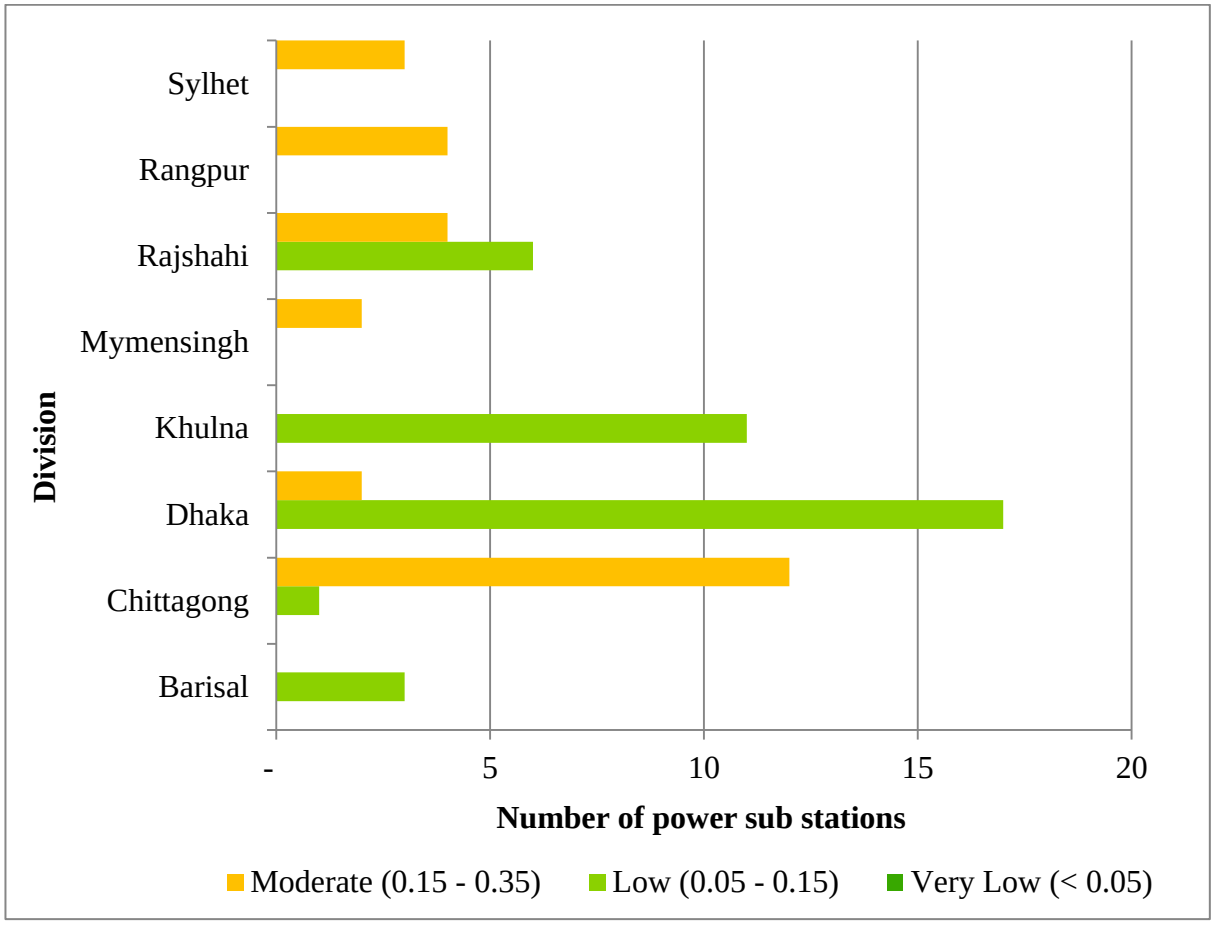

Figure 2.67: Number of Power sub-stations exposed to different intensity of earthquake at division level

Power sub stations existing in different earthquake hazard levels at district level is shown in figure 2.68.

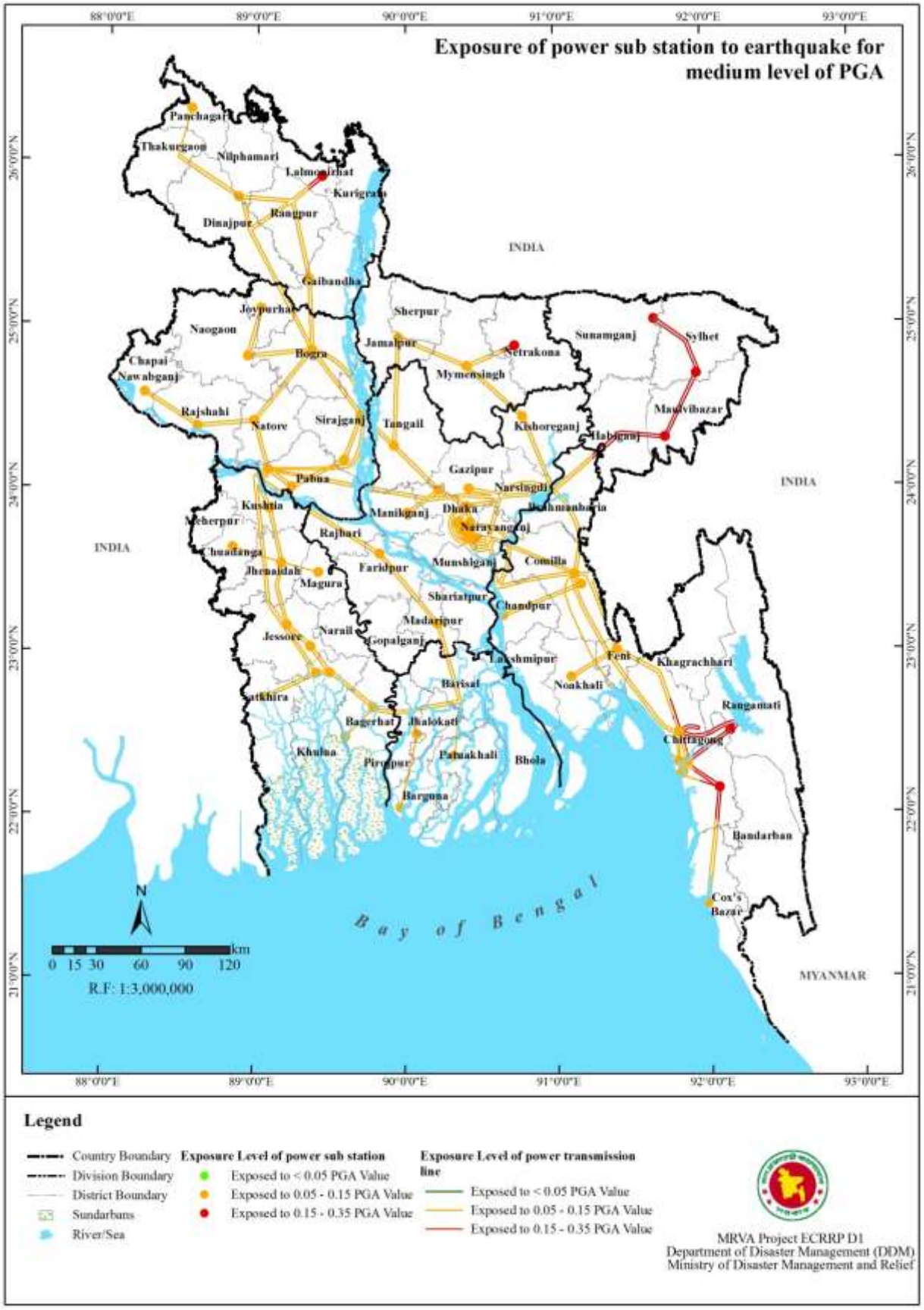

Figure 2.68: Exposure of Power sub-stations to earthquake at district level

2.2 Risk Assessment

2.2.1 Household structures

The damage curves representing the vulnerability of household structures are developed based on the literature and limited field data analysis (more details in Annexure – I: Probabilistic damage functions report). The damage curves developed for household structures due to earthquake is given as table 2.47.

Table 2.47: Damage function table for household structures due to earthquake

Earthquake Hazard Categories	PGA Range (g)	Representative PGA (g)	Damage Rates (%)			
			Jhupri	Katcha	Semi-Pucca & Pucca-L	Pucca-M & Pucca-H
Very Low	< 0.05	0.03	~0	~0	3	~0
Low	0.05 – 0.15	0.1	5	5	15	5
Medium	0.15 – 0.35	0.25	15	15	35	20
High	0.35 – 0.5	0.42	25	25	50	40
Very High	>0.5	0.6	30	30	65	55

Using the above damage function table and exposure of household structures to different range of PGA, possible % of damage of household structures is calculated. The percentage of damages are grouped into 5 risk levels (D0: 0, D1:1-15 %, D2: 15-35%, D3:35-60%, D4:>60%) as explained in section 1.6.

Risk level of Pucca household structures at division level is shown in table 2.48 and figure 2.69. Pucca household structures at district level are shown in figure 2.70.

Table 2.48: Number of Pucca household structures at different risk levels to earthquake at division level

Division Name	**Risk level / household structures**		
	D0 (No Damage)	**D1 (0%-15%)**	**D2 (15%-35%)**
Barisal	-	77,994	-
Chittagong	-	402,722	322,524
Dhaka	-	1,670,840	3,013
Khulna	-	509,340	-
Mymensingh	-	43,752	21,420
Rajshahi	136	307,047	-
Rangpur	-	84,614	26,238
Sylhet	-	802	222,550
Total	136	2,583,641	1,109,262

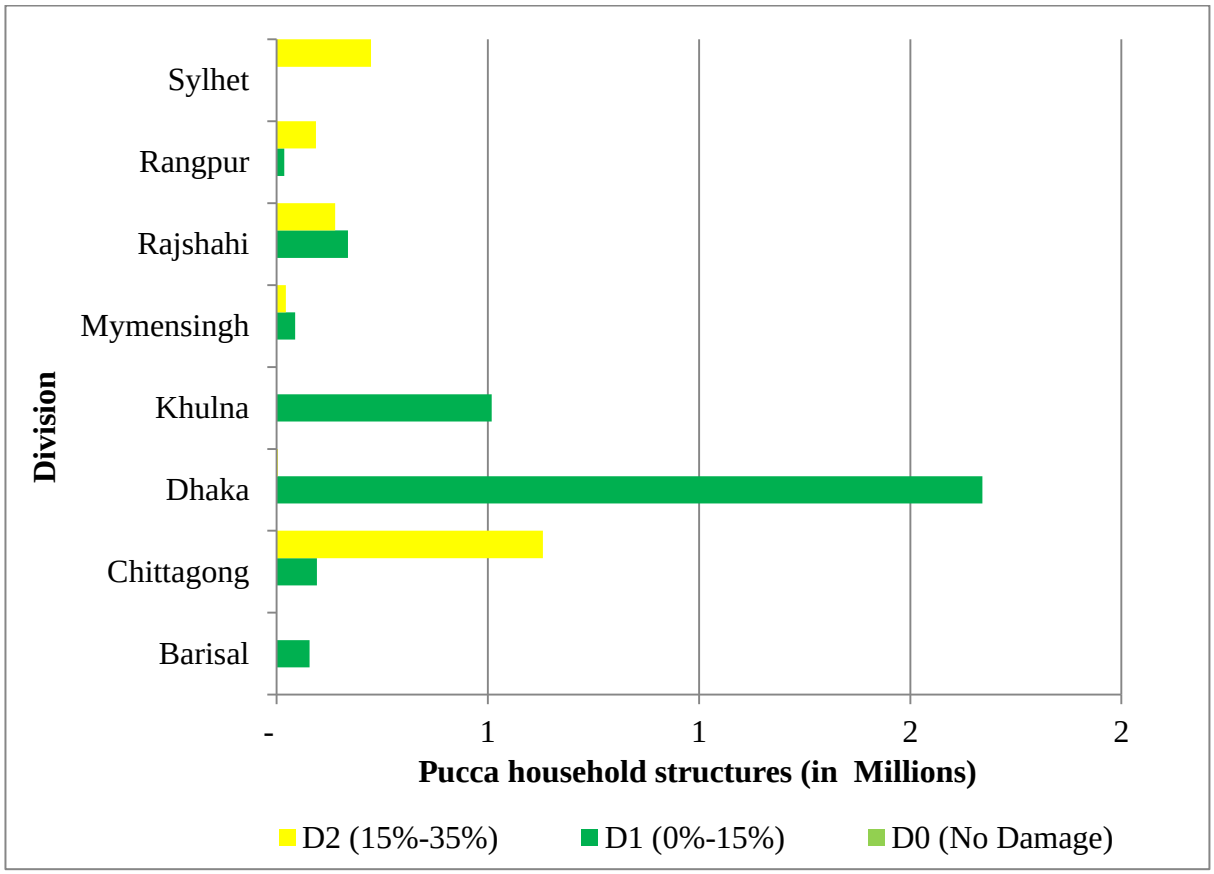

Figure 2.69: Number of Pucca household structures at different risk levels to earthquake at division level

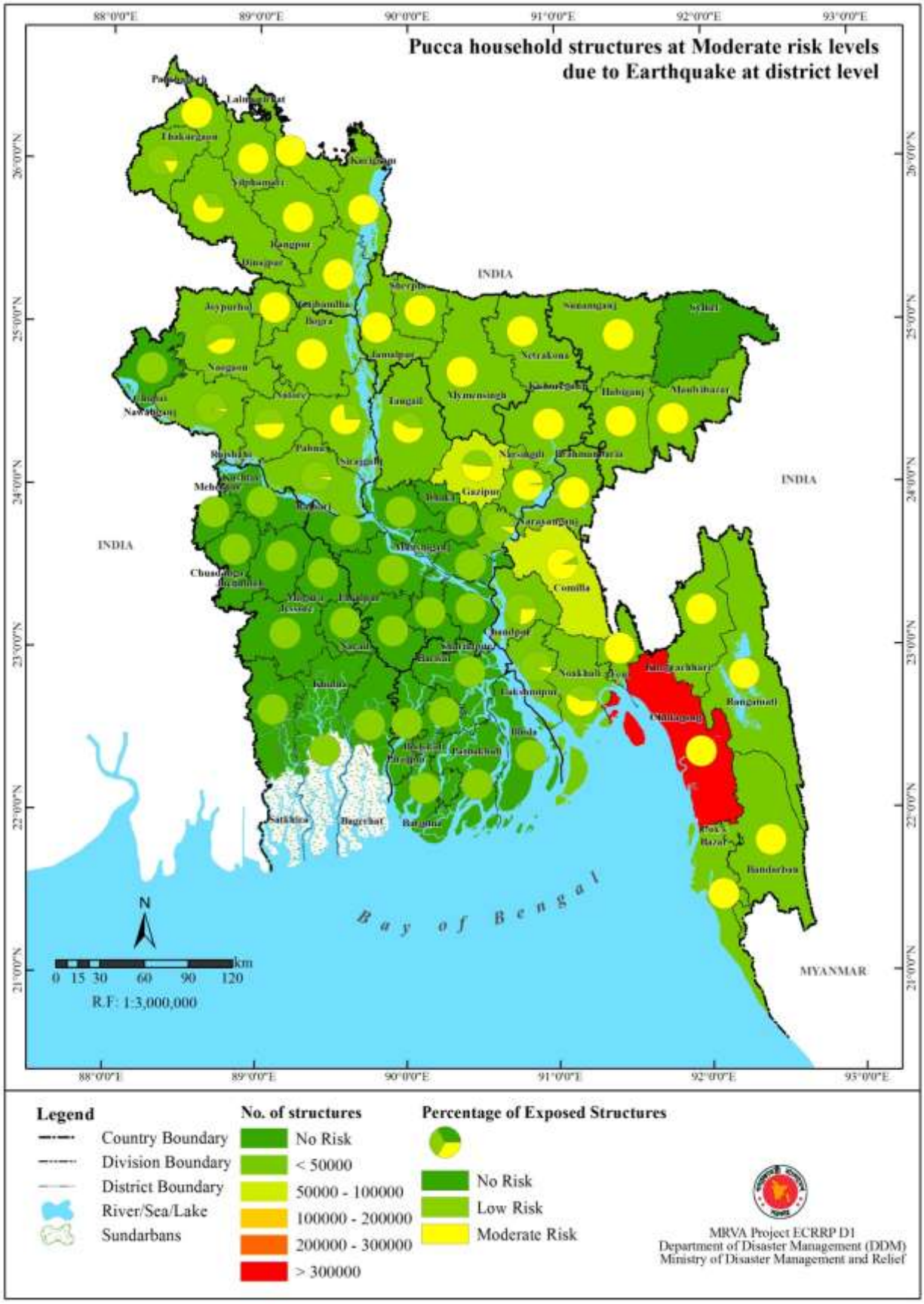

Figure 2.70: Number of Pucca household structures at Moderate Risk Level due to earthquake at district level

Risk level of Semi-Pucca household structures damaged at division level is shown in table 2.49 and Figure 2.71.

Table 2.49: Number of semi-Pucca household structures at different risk levels to earthquake at division level

Division Name	Risk level / household structures		
	D0 (No Damage)	D1 (0%-15%)	D2 (15%-35%)
Barisal	-	152,933	-
Chittagong	-	440,610	352,867
Dhaka	-	2,152,295	12,374
Khulna	-	1,023,972	-
Mymensingh	-	157,742	100,403
Rajshahi	-	965,489	-
Rangpur	-	430,694	133,555
Sylhet	-	1,490	413,444
Total		4,213,336	2,124,545

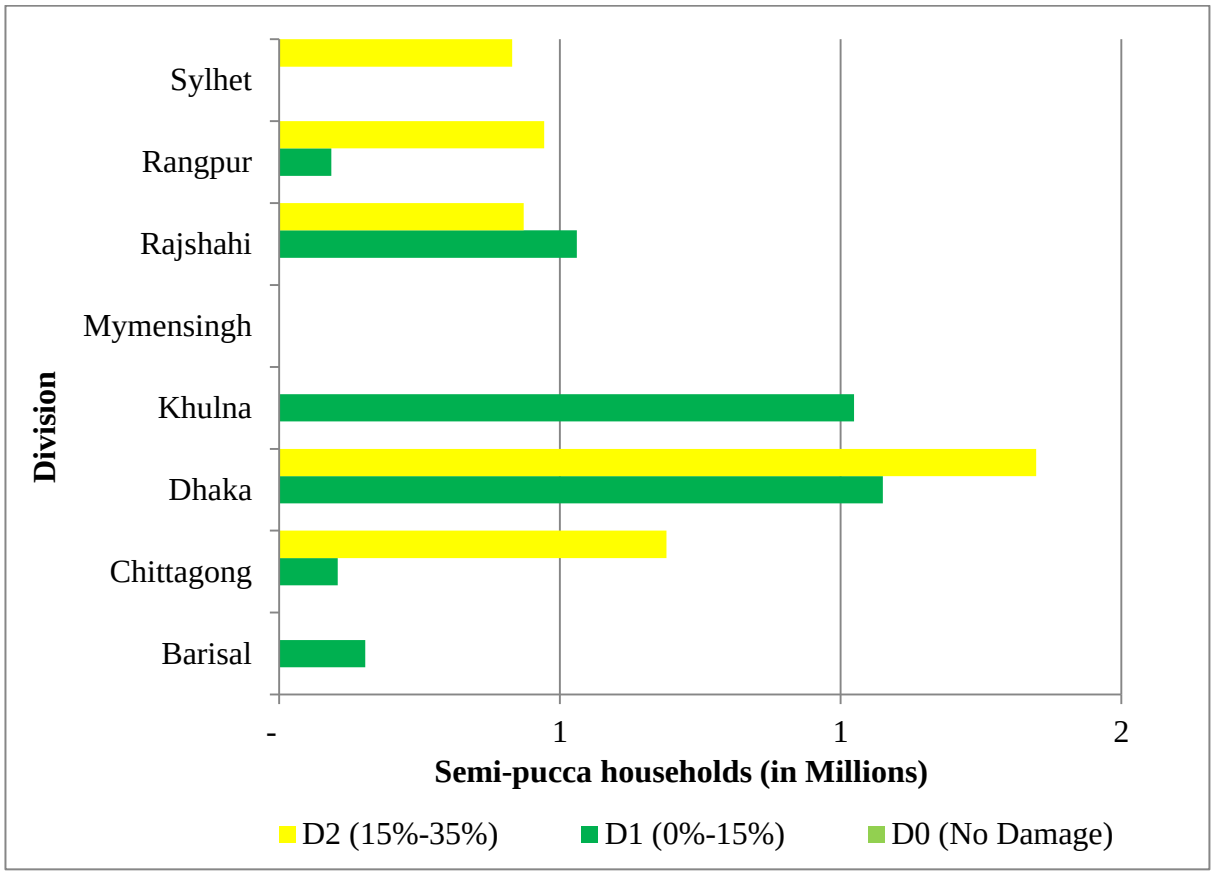

Figure 2.71: Number of semi-pucca household structures at different risk levels to earthquake at division level

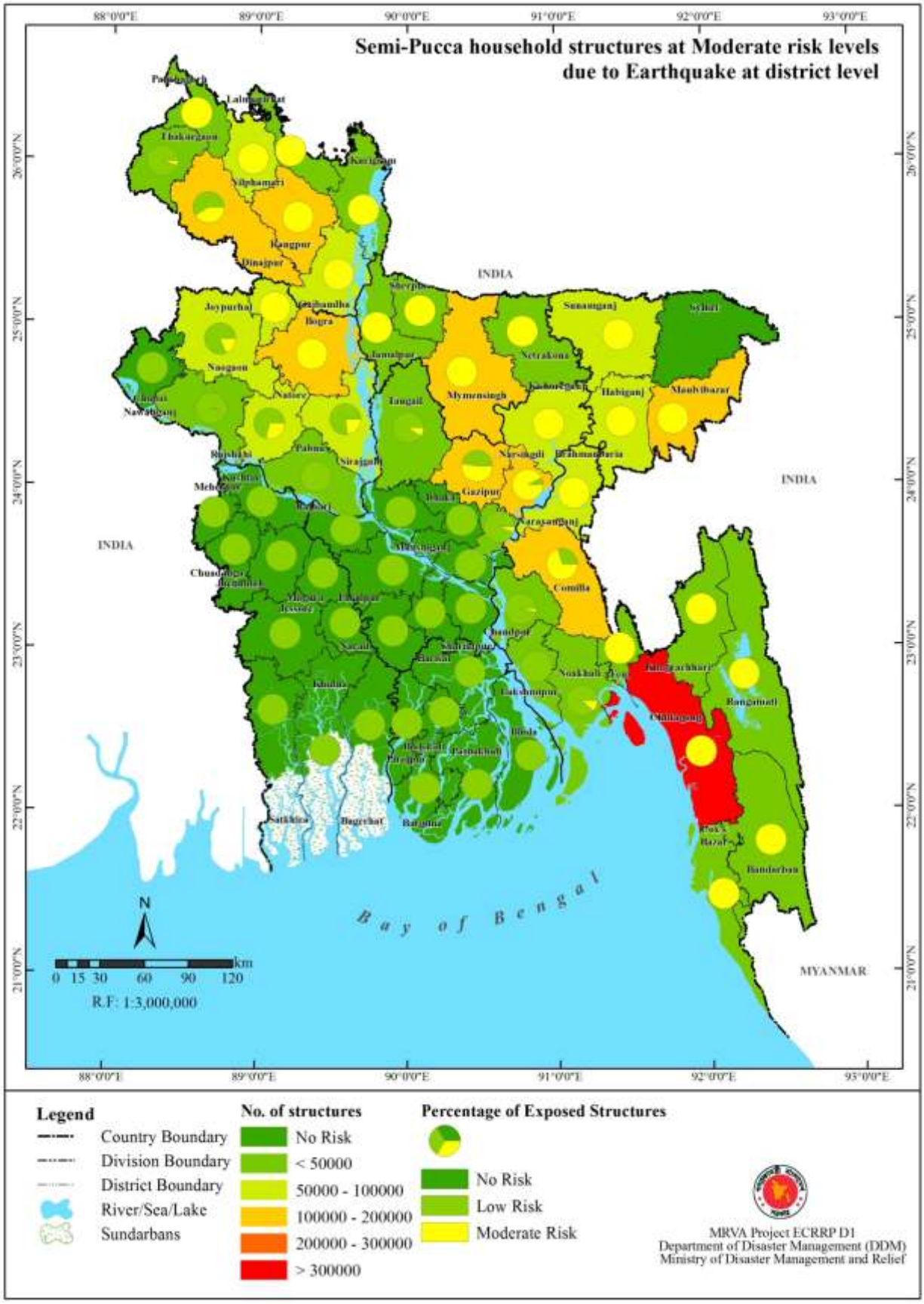

Figure 2.72: Number of Semi-Pucca household structures at Moderate Risk Level due to earthquake at district level

Risk level of Kutcha household structures damaged at division level is shown in table table 2.50 and figure 2.73.

Table 2.50: Number of Kutcha household structures at different risk levels to earthquake at division level

Division Name	Risk level / household structures		
	D0 (No Damage)	D1 (0%-15%)	D2 (15%-35%)
Barisal	-	1,572,238	-
Chittagong	-	3,881,987	-
Dhaka	-	4,431,534	-
Khulna	-	2,095,162	-
Mymensingh	-	2,116,618	-
Rajshahi	1,367	3,084,008	-
Rangpur	-	3,024,928	-
Sylhet	-	1,099,584	-
Total	1,367	21,306,485	0

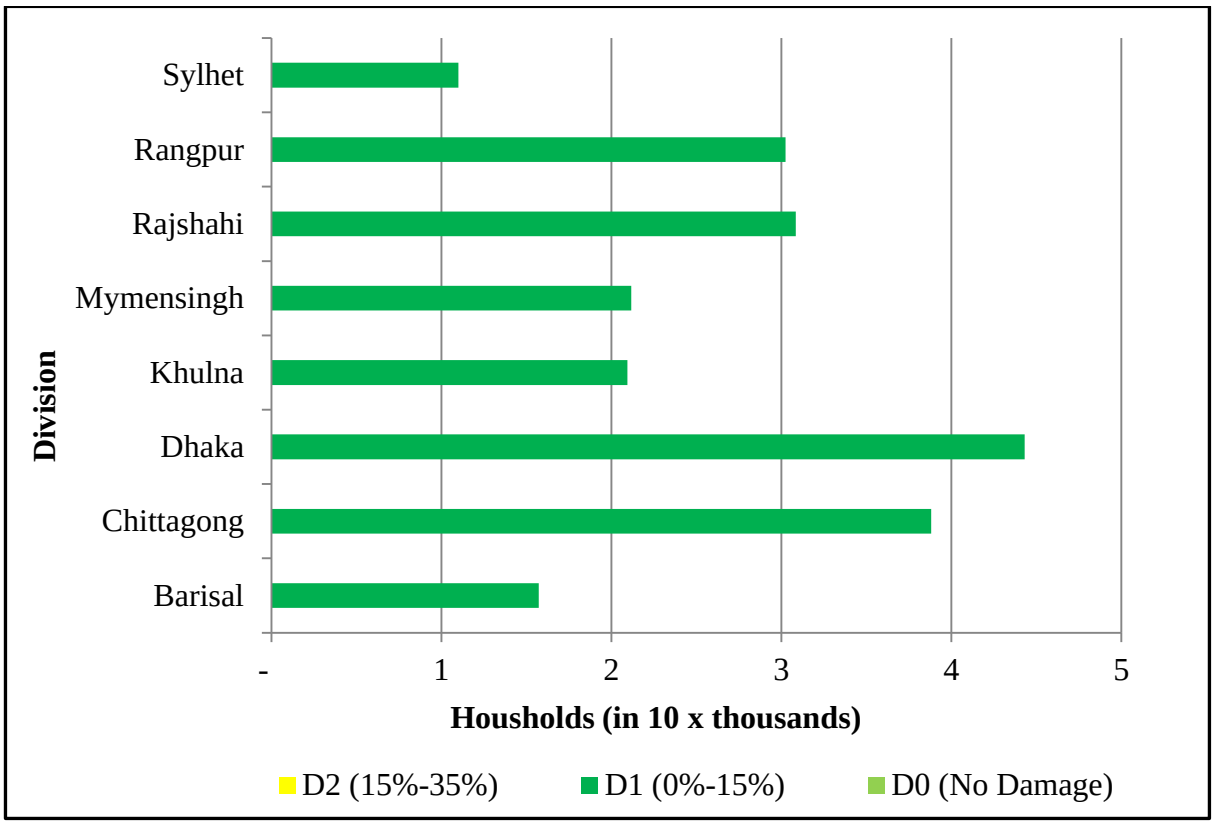

Figure 2.73: Number of Kutcha household structures at different risk levels to earthquake at division level

Risk level of Jhupri household structures of at division level is shown in 2.51 and figure 2.74.

Table 2.51: Number of Jhupri household structures at different risk levels to earthquake at division level

Division Name	Risk level / household structures		
	D0 (No Damage)	D1 (0%-15%)	D2 (15%-35%)
Barisal	-	59,673	-
Chittagong	-	225,511	-
Dhaka	-	129,869	-
Khulna	-	111,309	-
Mymensingh	-	99,457	-
Rajshahi	57	128,723	-
Rangpur	-	117,636	-
Sylhet	-	53,020	-
Total	57	925,217	0

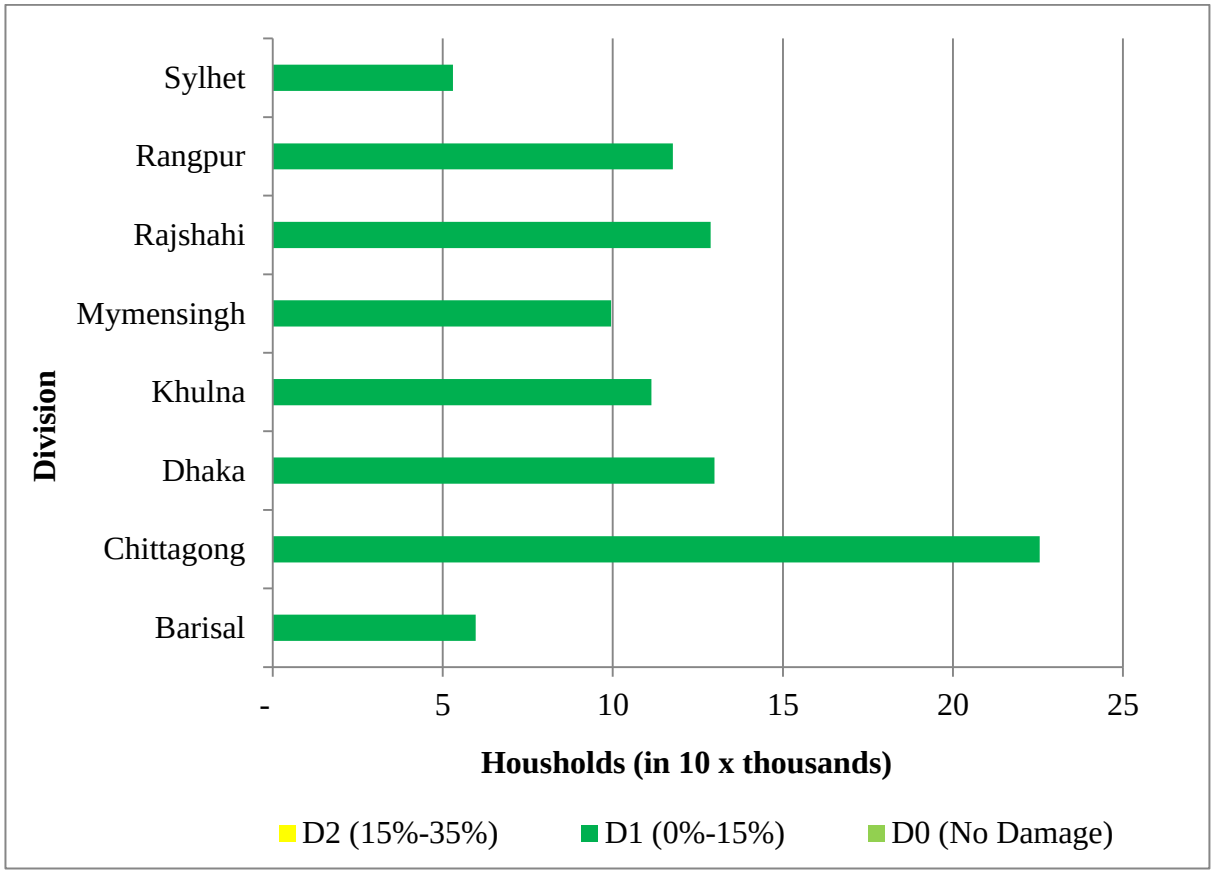

Figure 2.74: Number of Jhupri household structures at different risk levels to earthquake at division level

2.2.2 Infrastructure

Elements at risk considered in infrastructure category are road, bridges, Railways, Air, sea and river ports and Power stations. The vulnerability of road types is developed in this project.

2.2.2.1 Vulnerability / Damage curves of road

The damage function table representing the vulnerability of different types of road is developed based on the literature and limited field data analysis (more details in Annexure – I: Probabilistic damage functions report). The damage curves developed for different types of road is given in table 2.52.

Table 2.52: Damage function table for different types of road to earthquake

FEMA (2013) Road Type			Major	Major	Urban	Urban	Urban	Urban
Earthquake Hazard Categories	PGA Range (g)	Representative PGA (g)	National Highway	Regional Highway	City Road	Upazila Road	Union Road	Village Road
Very Low	< 0.05	0.03	~0	~0	~0	2	2	2
Low	0.05 – 0.15	0.1	2	5	10	15	15	15
Medium	0.15 – 0.35	0.25	12	20	30	40	40	40
High	0.35 – 0.5	0.42	50	60	70	80	80	80
Very High	>0.5	0.6	70	80	85	90	90	90

Using the above damage function table and exposure of different types of road to different range of PGA, possible % of physical damage to different types of road is calculated. The percentage of damage is grouped into 5 risk levels (D0: 0, D1:1-15 %, D2: 15-35%, D3:35-60%, D4:>60%) as explained in section 1.6.

Length of National Highway in different damage categories due to earthquake hazard at division level is shown in table 2.53 and figure 2.75.

Table 2.53: Length of National Highway in different risk levels to earthquake at division level

Division	**Risk levels / length of road (Km)**			
	No Damage (D0)	**Low (D1)**	**Moderate (D2)**	**High (D3)**
Barisal	-	159.22	-	-
Chittagong	-	677.20	-	-
Dhaka	-	837.67	-	-
Khulna	-	568.52	-	-
Mymensingh	-	135.11		
Rajshahi	-	613.21	-	-
Rangpur	-	403.52	-	-
Sylhet	-	247.67	-	-
Total	-	3,642.11	-	-

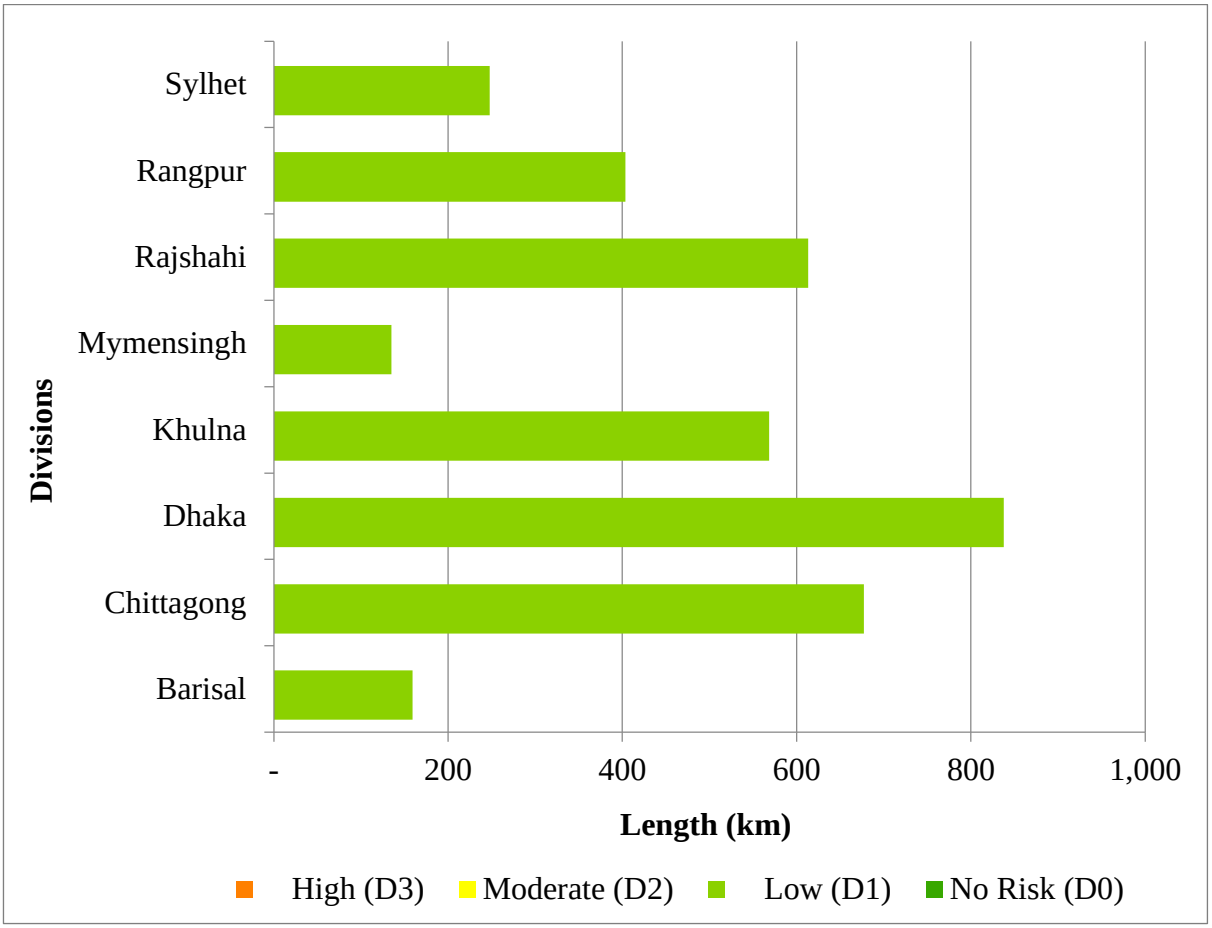

Figure 2.75: Length of National Highway in different risk levels to earthquake at division level

Length of Regional Highway in different damage categories due to earthquake hazard at division level is shown in table 2.54 and figure 2.76.

Table 2.54: Length of Regional Highway in risk levels to earthquake at division level

Division Name	Risk levels / length of road (km)			
	No Damage (D0)	Low (D1)	Moderate (D2)	High (D3)
Barisal	-	812.90	-	-
Chittagong	-	341.33	2,339.74	-
Dhaka	-	1,036.35	630.76	-
Khulna	-	1,257.40	-	-
Mymensingh	-	-	1,096.92	
Rajshahi	-	956.02	796.68	-
Rangpur	-	258.61	1,135.41	-
Sylhet	-	-	855.79	-
Total	-	4,662.61	6,855.30	-

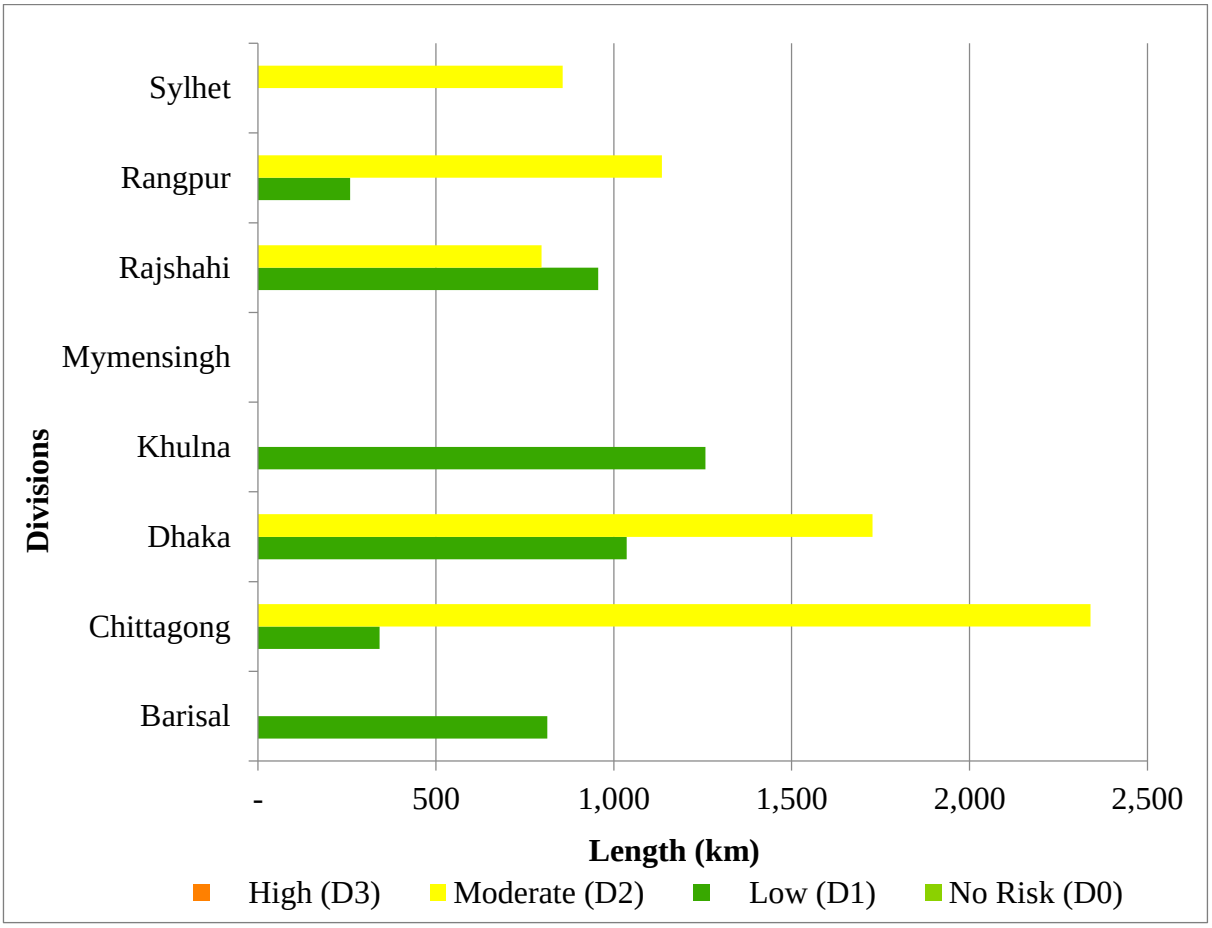

Figure 2.76: Length of Regional Highway in risk levels to earthquake at division level

Length of Upazila Road in different damage categories due to earthquake hazard at division level is shown in table 2.55 and figure 2.77.

Table 2.55: Length of Upazila Road in risk levels to earthquake at division level

Division Name	Risk levels / length of road (Km)			
	No Damage (D0)	Low (D1)	Moderate (D2)	High (D3)
Barisal	-	2,921.77	-	-
Chittagong	-	753.79	-	4,433.90
Dhaka	-	4,154.15	-	4,800.53
Khulna	-	5,531.51	-	-
Mymensingh	-	-	-	2,612.32
Rajshahi	-	2,867.75	-	2,574.69
Rangpur	-	770.44	-	3,731.95
Sylhet	-	-	-	2,356.43
Total	-	16,999.42	-	20,509.82

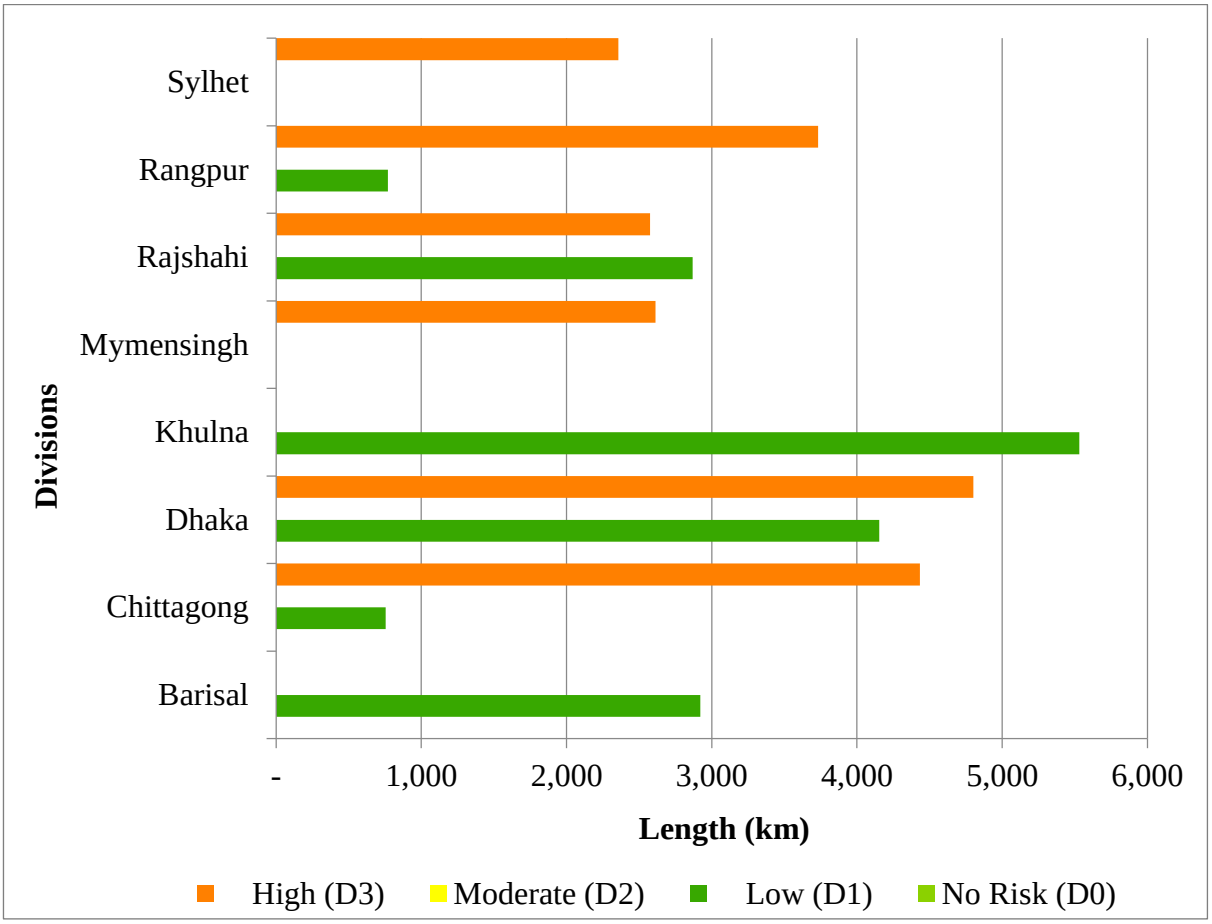

Figure 2.77: Length of Upazila Road in risk levels to earthquake at division level

Length of Union Road in different damage categories due to earthquake hazard at division level is shown in table 2.56 and figure 2.78.

Table 2.56: Length of Union Road in risk levels to earthquake at division level

Division Name	Risk levels / length of road (Km)			
	No Damage (D0)	Low (D1)	Moderate (D2)	High (D3)
Barisal	-	3,845.85	-	-
Chittagong	-	973.03	-	5,539.61
Dhaka	-	4,546.42	-	2,131.98
Khulna	-	4,582.21	-	-
Mymensingh	-	-		3,382.36
Rajshahi	-	3,051.61	-	2,670.61
Rangpur	-	1,025.98	-	4,733.55
Sylhet	-	-	-	2,407.76
Total	-	18,025.09	-	20,865.87

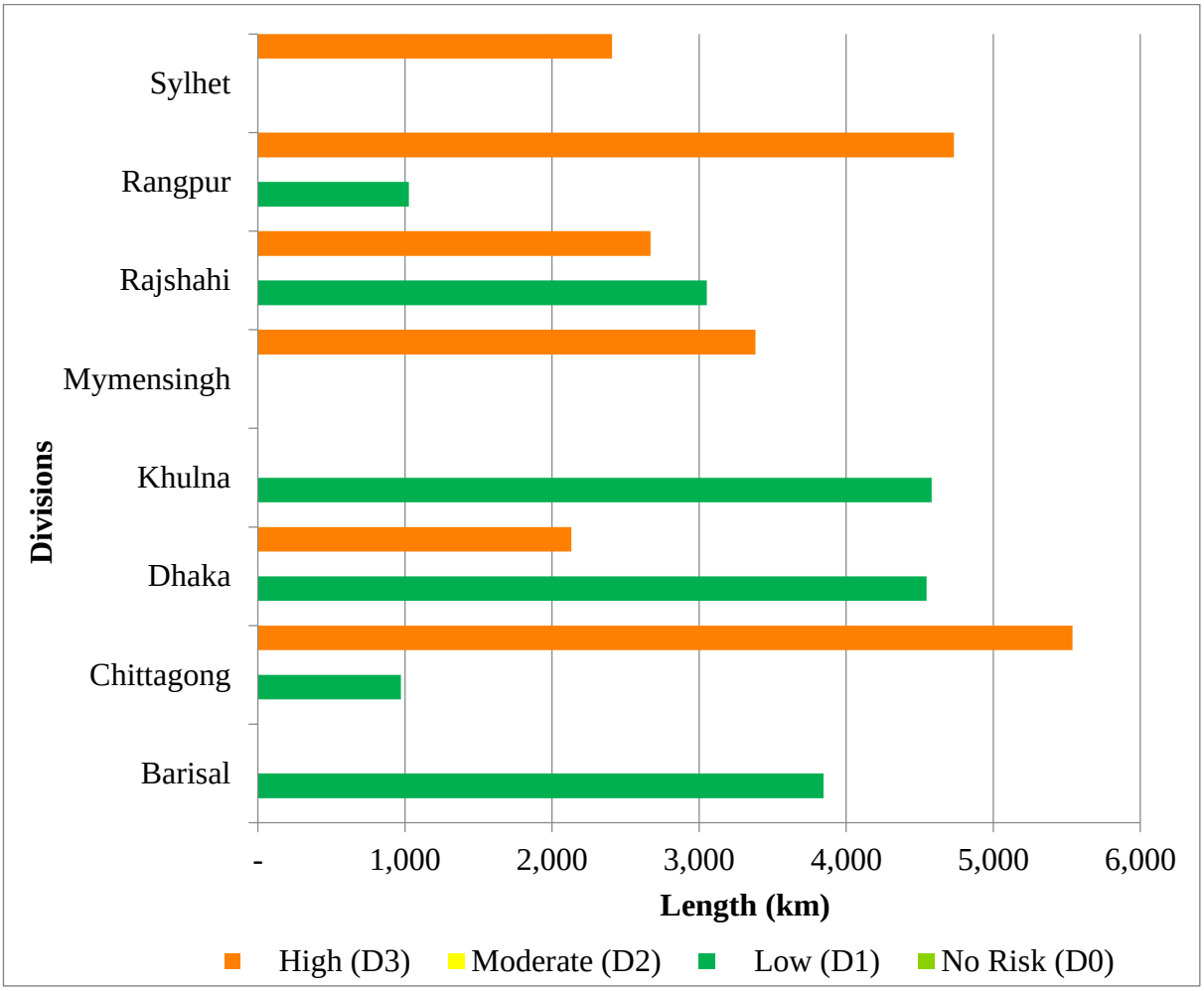

Figure 2.78: Length of Union Road in risk levels to earthquake at division level

Length of Village Road in different damage categories due to earthquake hazard at division level is shown in table 2.57 and figure 2.79.

Table 2.57: Length of Village Road in risk levels to earthquake at division level

Division Name	Risk levels / length of road (Km)			
	No Damage (D0)	Low (D1)	Moderate (D2)	High (D3)
Barisal	-	14,705.98	-	-
Chittagong	-	4,037.82	-	23,489.08
Dhaka	-	14,440.91	-	7,807.66
Khulna	-	20,591.93	-	-
Mymensingh	-	-		10,888.03
Rajshahi	-	8,819.75	-	6,805.14
Rangpur	-	2,890.06	-	14,002.12
Sylhet	-	-	-	8,834.78
Total	-	65,486.46	-	71,826.24

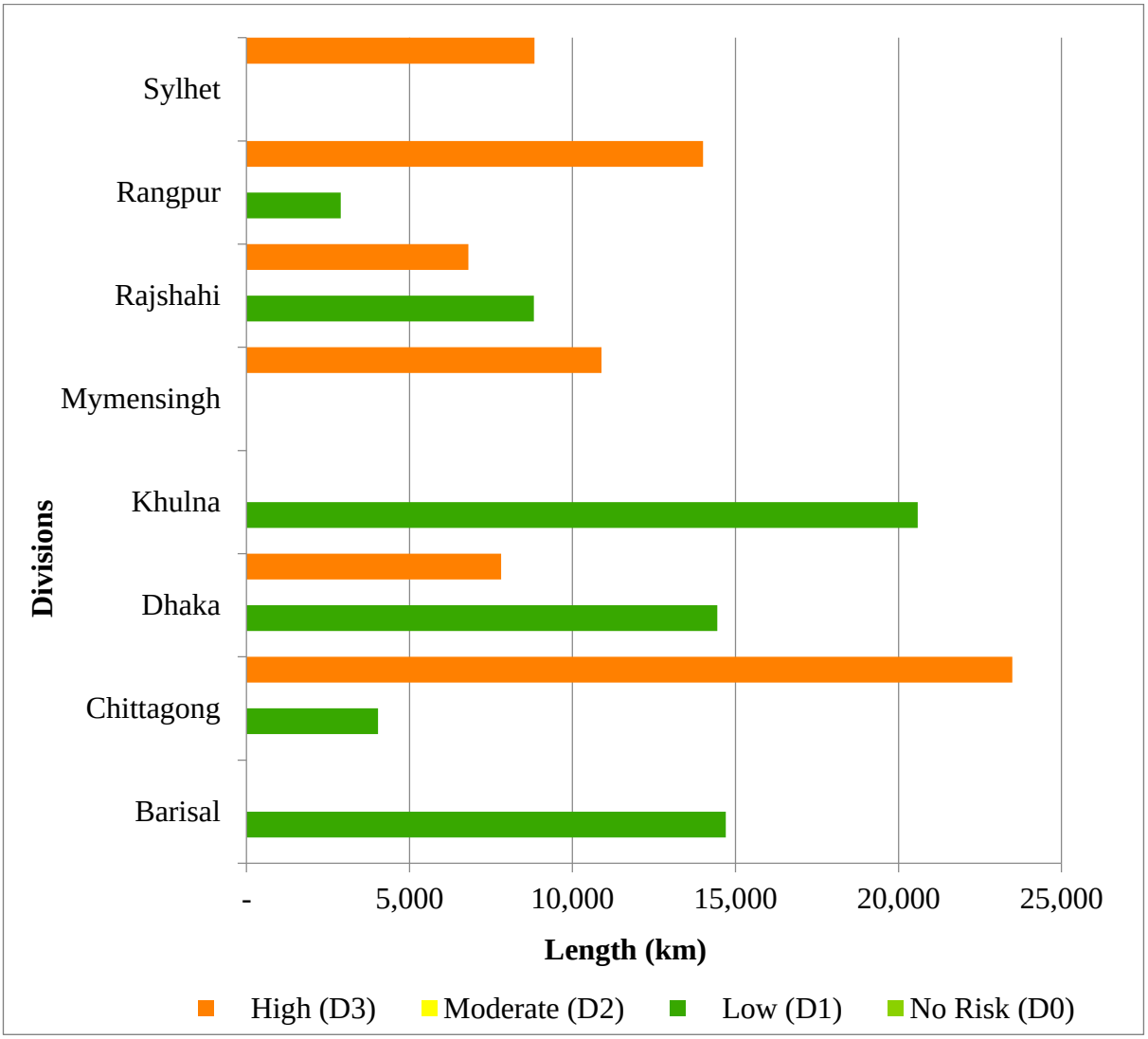

Figure 2.79: Length of Village Road in risk levels to earthquake at division level

Risk of major roads (national and regional highway) due to earthquake at district level is shown in figure 2.80

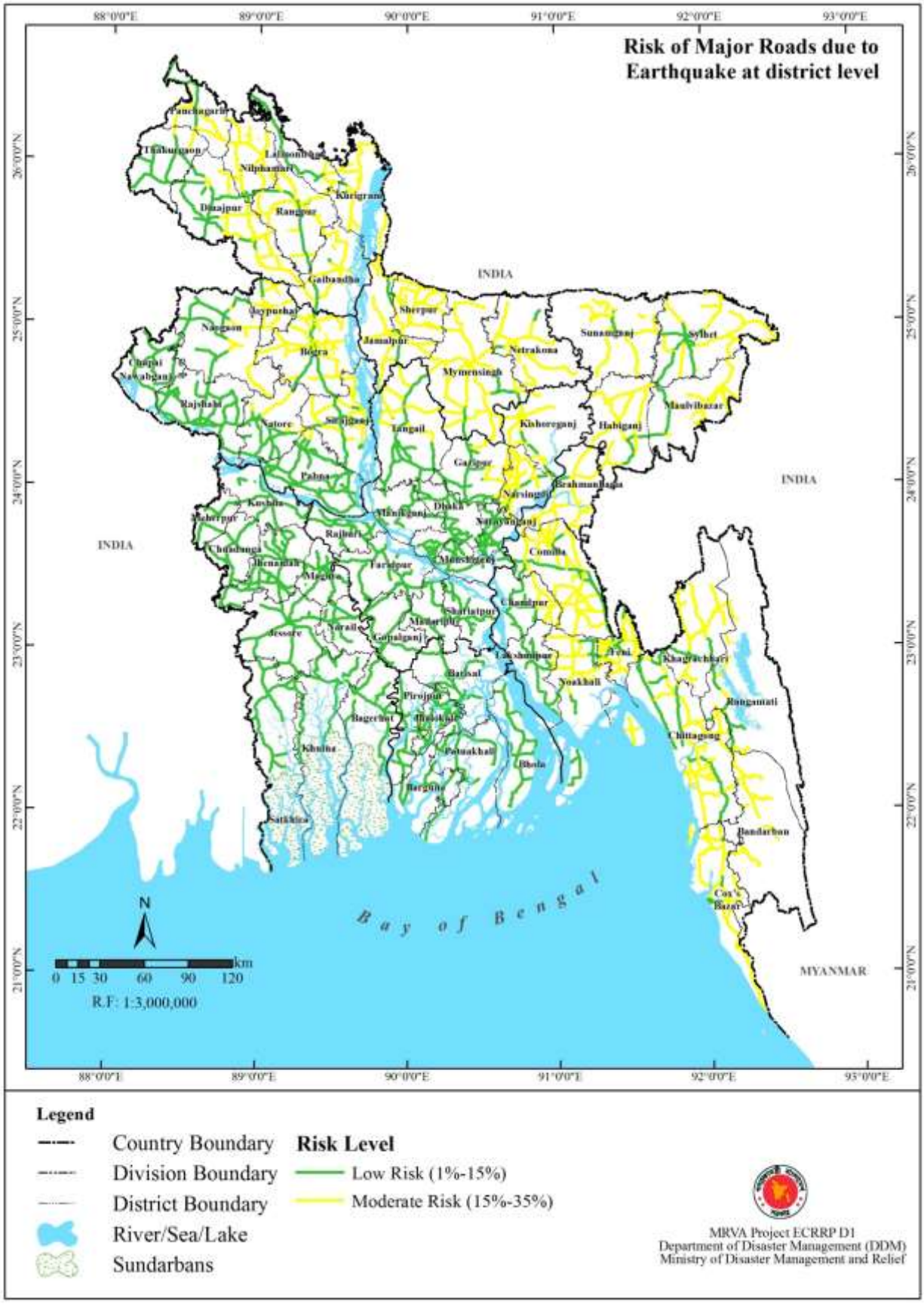

Figure 2.80: Risk of major roads (National and Regional) due to earthquake at district level

Chapter 3: Exposure, Vulnerability and Risk Assessment to Tsunami

3.1 Exposure Assessment

As explained in section 3.2 (Volume – 1 of report) tsunami hazard maps consists of tsunami inundation depth of 5 categories. They are < 0.5 m, 0.5 – 1.0 m, 1.0 – 2.0 m, > 2.0 and not affected.

As explained in section 1.4, tsunami hazard map for 50 year return period is selected for exposure assessment of elements at risk.

3.1.1 Population

As explained in section 1.5, based on the area of exposure of the settlements in each union, the vulnerability of population is calculated as affected population for tsunami hazard at division / district / upazila level.

3.1.1.1 Gender

Total population (male) exposed to tsunami inundation depth at division level is given in table 3.1 and figure 3.1. Population (male) exposed to more than 1.0 m tsunami inundation depth at district level is shown in figure 3.2.

Table 3.1: Population (male) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	25,298	15,526	8,482	27,331	4,012,871	4,089,508
Chittagong	8,616	20,449	2,708	7,176	13,894,366	13,933,314
Khulna	706	194	113	466	7,841,054	7,842,533
Total	34,621	36,168	11,302	34,972	25,748,291	25,865,355

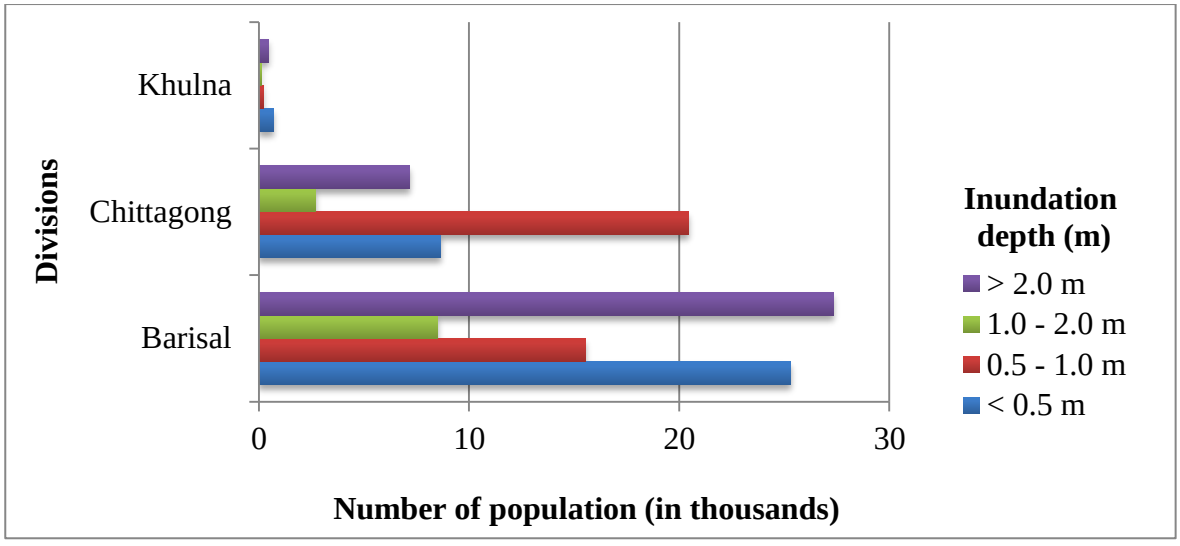

Figure 3.1: Population (male) exposed to different tsunami inundation depth at division level

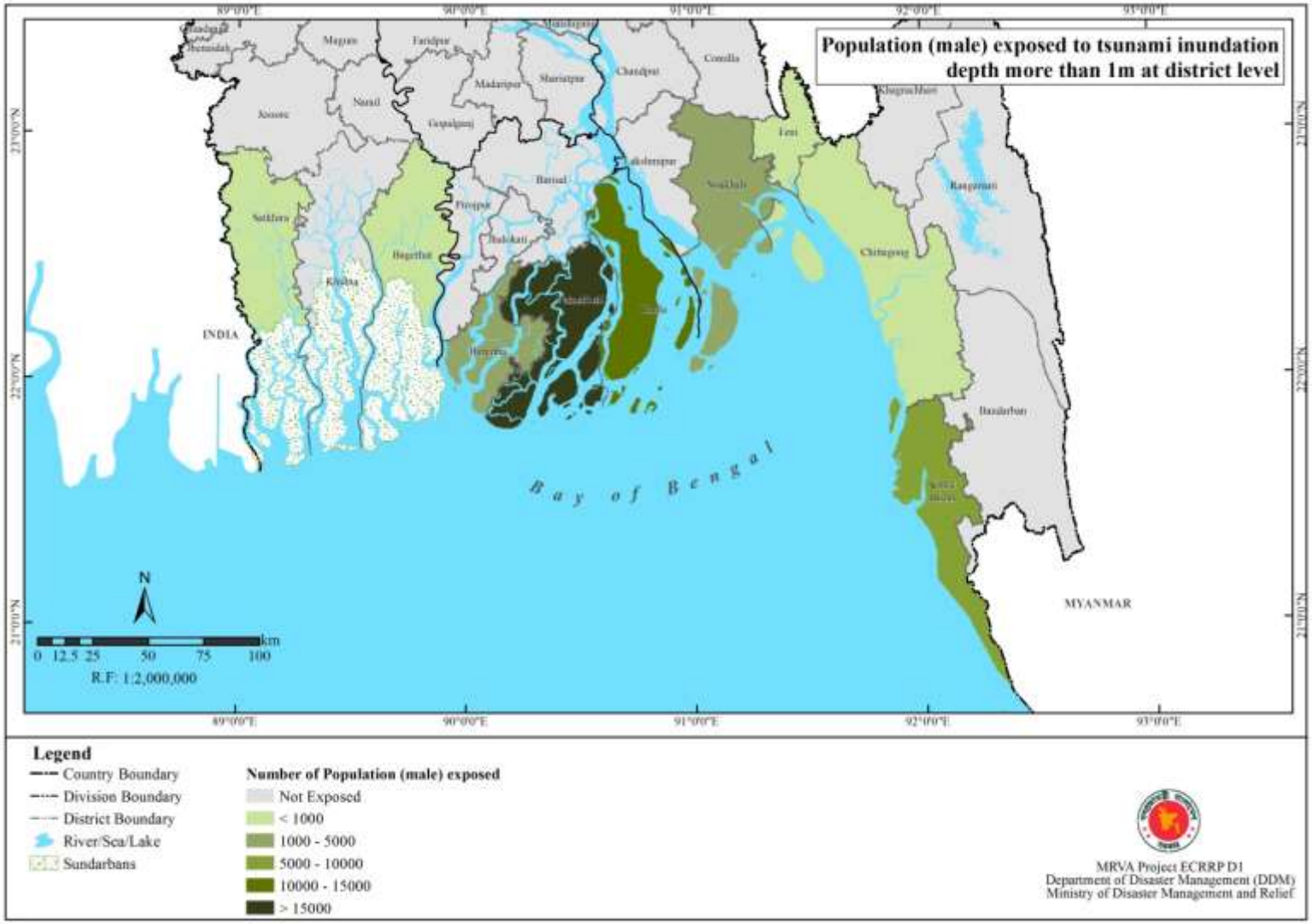

Figure 3.2: Population (male) exposed to tsunami inundation depth of more than 1 m at district level

Total population (female) exposed to tsunami inundation depth at division level is given in Table 3.2 and figure 3.3. Population (female) exposed to tsunami inundation depth of more than 1.0 m at district level is shown in figure 3.4.

Table 3.2: Population (female) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5 m	0.5 - 1.0 m	1.0 - 2.0 m	> 2.0 m		
Barisal	26,206	16,082	8,786	28,311	4,156,773	4,236,158
Chittagong	8,960	21,265	2,816	7,462	14,449,202	14,489,705
Khulna	707	194	113	466	7,843,747	7,845,226
Total	35,872	37,542	11,715	36,239	26,449,721	26,571,089

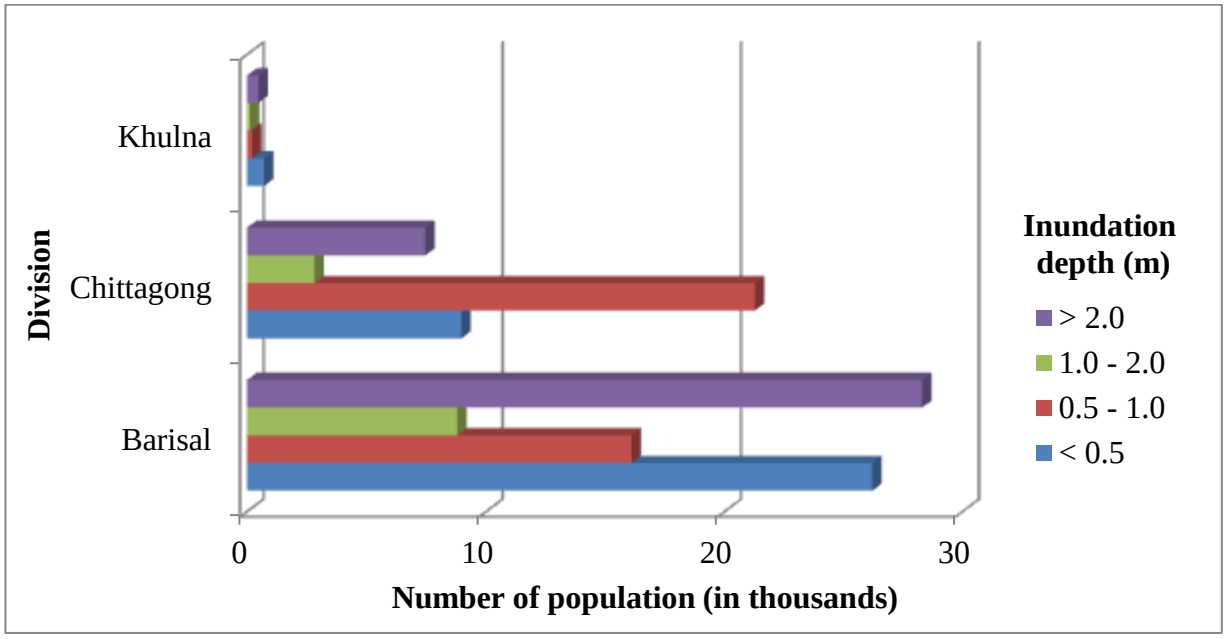

Figure 3.3: Population (female) exposed to tsunami inundation depth at division level

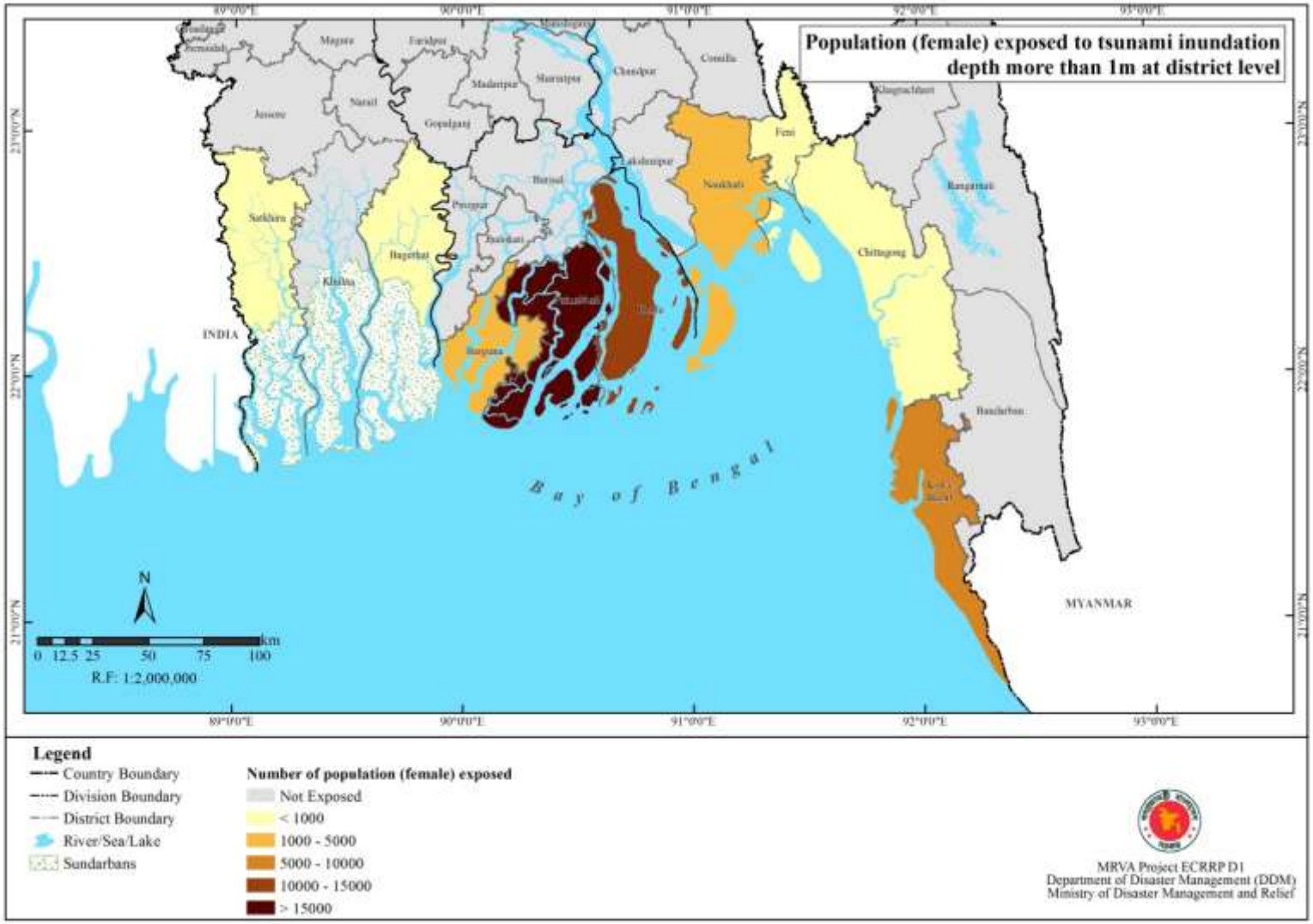

Figure 3.4: Population (female) exposed to tsunami inundation depth more than 1.0 m at district level

3.1.1.2 Age

As explained in section 4.1.2, population by age is regrouped into 0-14 years, 14 - 59 years and more than 59 years. Population in the age group of 0 - 14 years exposed to tsunami inundation depth in each division is given Table 3.3 and figure 3.5. Population exposed to tsunami inundation depth of more than 1.0 m and in the age group of 0 – 14 years at district level is shown in figure 3.6. Population in the age group of 14 - 59 years exposed to tsunami inundation depth in each division is given Table 3.4 and figure 3.7. Population exposed to tsunami inundation depth of more than 1.0 m and in the age group of 14 - 59 years at district level is shown in figure 3.8. Population in the age of more than 59 years exposed to tsunami inundation depth in each division is given Table 3.5 and figure 3.9. Population exposed to tsunami inundation depth of more than 1.0 m and in the age of > 59 years at district level is shown in figure 3.10.

Table 3.3: Population (0 - 14 years) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	18726	11492	6278	20230	2970359	3,027,086
Chittagong	6687	15870	2102	5569	10783434	10,813,662
Khulna	439	121	70	290	4876787	4,877,707
Total	25852	27483	8450	26089	18630580	18,718,455

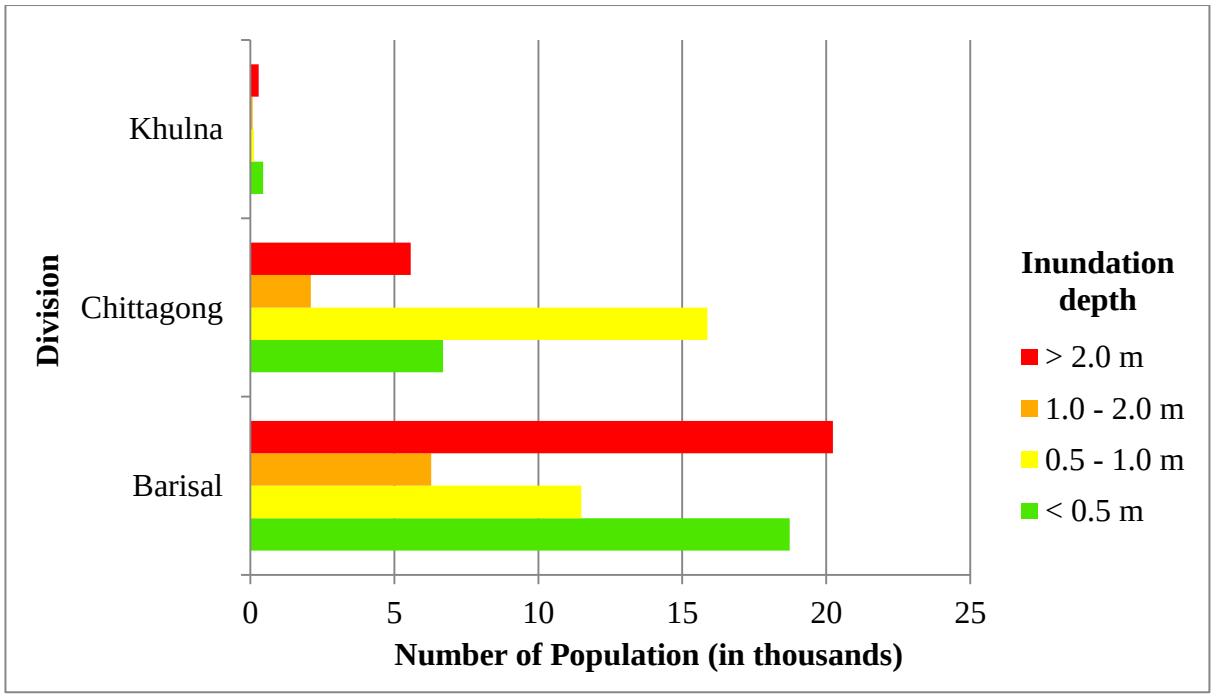

Figure 3.5: Population (0 - 14 years) exposed to different tsunami inundation depth at division level

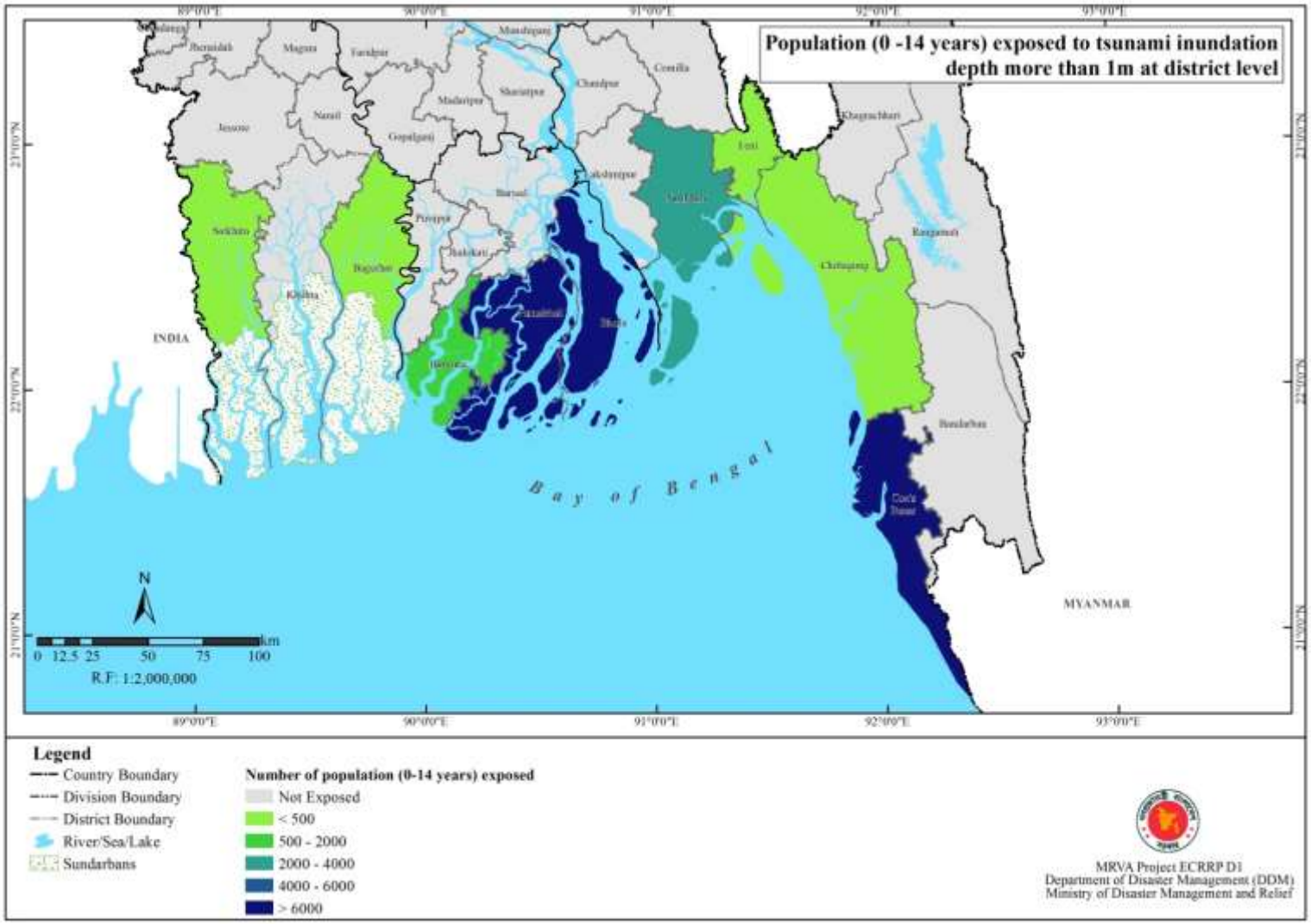

Figure 3.6: Population (0 - 14 years) exposed to tsunami inundation depth of more than 1 m at district level

Table 3.4: Population (14 - 59 years) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	28157	17280	9440	30419	4466296	4,551,592
Chittagong	9623	22839	3024	8014	15518597	15,562,098
Khulna	855	235	136	564	9492556	9,494,346
Total	38635	40354	12601	38997	29477448	29,608,036

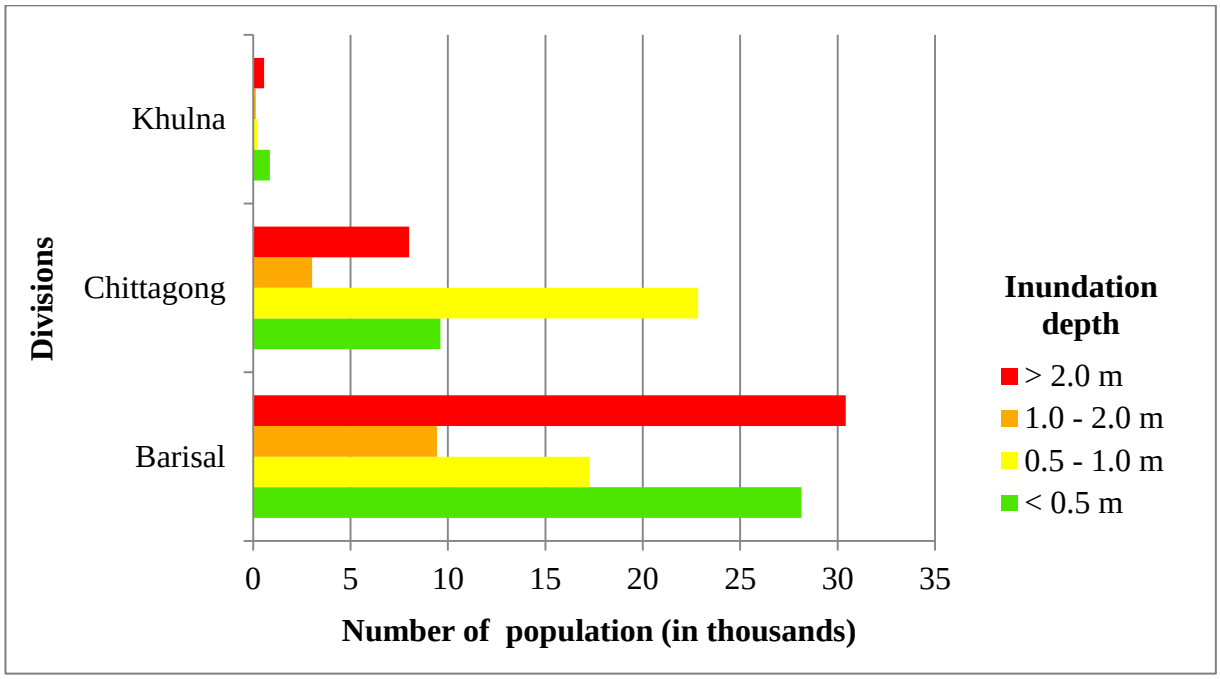

Figure 3.7: Population (14 - 59 years) exposed to different tsunami inundation depth at division level

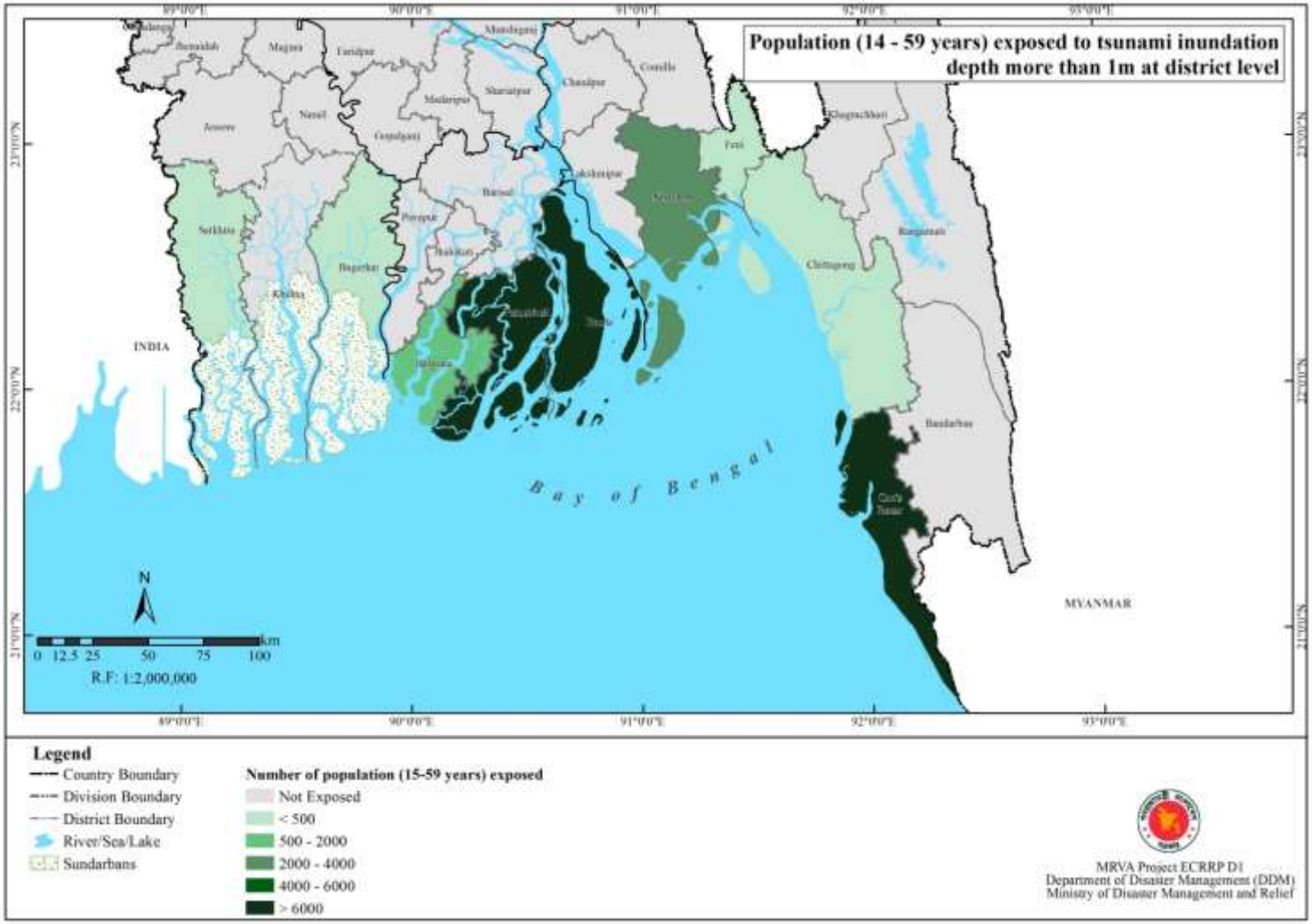

Figure 3.8: Population (14 - 59 years) exposed to tsunami inundation depth of more than 1 m at district level

Table 3.5: Population (more than 59 years) exposed to tsunami inundation depth at district level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	4621	2836	1549	4992	732988	746,986
Chittagong	1266	3005	398	1054	2041536	2,047,259
Khulna	119	33	19	78	1315458	1,315,706
Total	6005	5873	1966	6125	4089982	4,109,951

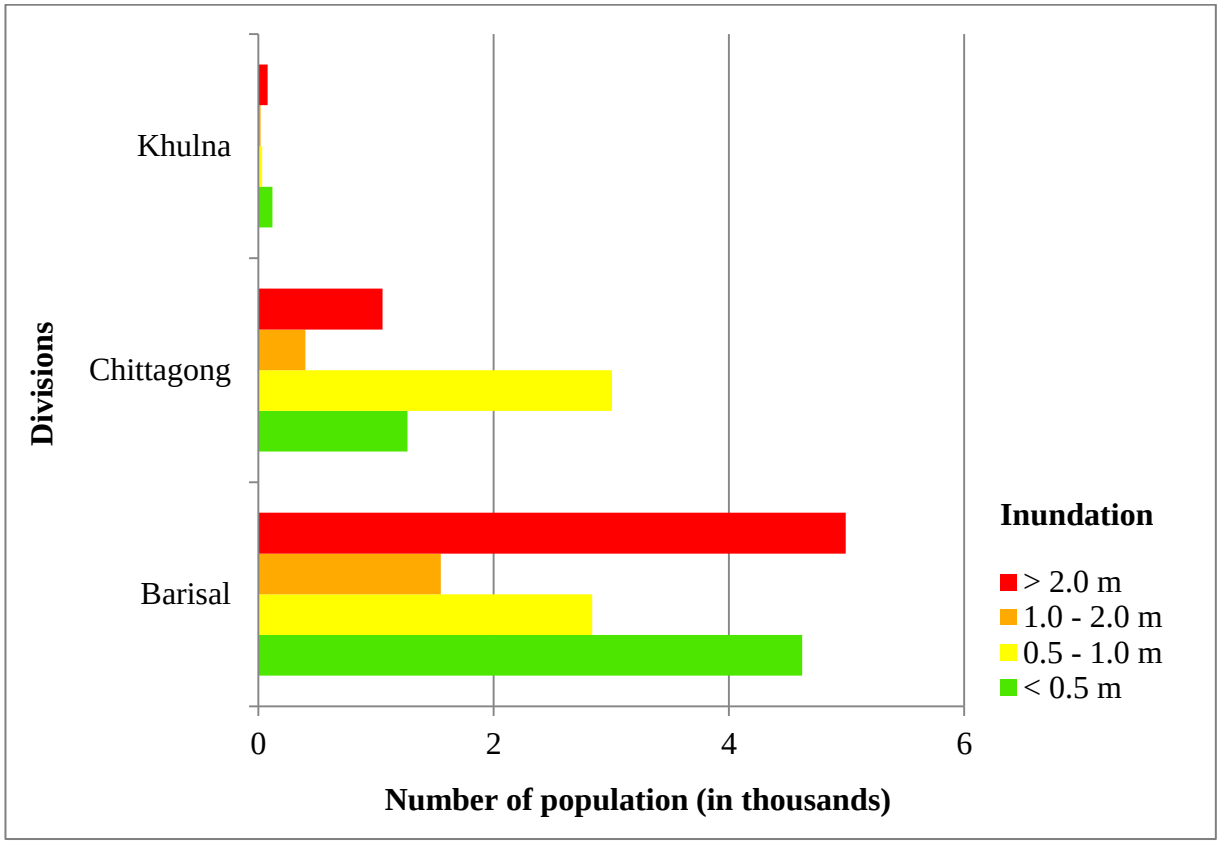

Figure 3.9: Population (more than 59 years) exposed to different tsunami inundation depth at district level

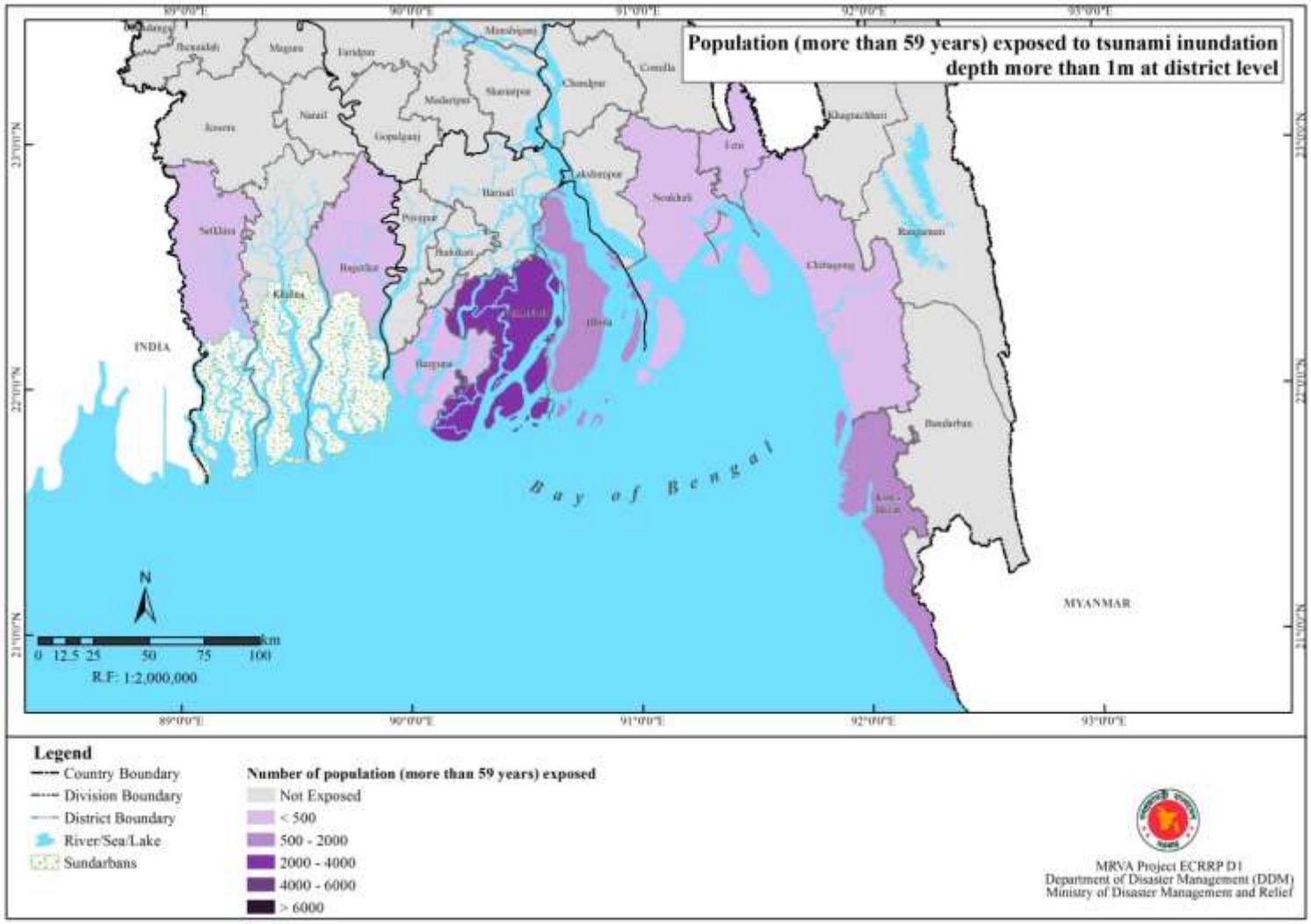

Figure 3.10: Population (more than 59 years) exposed to tsunami inundation depth of more than 1 m at district level

3.1.1.3 Ethnicity

As the ethnicity population is very less, exposure to tsunami inundation depth is not considered.

3.1.1.4 Employment

As explained in section 1.1.4 of volume III of this report, the employment types considered are agriculture and industry. Population employed in Agriculture activity at division level is given Table 3.6 and Figure 3.11. Population exposed to tsunami inundation depth of more than 1.0 m and employed in agriculture sector at district level is shown in figure 3.12. Population employed in industry sector at division level is given Table 3.7 and figure 3.13. Population exposed to tsunami inundation depth of more than 1.8 m and employed in industry sector at district level is shown in figure 3.14.

Table 3.6: Employed (Agriculture) Population exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	2833	1739	950	3061	449451	458,034
Chittagong	922	2189	290	768	1487487	1,491,657
Khulna	113	31	18	74	1248715	1,248,951
Total	3868	3959	1258	3903	3185653	3,198,642

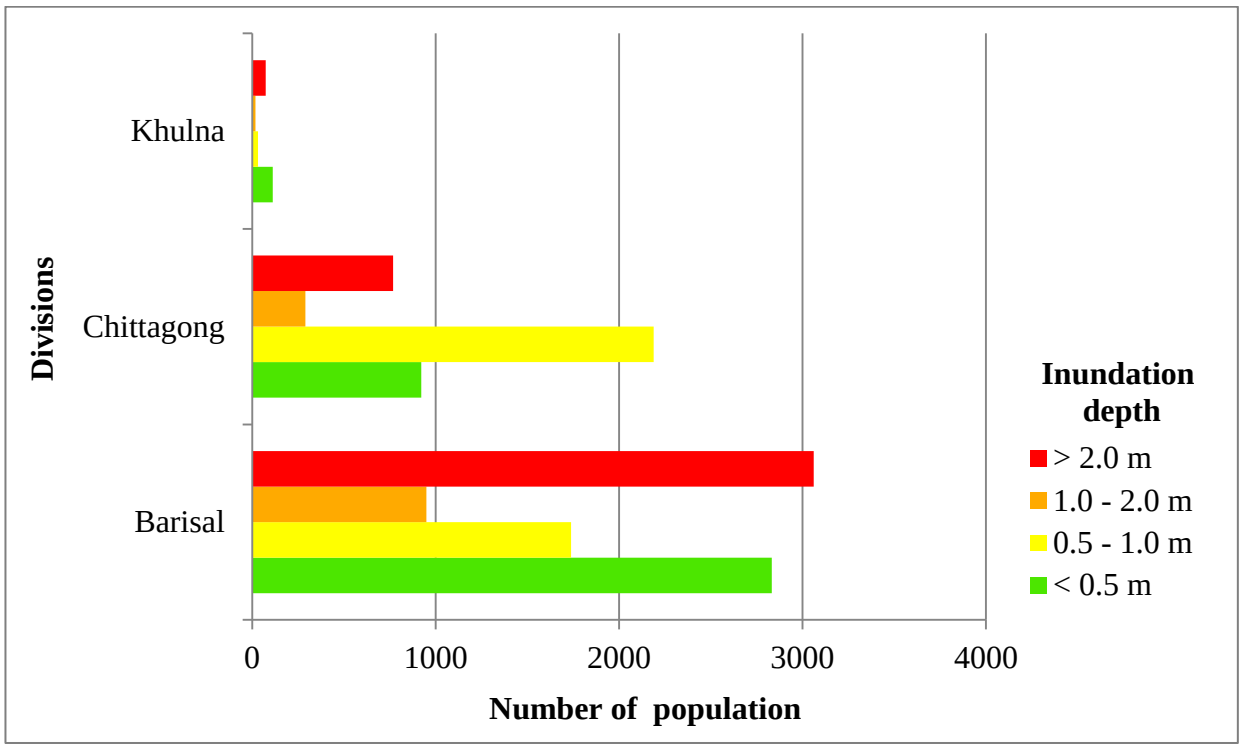

Figure 3.11: Employed (Agriculture) population exposed to different tsunami inundation depth at division level

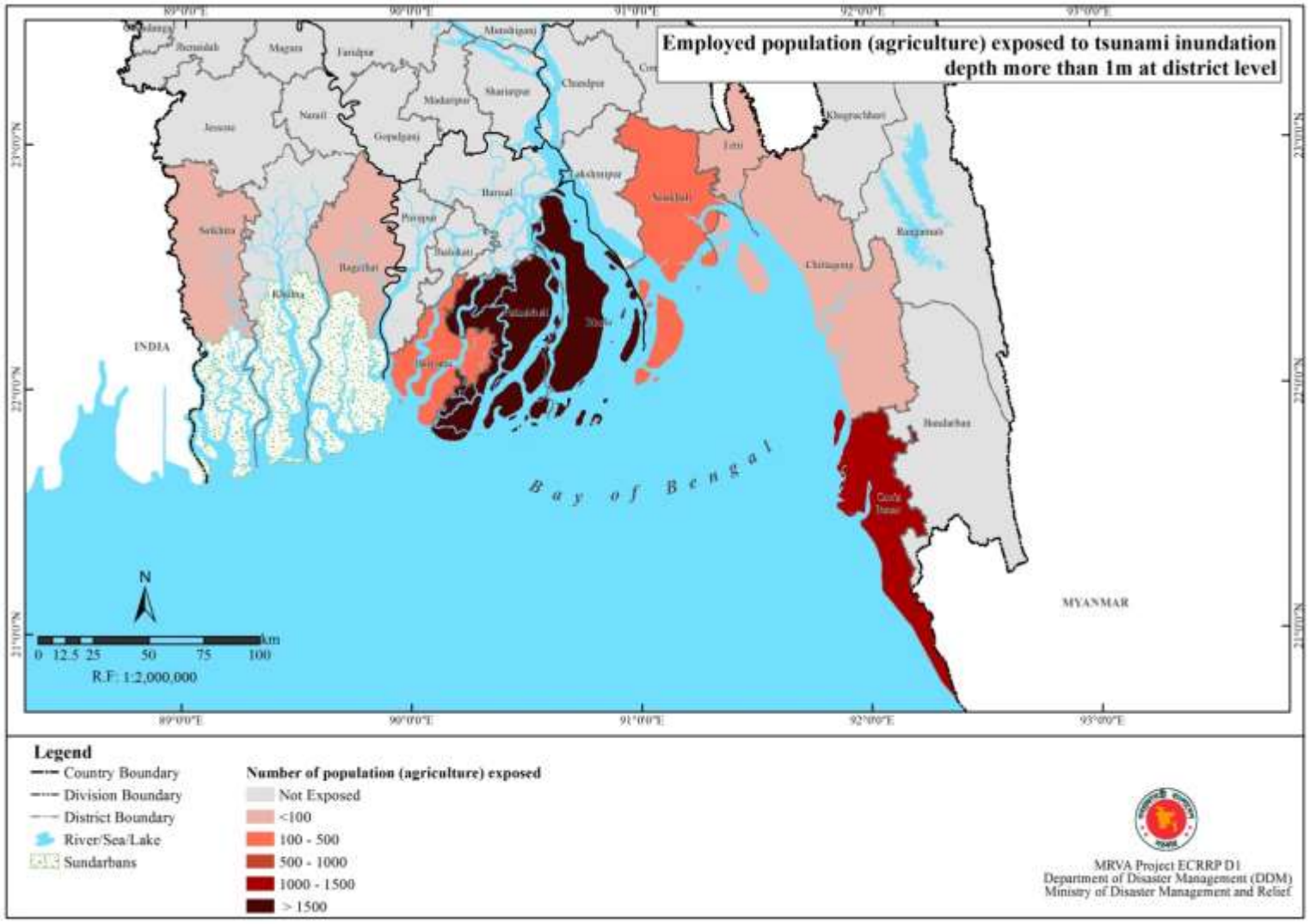

Figure 3.12: Employed (Agriculture) Population exposed to tsunami inundation depth more than 1 m at division level

Table 3.7: Employed (Industry) Population exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	207	127	69	223	32808	33,435
Chittagong	139	329	44	116	223874	224,502
Khulna	9	3	1	6	102269	102,288
Total	355	459	114	345	358952	360,225

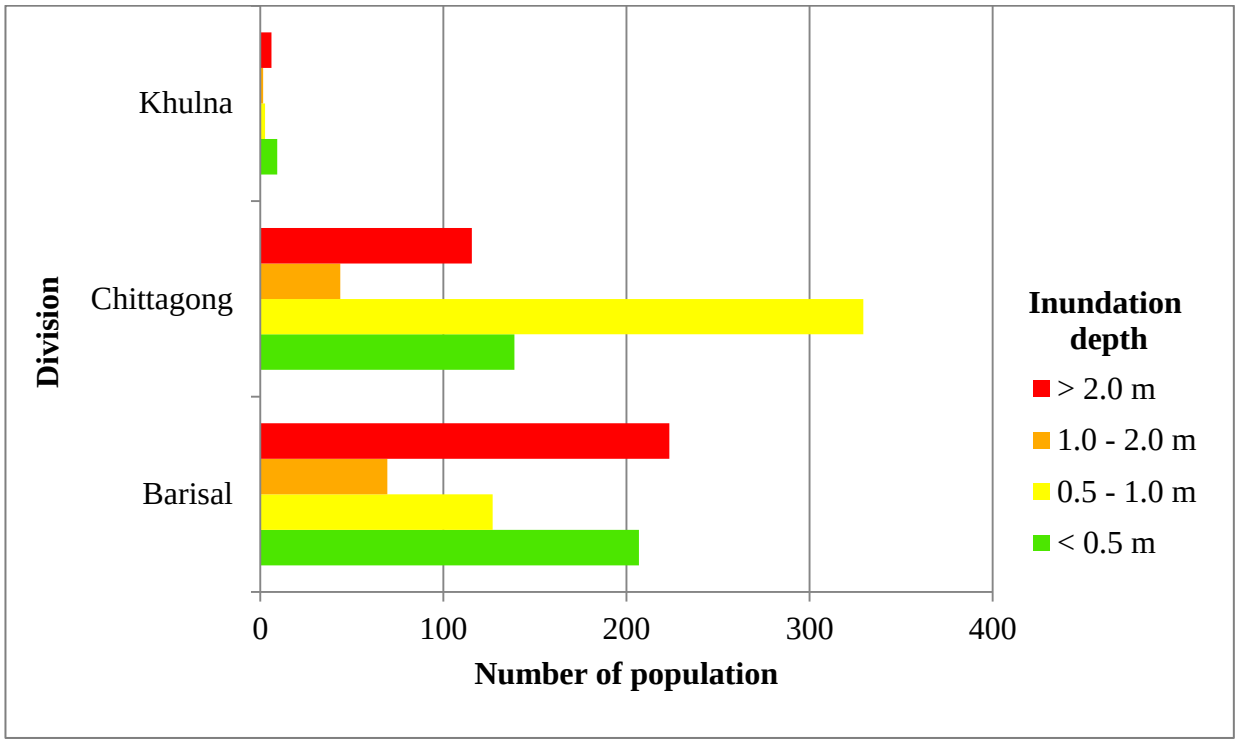

Figure 3.13: Employed (Industry) Population exposed to tsunami inundation depth at division level

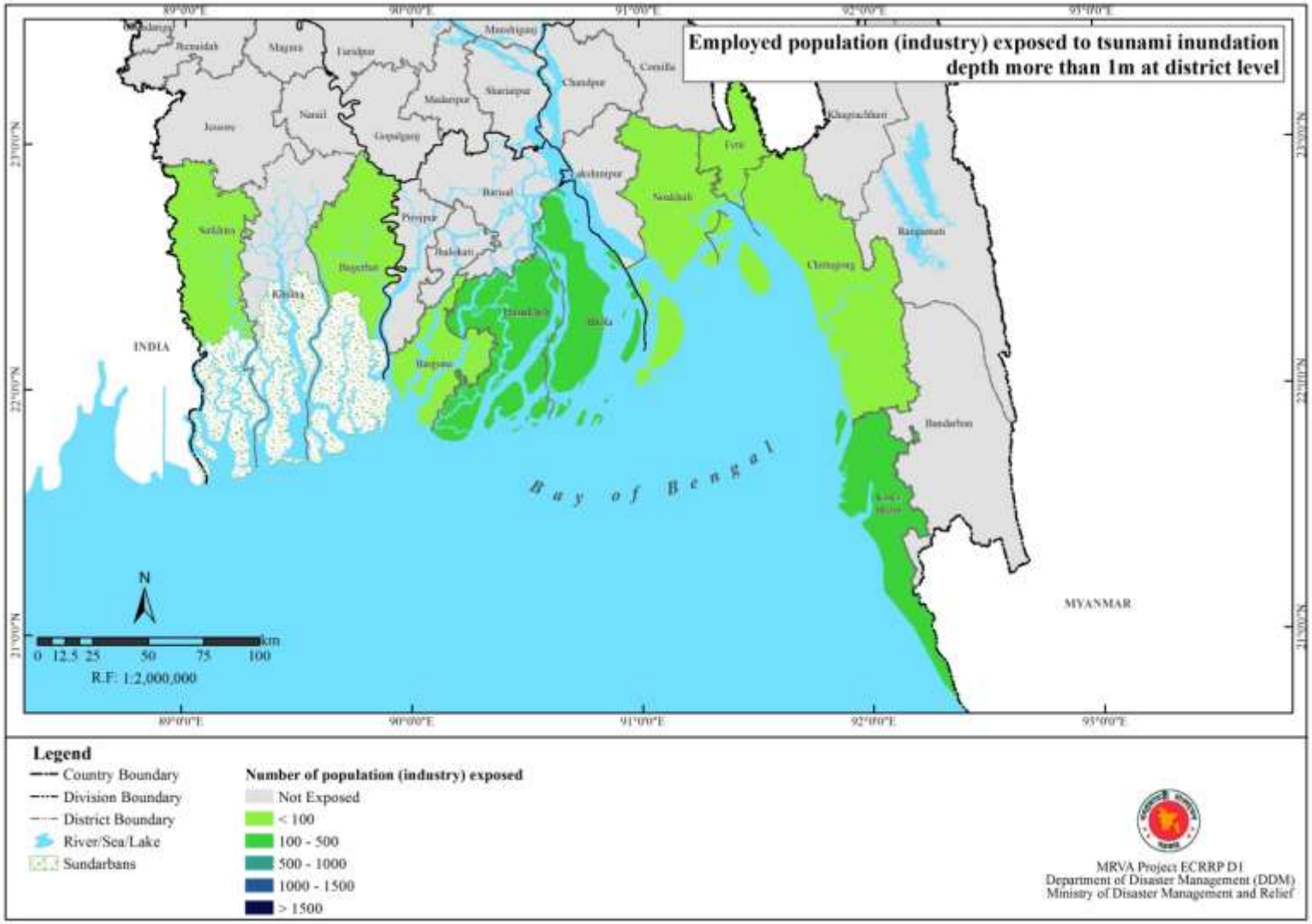

Figure 3.14: Employed (Industry) Population exposed to tsunami inundation depth more than 1 m at division level

3.1.1.5 Education

Details of population with education are given in section 1.1.5 (Volume III of this report). Literate Population (male) exposed to tsunami inundation depth is given in Table 3.8 and Figure 3.15. Literate Population (female) exposed to tsunami inundation depth is given in Table 3.9 and Figure 3.16.

Table 3.8: Literate Population (male) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	14541	8924	4875	15710	2306570	2,350,620
Chittagong	4632	10994	1456	3858	7470090	7,491,030
Khulna	394	108	63	260	4369462	4,370,286
Total	19567	20026	6394	19827	14146122	14,211,936

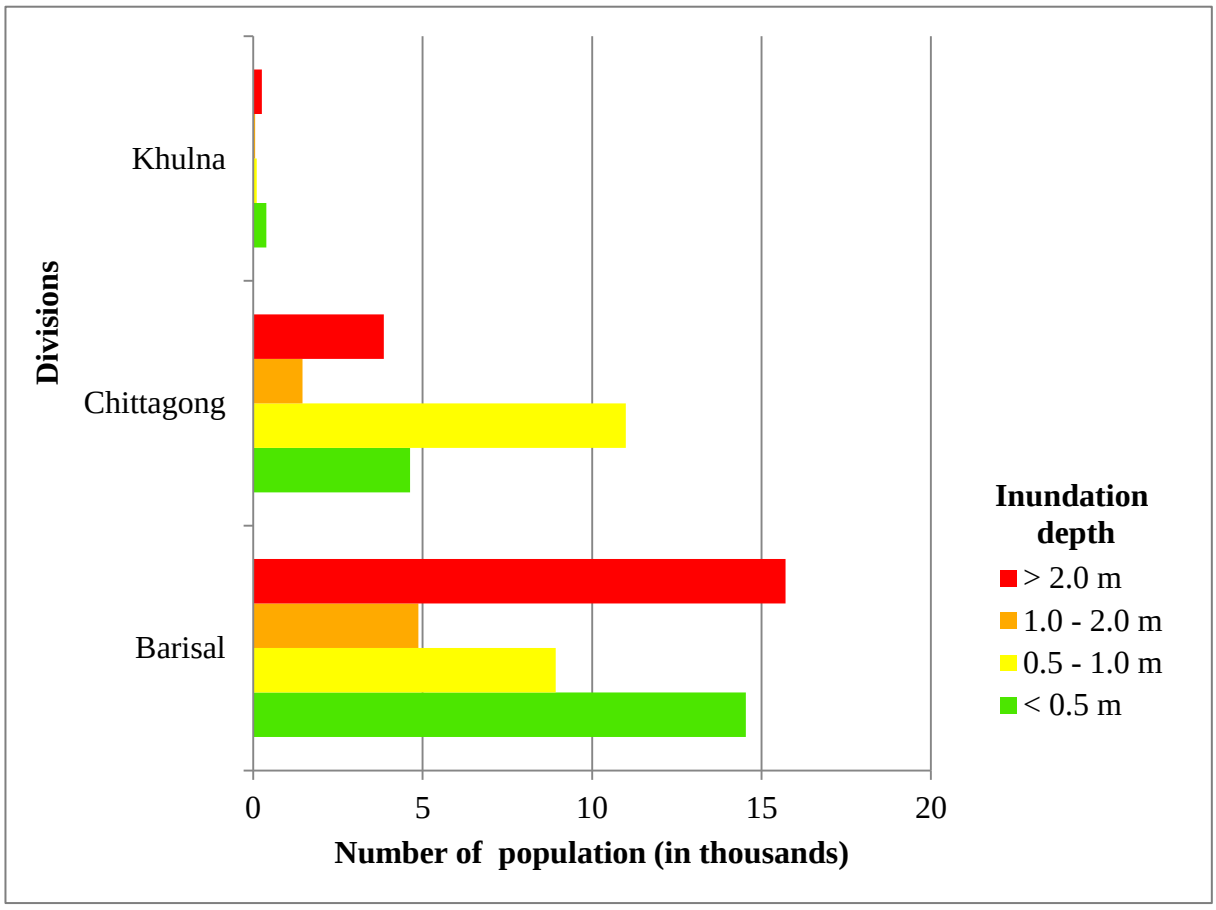

Figure 3.15: Literate Population (male) exposed to different tsunami inundation depth at division level

Table 3.9: Literate Population (female) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	14617	8971	4901	15791	2318589	2,362,869
Chittagong	4606	10932	1448	3836	7428129	7,448,951
Khulna	359	99	57	237	3982035	3,982,786
Total	19582	20001	6406	19864	13728753	13,794,606

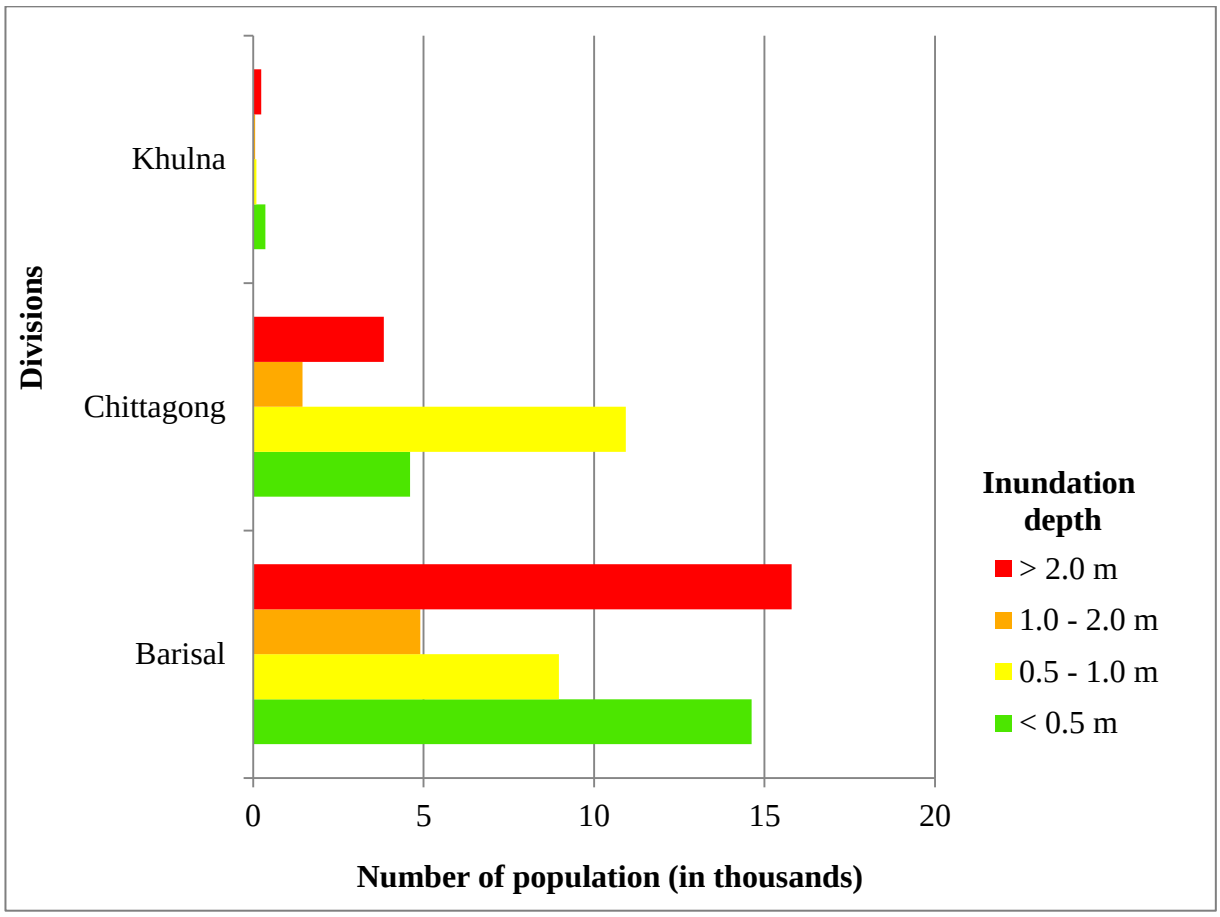

Figure 3.16: Literate Population (male) exposed to different tsunami inundation depth at division level

3.1.1.6 Disability

Details of population with disability are given in section 1.1.6 (Volume III of this report). Disabilities of population mentioned are Speech, Vision, Hearing, Physical, Mental, and Autism. Population with disability of Vision exposed to tsunami inundation depth at division level is given Table 3.10 and Figure 3.17. Population with disability of Physical exposed to tsunami inundation depth at division level is given table 3.11 and figure 3.18. Population with disability of Mental exposed to tsunami inundation depth at division level is given Table 3.12 and figure 3.19. Population with disability of Autism exposed to tsunami inundation depth at

division level is given Table 3.13 and figure 3.20. Disable population exposed to tsunami inundation depth more than 1.0 m at district level is shown in figure 3.21.

Table 3.10: Disable Population (Vision) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	157	96	53	169	24,867	25,342
Chittagong	41	97	13	34	65,978	66,163
Khulna	4	1	1	3	43,744	43,752
Total	202	194	66	206	134,589	135,257

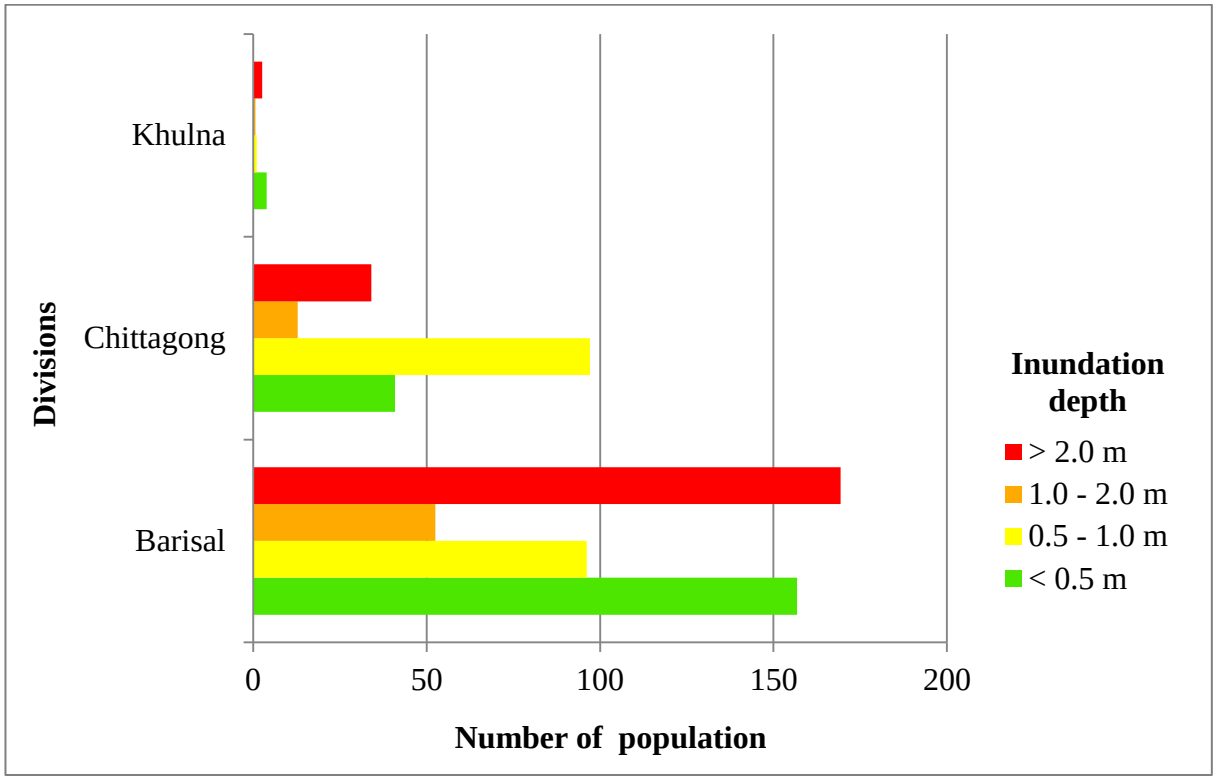

Figure 3.17: Disable Population (Vision) exposed to different tsunami inundation depth at division level

Table 3.11: Disable Population (Physical) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	350	215	117	378	55489	56,549
Chittagong	96	227	30	80	154262	154,694
Khulna	9	3	1	6	103902	103,922
Total	455	444	149	464	313,653	315,165

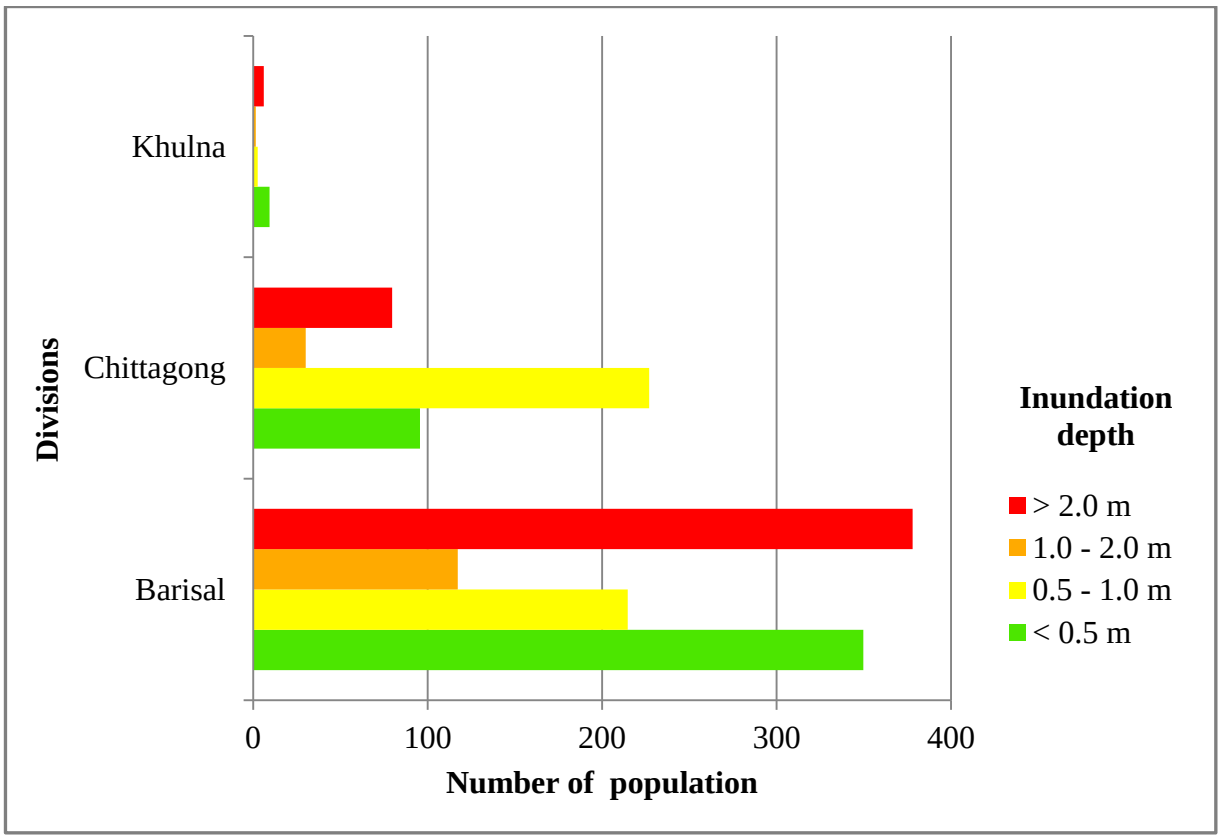

Figure 3.18: Disable Population (Physical) exposed to different tsunami inundation depth at division level

Table 3.12: Disable Population (Mental) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5 m	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	92	56	31	99	14597	14,876
Chittagong	32	76	10	27	51350	51,494
Khulna	3	1	0	2	31370	31,376
Total	127	133	41	128	97,317	97,746

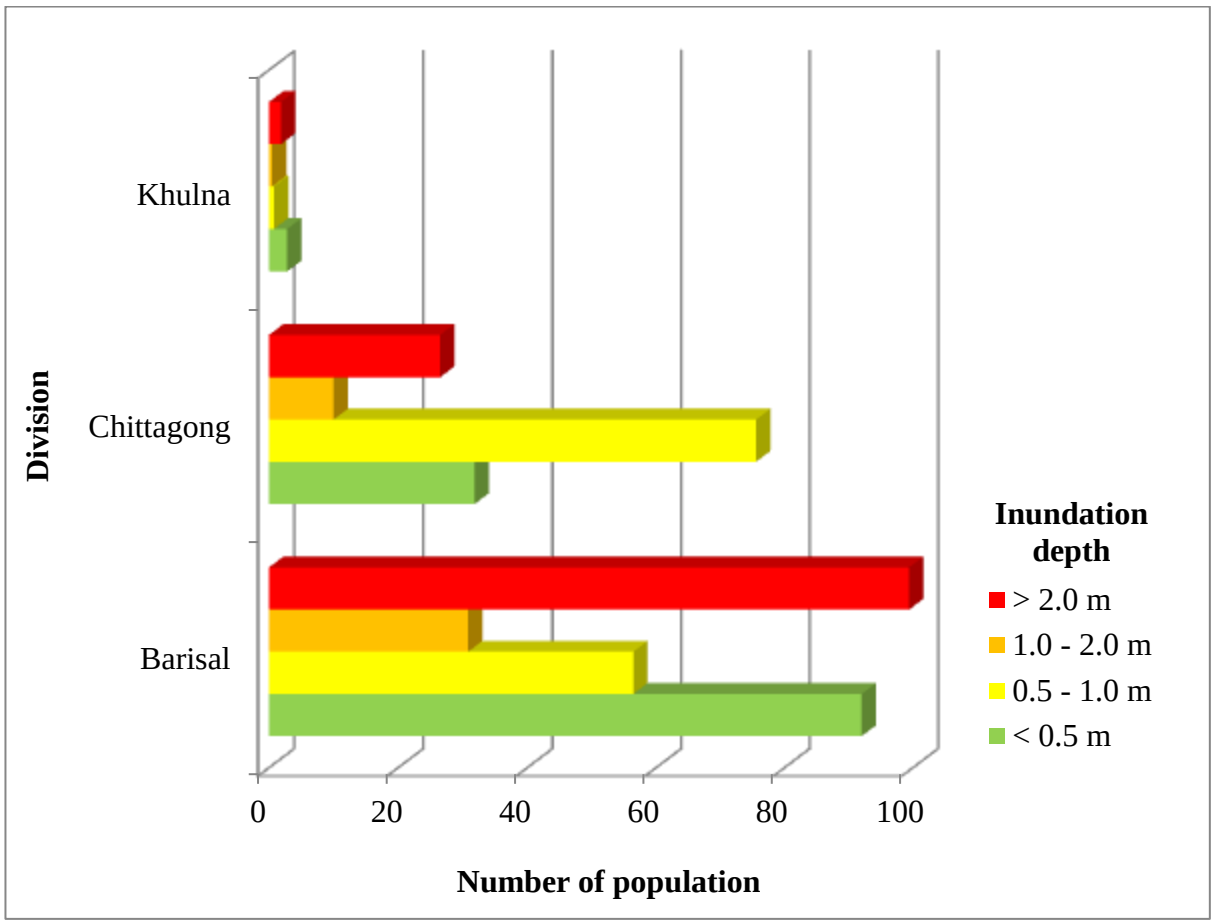

Figure 3.19: Disable Population (Mental) exposed to different tsunami inundation depth at division level

Table 3.13: Disable Population (Autism) exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	52	32	17	56	8170	8,326
Chittagong	18	42	6	15	28342	28,421
Khulna	1	0	0	1	15685	15,688
Total	70	74	23	71	52,197	52,435

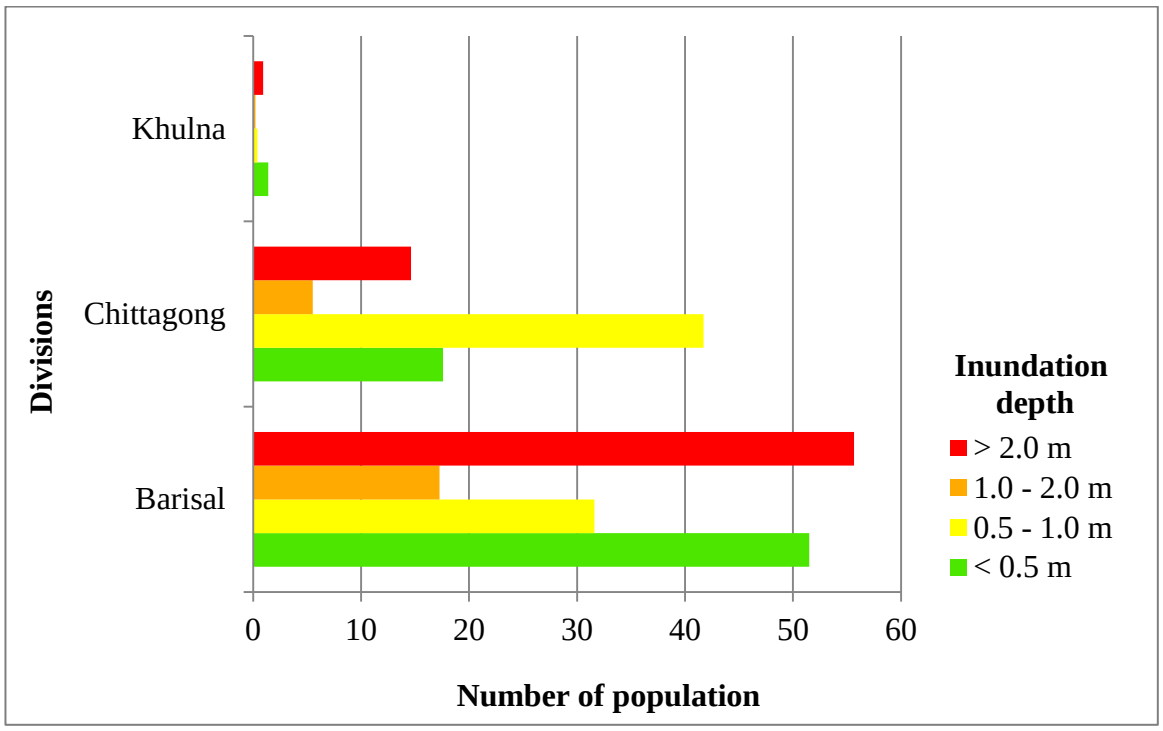

Figure 3.20: Disable Population (Autism) exposed to different tsunami inundation depth at division level

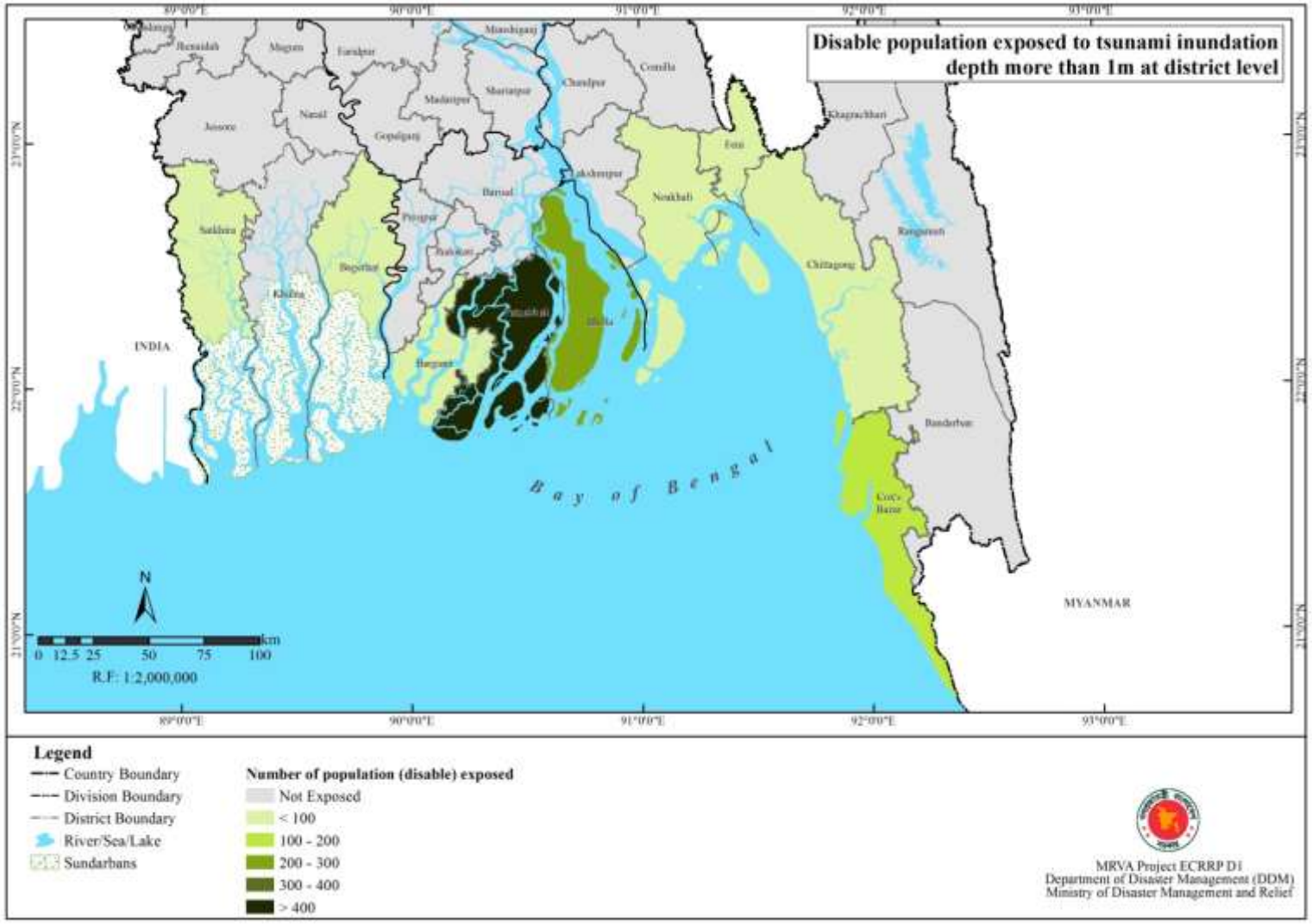

Figure 3.21: Disable Population exposed to different tsunami inundation depth more than 1.0 m at district level

3.1.1.7 Poverty

The exposure of population in poverty (extreme poor) to tsunami at division level is provided in table 3.14 and figure 3.22. At district level shown in figure 3.23.

Table 3.14: Population (extreme poor) exposed to tsunami inundation depth at district level

District	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Bagerhat	78	21	7	40	64442	64587
Barguna	339	124	119	216	67571	68369
Bhola	2585	1062	878	2748	75593	82866
Chittagong	0	0	4	34	63188	63226
Cox's Bazar	1686	1806	535	2352	301419	307798
Feni	0	0	0	58	74768	74826
Noakhali	500	1526	138	109	30686	32959
Patuakhali	2744	2013	871	2656	66846	75129
Satkhira	46	3	8	18	107495	107570
Total	7978	6556	2559	8229	852007	877330

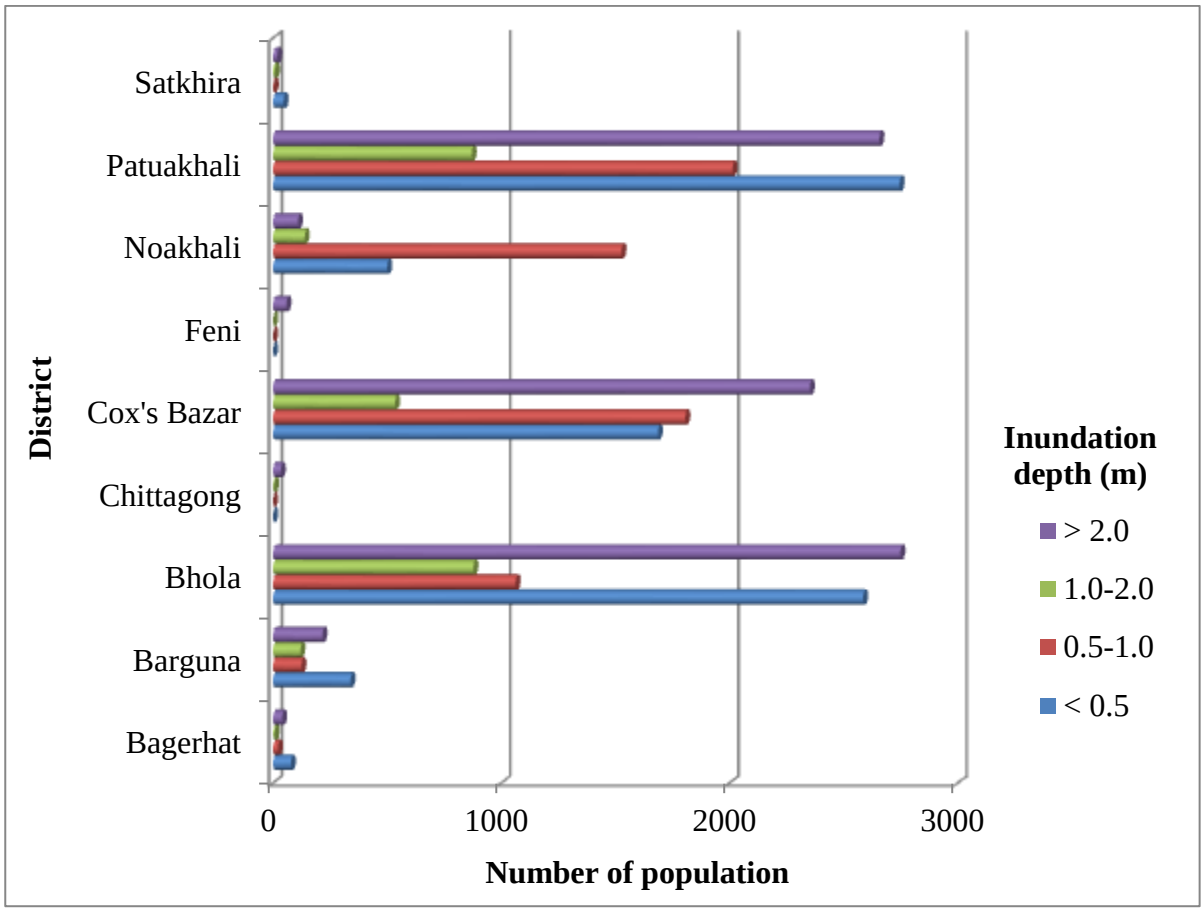

Figure 3.22: Population (extreme poor) exposed to tsunami inundation depth at district level

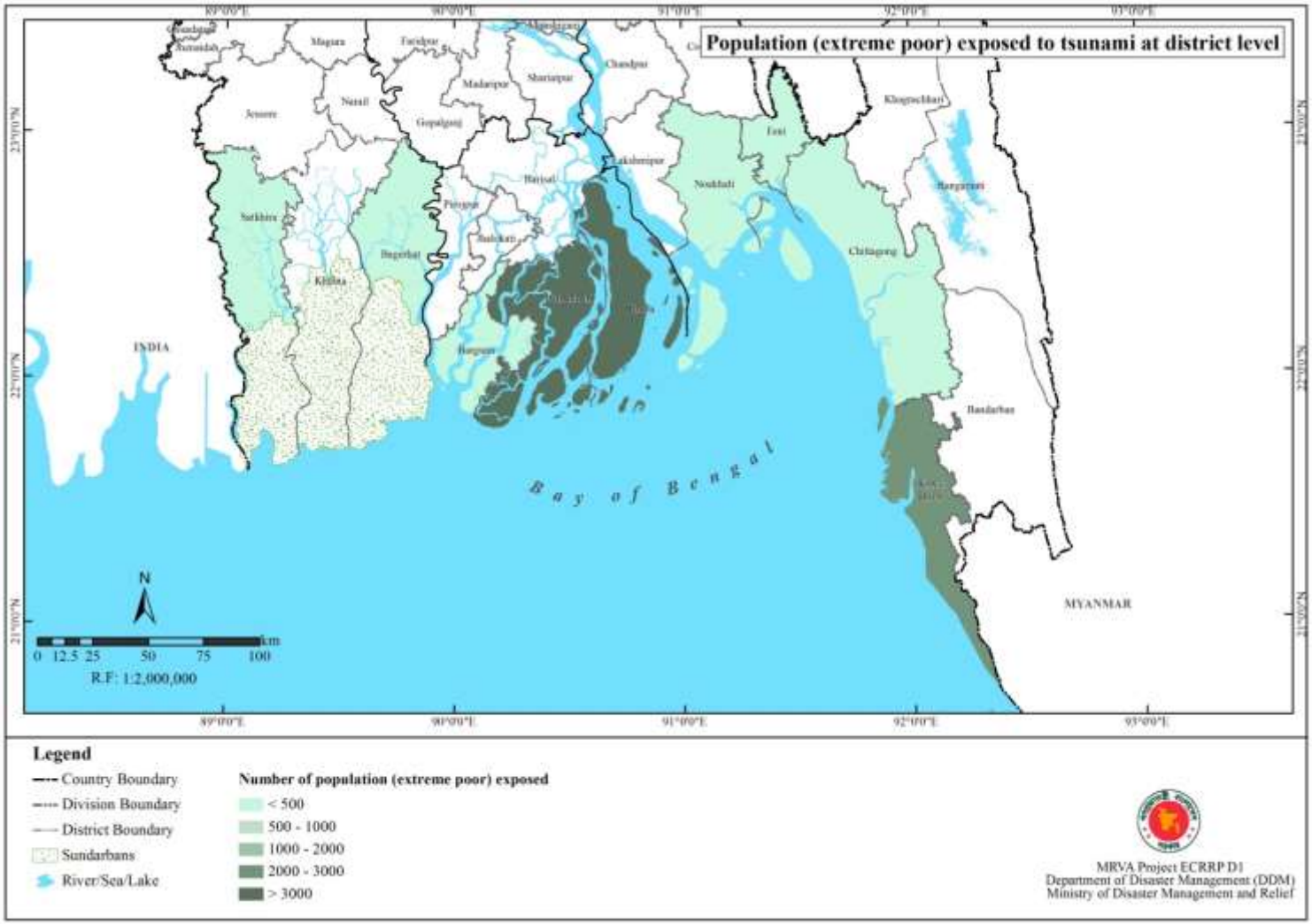

Figure 3.23: Population (extreme poor) exposed to tsunami inundation depth at district level

The exposure of population in poverty (poor) to tsunami at division level is provided in table 3.15 and figure 3.24. At district level shown in figure 3.25.

Table 3.15: Population (poor) exposed to tsunami inundation depth at district level

District	Inundation depth (m) / Population				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Bagerhat	134	37	12	69	114138	114390
Barguna	675	253	241	417	131481	133068
Bhola	4892	2011	1662	5199	140070	153834
Chittagong	0	0	11	90	160341	160442
Cox's Bazar	3384	3542	1054	4542	599699	612220
Feni	0	0	0	91	116742	116833
Noakhali	1355	4139	375	296	85273	91438
Patuakhali	5018	3647	1603	4935	127073	142275
Satkhira	68	4	11	27	159653	159764
Total	15527	13633	4969	15666	1634469	1684264

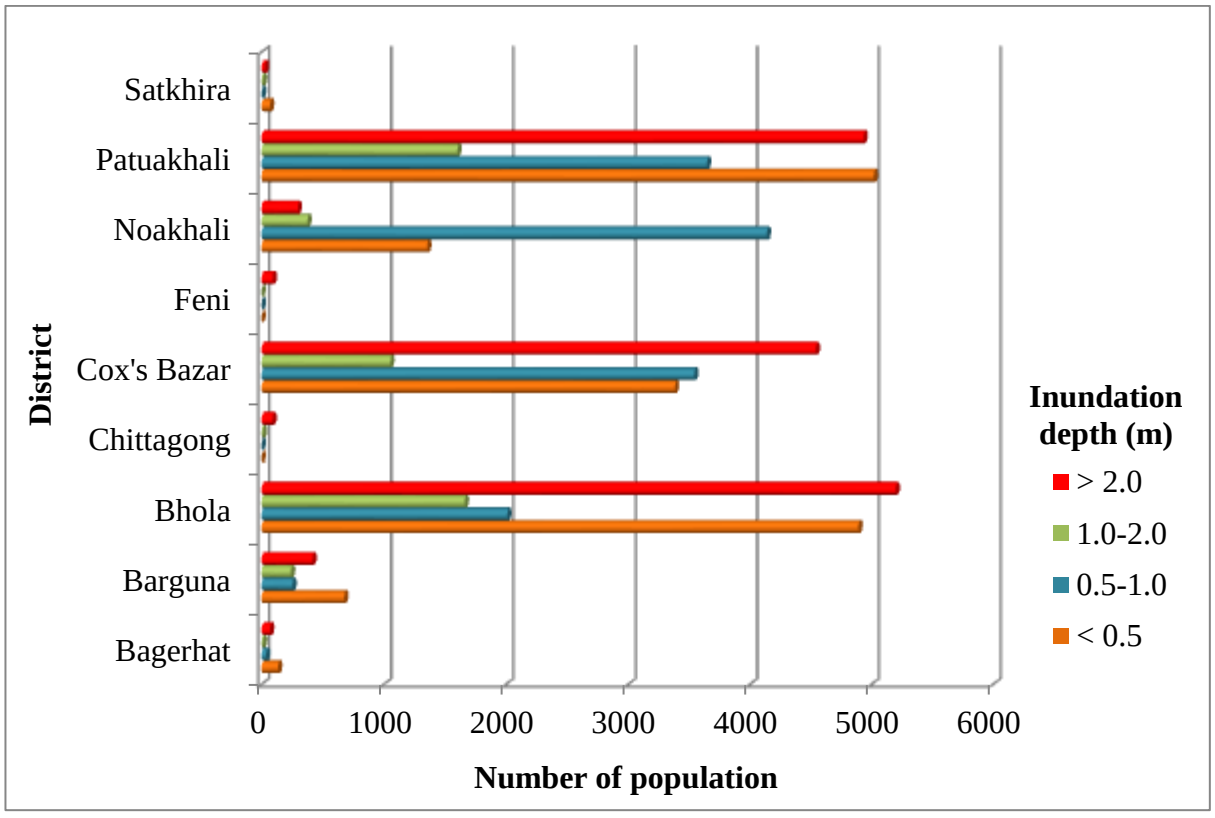

Figure 3.24: Population (poor) exposed to tsunami inundation depth at district level

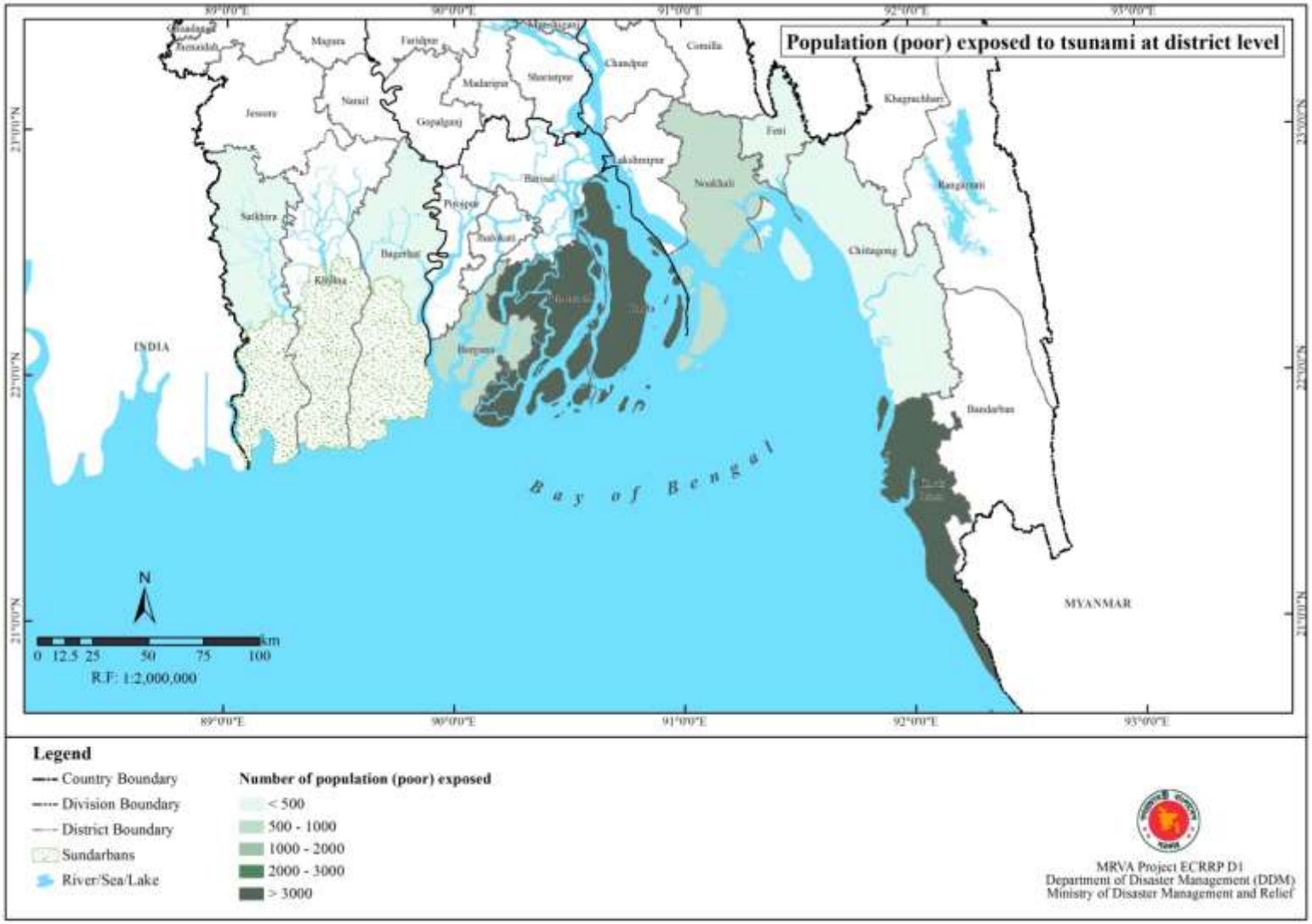

Figure 3.25: Population (poor) exposed to tsunami inundation depth at district level

3.1.2 Housing

Household structure types are Pucca, Semi-Pucca, Katcha, Jhupri. Exposure of the household structures to tsunami inundation depth is assessed by combining tsunami hazard map and household structure maps. Number of Pucca household structures in each tsunami inundation depth category in each division is given in Table 3.16 and figure 3.26. Number of semi-Pucca household structures in each tsunami inundation depth category in each division is given in Table 3.17 and figure 3.27. Number of Katcha household structures in each tsunami inundation depth category in each division is given in Table 3.18 and figure 3.28. Number of Jhupri household structures in each tsunami inundation depth category in each division is given in Table 3.19 and figure 3.29.

Table 3.16: Number of Pucca household structures exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / household structures				Not Affected	Total
	< 0.5 m	0.5 - 1.0 m	1.0 - 2.0 m	> 2.0 m		
Barisal	482	296	162	521	76532	77994
Chittagong	448	1064	141	374	723230	725257
Khulna	46	13	7	30	509244	509340
Total	977	1373	310	925	1309006	1312591

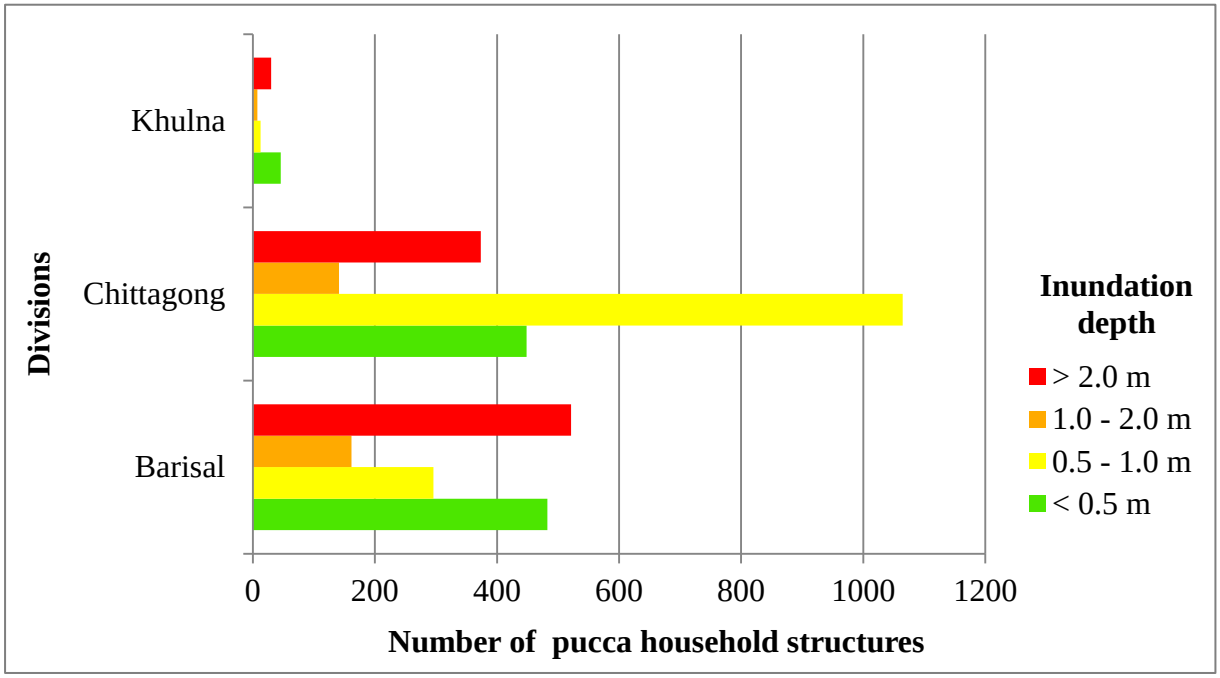

Figure 3.26: Number of Pucca household structures exposed to different tsunami inundation depth at division level

Table 3.17: Number of semi-Pucca household structures exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / household structures				Not Affected	Total
	< 0.5 m	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	946	581	317	1022	150067	152933
Chittagong	491	1165	154	409	791272	793490
Khulna	92	25	15	61	1023779	1023972
Total	1529	1770	486	1492	1965118	1970395

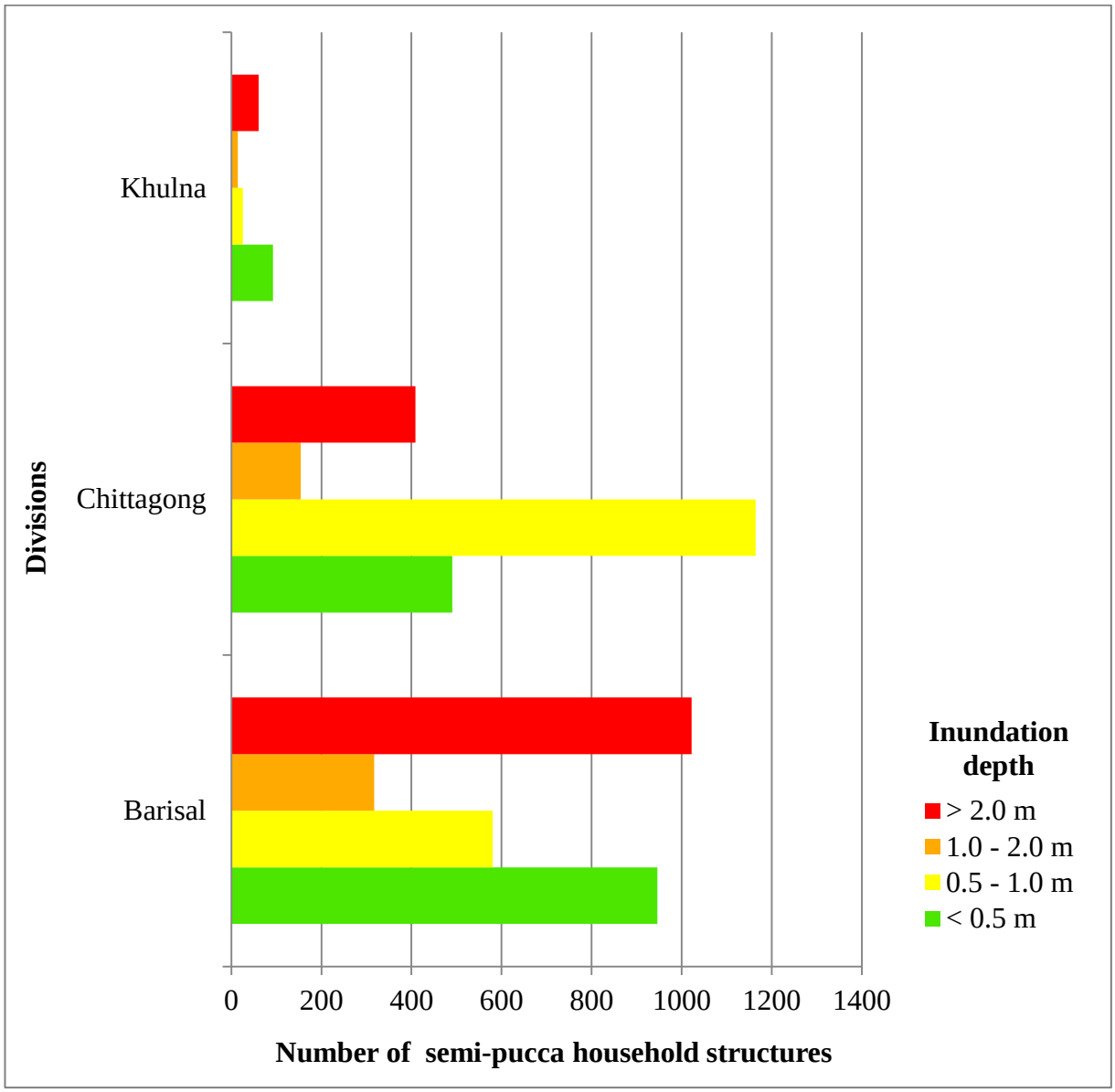

Figure 3.27: Number of semi-Pucca household structures exposed to different tsunami inundation depth at division level

Table 3.18: Number of Kutcha household structures exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / household structures				Not Affected	Total
	< 0.5 m	0.5 - 1.0 m	1.0 - 2.0 m	> 2.0 m		
Barisal	9726	5969	3261	10508	1542775	1572238
Chittagong	2400	5697	754	1999	3871197	3882049
Khulna	189	52	30	124	2094767	2095162
Total	12315	11718	4045	12631	7508739	7549449

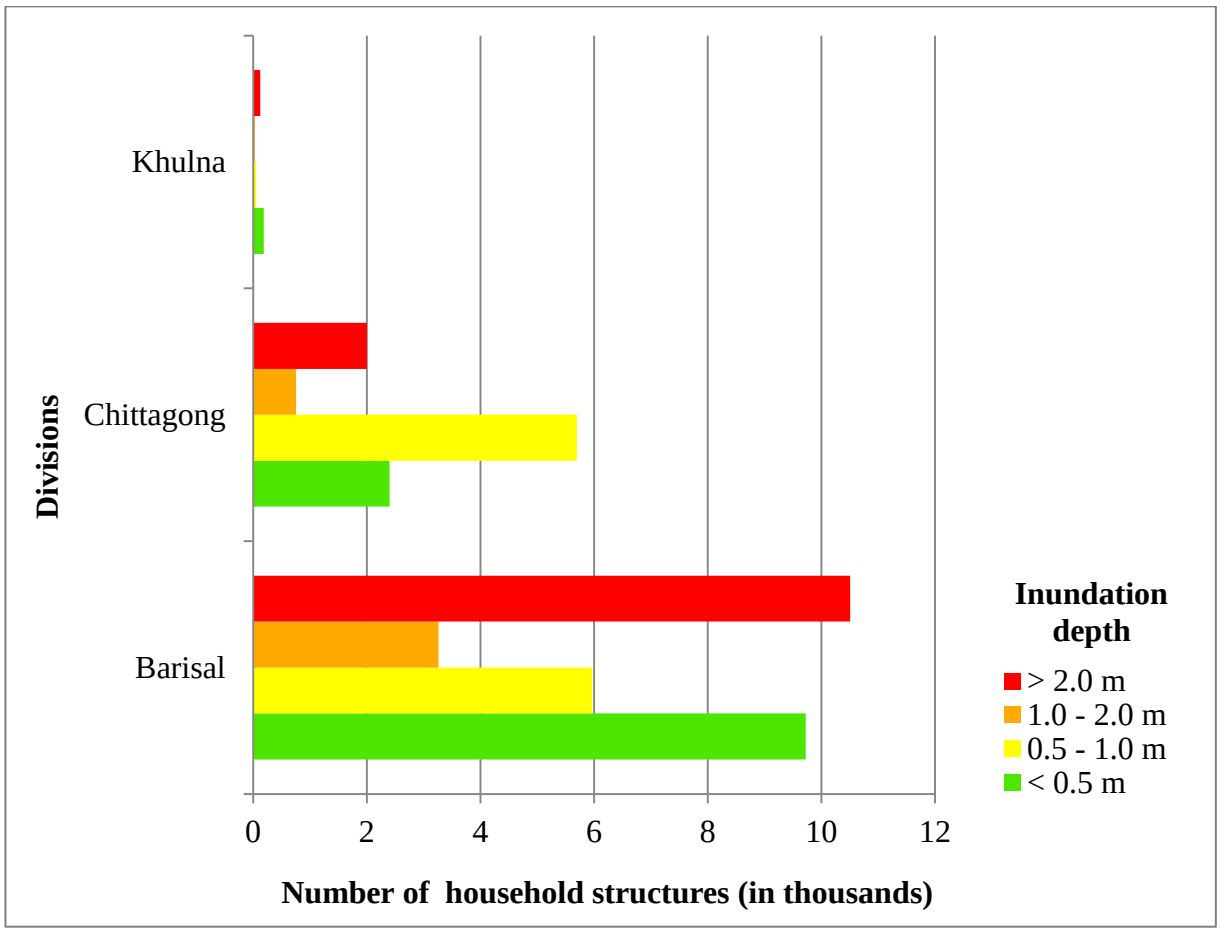

Figure 3.28: Number of Kutcha household structures exposed to tsunami inundation depth at division level

Table 3.19: Number of Jhupri household structures exposed to tsunami inundation depth at division level

Division	Inundation depth (m) household structures				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	369	227	124	399	58555	59673
Chittagong	139	331	44	116	224885	225515
Khulna	10	3	2	7	111288	111309
Total	519	560	169	522	394727	396497

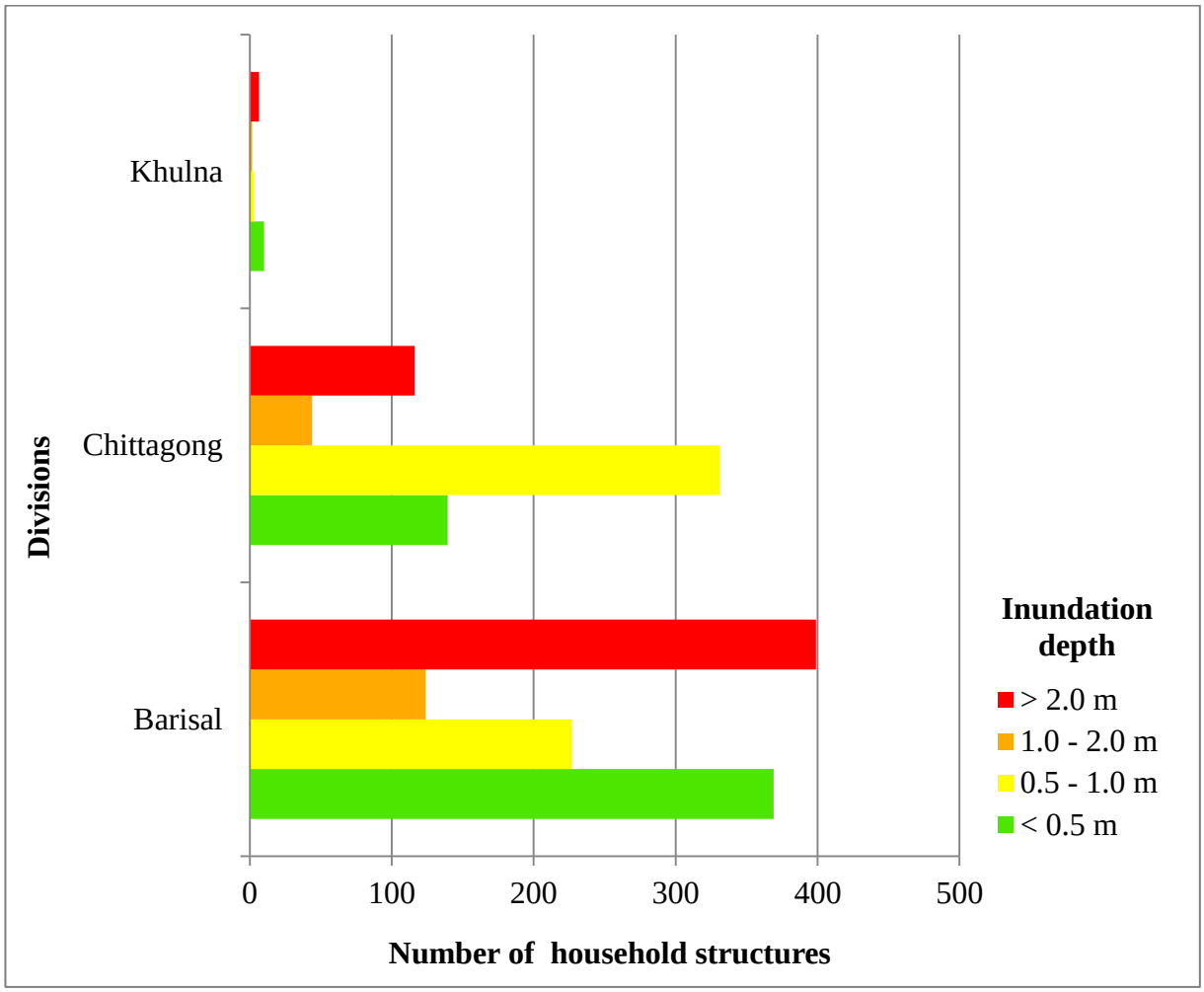

Figure 3.29: Number of Jhupri household structures exposed to different tsunami inundation depth at division level

3.1.3 Livelihood

Elements at risk considered in livelihood are crop (transplanted Aman) and industries.

3.1.3.1 Agriculture

The exposure of transplanted Aman crop is given in table 3.20 and shown in figure 3.30.

Table 3.20: Exposure of Transplanted Aman crop to Tsunami

Division	District	Upazila	Transplanted aman area (Km^2) exposed to inundation depth (m) due to Tsunami			
			<0.5	**0.5 - 1.0**	**1.0 - 2.0**	**> 2.0**
Barisal	Barguna	Amtali	0.64		0.07	0.37
		Barguna Sadar	1.26	0.34	0.21	0.48
		Patharghata	1.28	0.19	0.04	0.04
		Char Fasson	8.22	4.39	3.09	3.52
	Patuakhali	Galachipa	36.87	13.42	3.14	10.22
		Kala Para	3.71	0.45	0.99	4.03
Chittagong	Chittagong	Anowara			0.03	0.13
		Banshkhali				0.06
	Cox's Bazar	Cox's Bazar Sadar	1.68	0.68	0.02	0.19
		Kutubdia	0.00			0.09
		Maheshkhali	0.04	0.01	0.04	0.05
		Pekua	0.04		0.16	0.32
		Teknaf	3.72	2.10	0.99	2.18
	Feni	Sonagazi				0.16
	Noakhali	Companiganj				0.04
		Hatiya	0.01			
Total			57.46	21.59	8.77	21.89

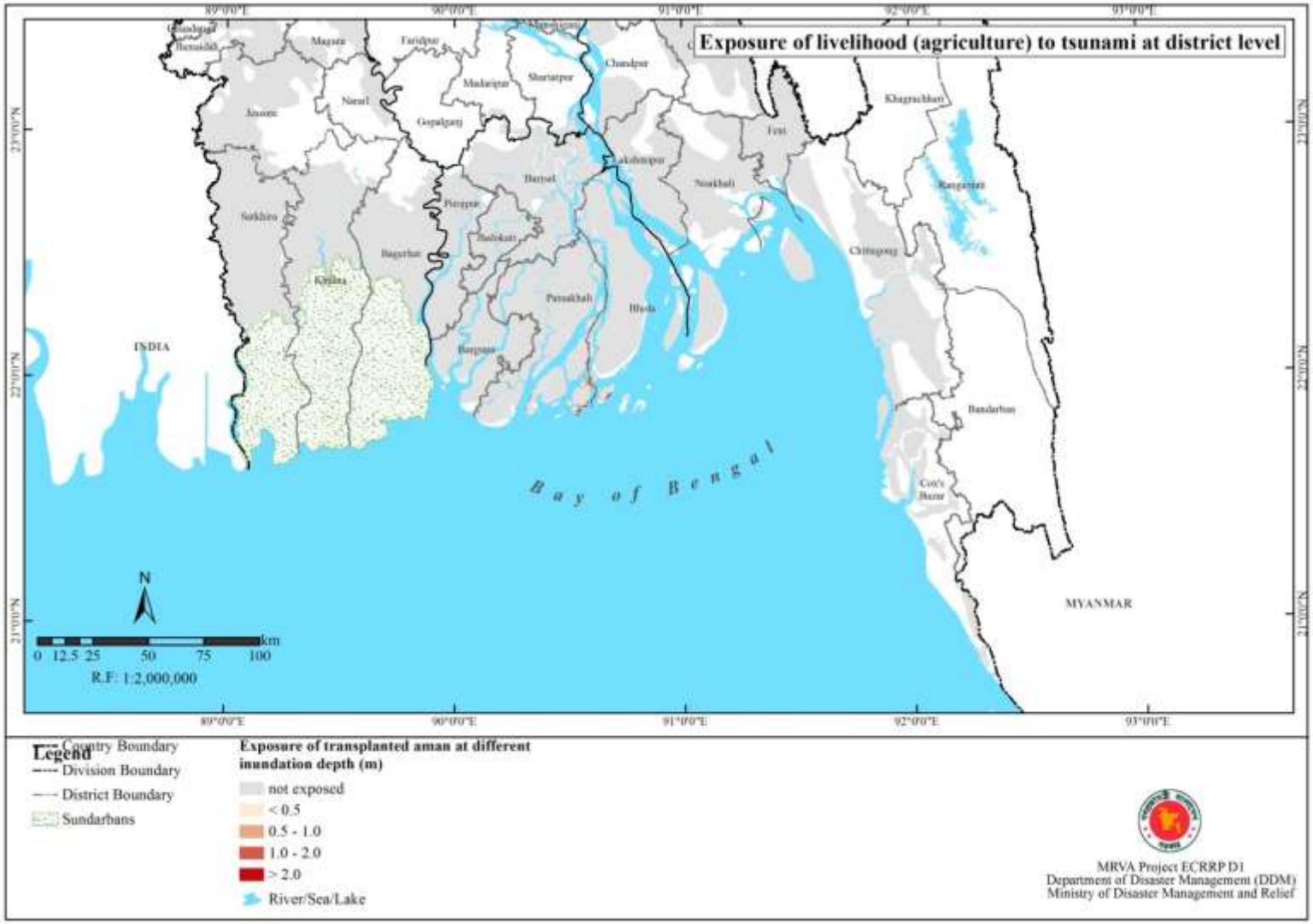

Figure 3.30: Exposure of livelihood (agriculture) to tsunami inundation depth at district level

3.1.3.2 Industries

The different types of industries existing in the database are not exposed to Tsunami hazard.

3.1.4 Critical Facilities

3.1.4.1 Health care facilities

Combining Tsunami hazard map and Health care facility map will provide existing hospitals and family welfare centers in tsunami prone areas.

The hospitals existing in the database are not exposed to Tsunami. The number of family welfare centers existing in different tsunami prone areas at division level is given in Table 3.21.

Table 3.21: Number of family welfare centres exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / family welfare centres				Not Affected
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0	
Barisal					207
Chittagong	1				351
Khulna					342
Total	1				900

3.1.4.2 Educational Institutions

Educational institutions database consists of categories of educational institutions as University, College, High School, Madrasa, Primary Schools. Combining tsunami hazard map and Educational institutions map will provide exposure of Educational institutions to tsunami.

The number of High Schools exposed to tsunami inundation depth at division level is given in Table 3.22.

Table 3.22: Number of High Schools exposed to tsunami inundation depth at division level

Name of Division	Inundation depth (m) / High Schools				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	1		0	0	834	835
Chittagong		1	0	0	1245	1246
Khulna			0	0	1048	1048
Total	1	1	0	0	3127	3129

The number of Madrasa existing in different tsunami prone areas at division level is given in Table 3.23.

Table 3.23: Number of Madrasa exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Madrasa				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal					315	315
Chittagong		1			674	675
Khulna					507	507
Total	0	1	0	0	1496	1497

The number of Primary School existing in different tsunami prone areas at division level is given in table 3.24 and figure 3.31. Primary School s existing in tsunami prone areas at district level is shown in figure 3.32.

Table 3.24: Number of Primary School exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Primary schools				Not Affected	Total
	< 0.5 m	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal			1		2256	2257
Chittagong	2	2	1		6316	6321
Khulna					4191	4191
Total	2	2	2		12763	12769

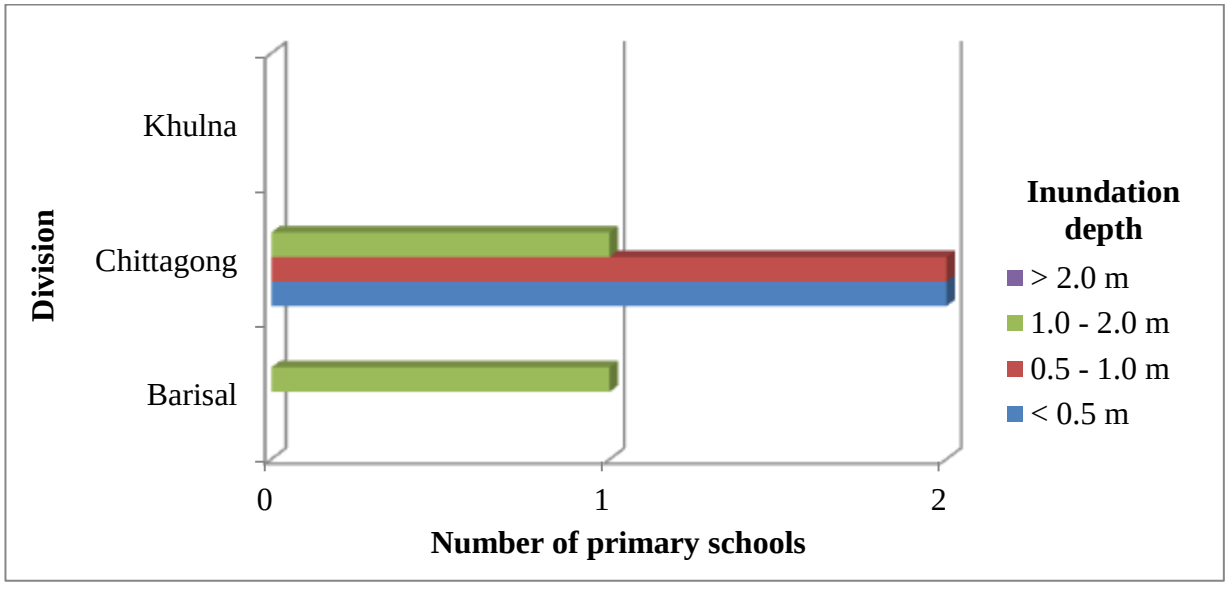

Figure 3.31: Number of primary schools exposed to different tsunami inundation depth at division level

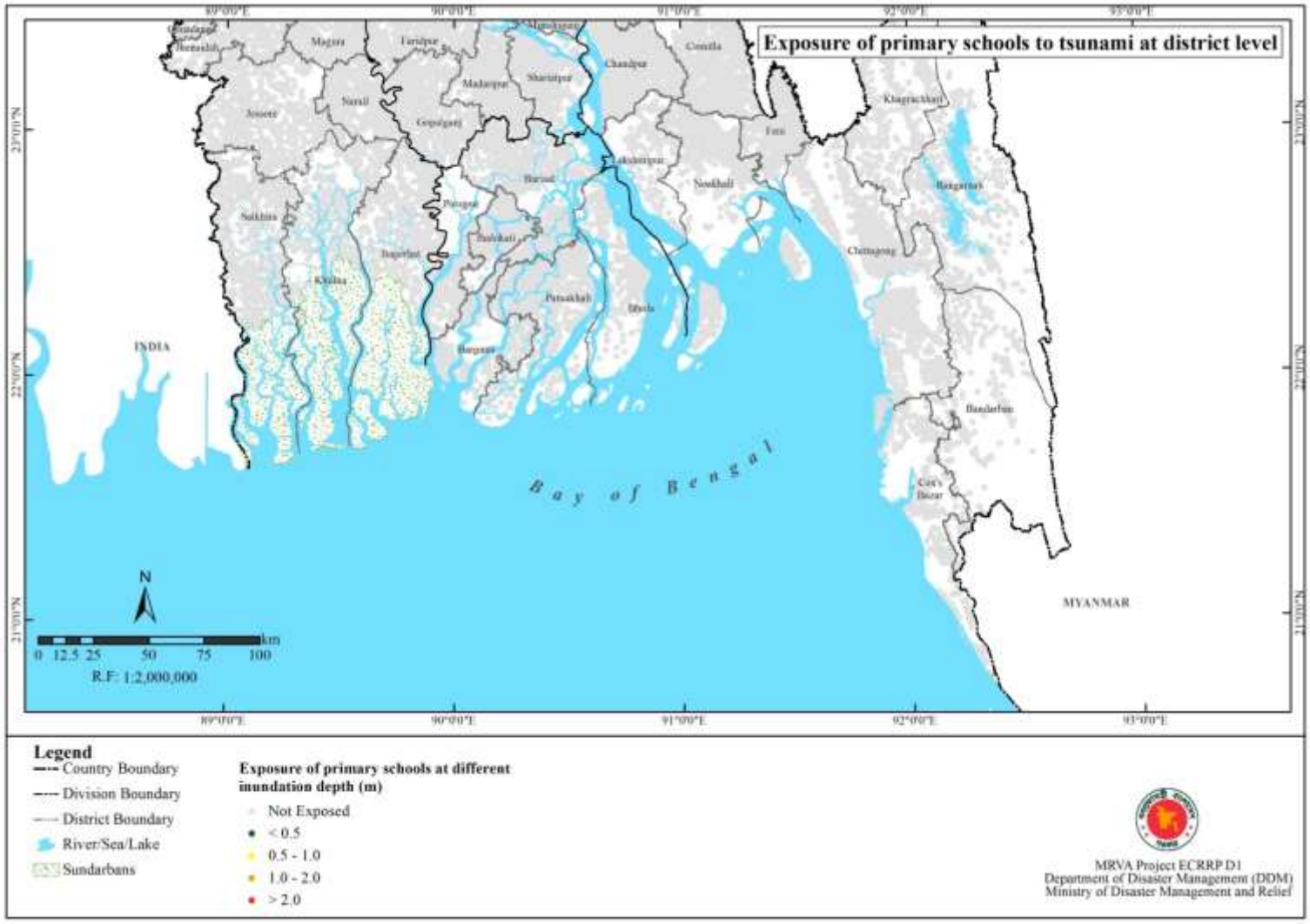

Figure 3.32: Exposure of primary schools to different tsunami inundation depth at district level

3.1.4.3 First Responders

Fire stations

Existing Fire stations based on database are not exposed to Tsunami hazard.

Police stations

The number of Police stations existing in different tsunami prone areas at division level is given in Table 3.25 and figure 3.33. Police stations existing in different tsunami prone areas at district level is shown in figure 3.34.

Table 3.25: Number of Police stations exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Police stations				Not Affected
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0	
Barisal	2	1			566
Chittagong	1	4			2704
Khulna					3063
Total	3	5			6333

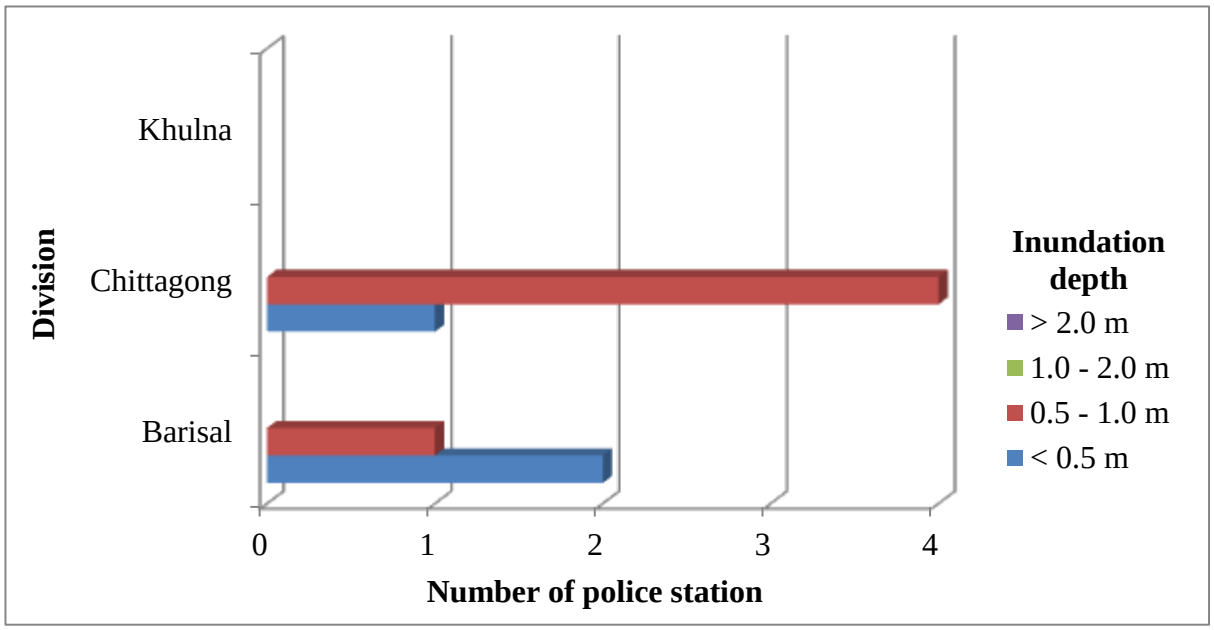

Figure 3.33: Number of police stations exposed to different tsunami inundation depth at district level

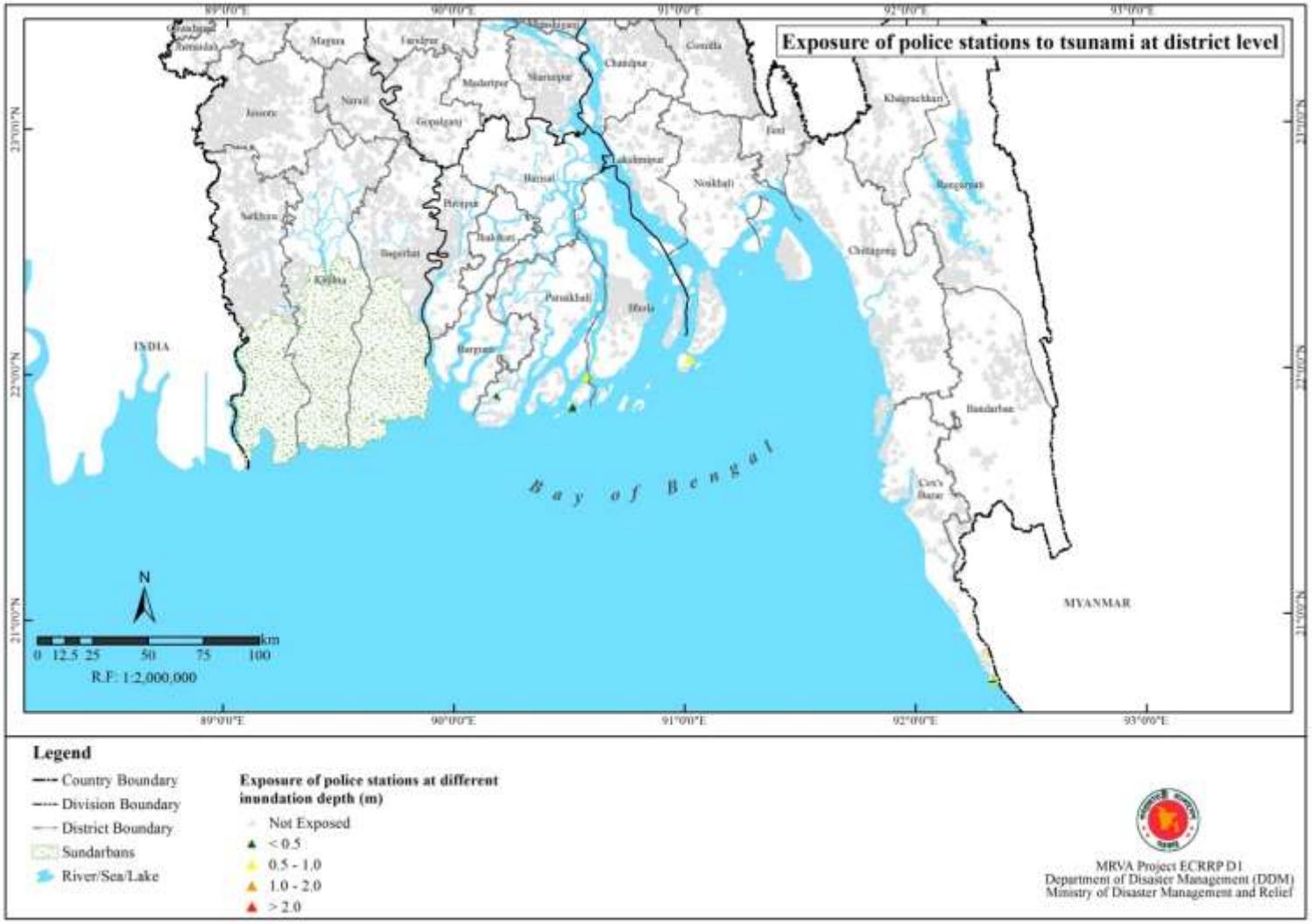

Figure 3.34: Exposure of police stations exposed to tsunami inundation depth at district level

3.1.4.4 Cyclone Shelters

The number of Cyclone Shelters existing in different tsunami prone areas at division level is given in Table 3.26 and figure 3.35. Cyclone Shelters existing in different tsunami prone areas at district level is shown in figure 3.36.

Table 3.26: Number of Cyclone Shelters exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Cyclone shelters				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	1	3	3	0	1423	1430
Chittagong	6	0	0	2	1490	1498
Khulna	0	0	0	0	451	451
Total	7	3	3	2	3364	3379

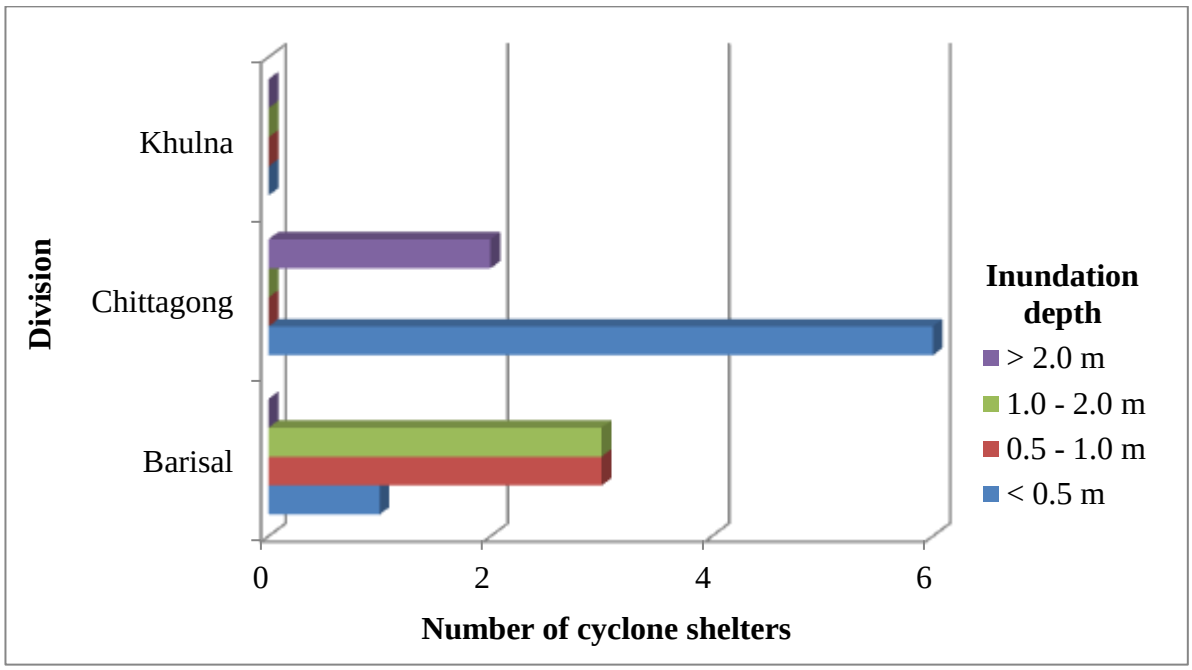

Figure 3.35: Number of Cyclone Shelters exposed to different tsunami inundation depth at division level

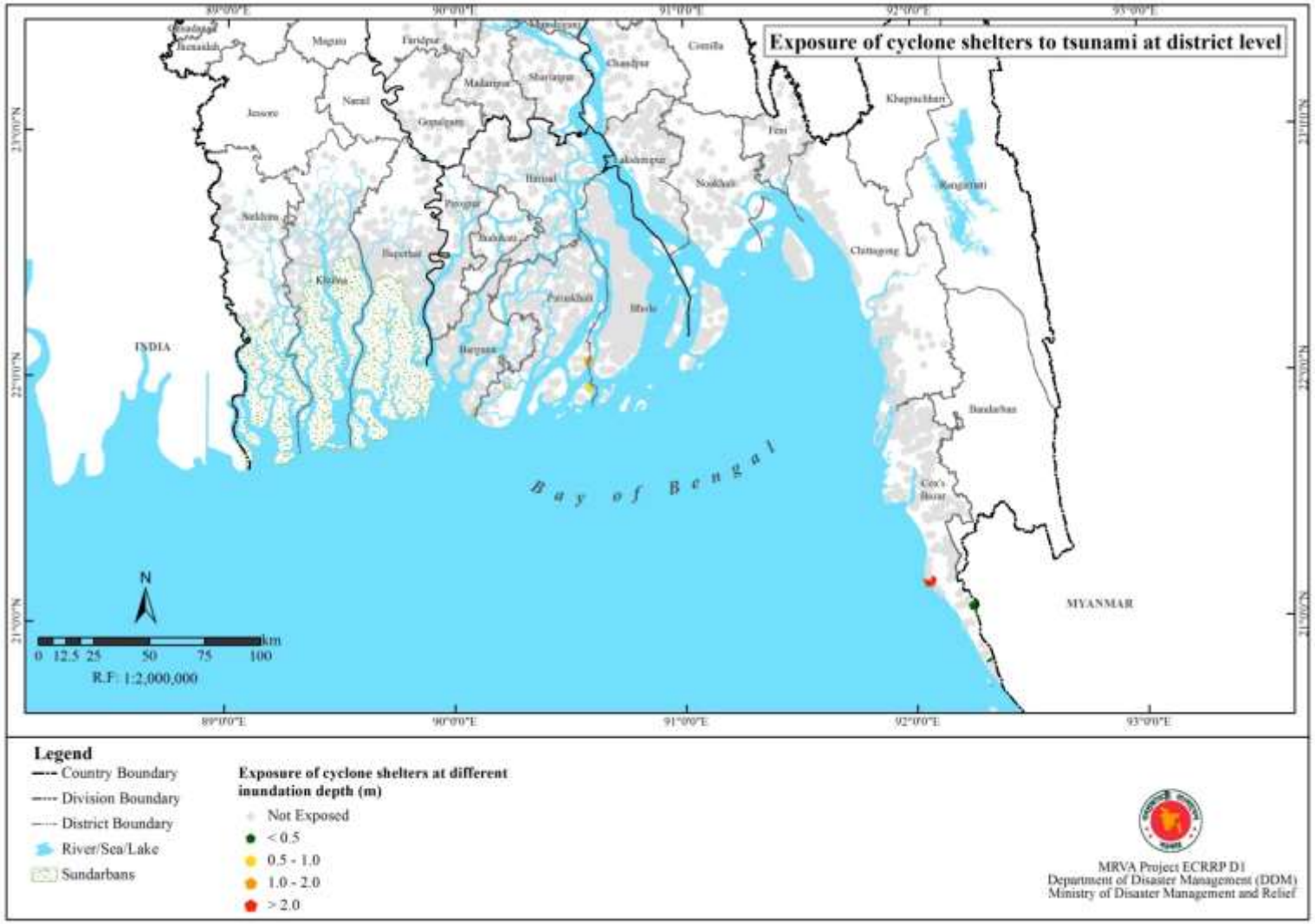

Figure 3.36: Exposure of Cyclone Shelters to tsunami inundation depth at district level

Based on the exposure of cyclone shelters and population to tsunami, capacity of cyclone shelters and population exposed is analysed and given in table 3.27.

Table 3.27: Population exposed and capacity of cyclone shelters in cyclone exposed upazilas

District	Upazila	No of cyclone shelters	total exposed population	total capacity of cyclone shelters	Deficit	Excess
Barguna	Amtali		1215		1215	
	Barguna Sadar		4003		4003	
	Patharghata		4194		4194	
Bhola	Char Fasson	1	48762	700	48062	
	Manpura		40		40	
Patuakhali	Galachipa	2	51566	1500	50066	
	Kala Para	5	8842	4525	4317	
Chittagong	Anowara		512		512	
	Banshkhali		78		78	
Cox's Bazar	Cox's Bazar Sadar	1	6507	900	5607	
	Kutubdia	1	753	950		197
	Maheshkhali		120		120	
	Pekua		653		653	
	Ramu	1	808	850		42
	Teknaf	3	20990	4500	16490	
	Ukhia	1	5390	850	4540	
Feni	Sonagazi		204		204	
Noakhali	Companiganj		22		22	
	Hatiya	5	38524	6250	32274	
Bagerhat	Mongla		146		146	
	Sarankhola		399		399	
Satkhira	Shyamnagar		221		221	
	Total	20	193948	21025	172923	239

As shown in table 3.27, above the existing capacity of cyclone shelters is deficit of more than 20000 population in Char Fasson of Bhoal district, Galachipa of Patuakhali district and Hatiya of Noakhali district.

3.1.5 Infrastructure

3.1.5.1 Road

The type of roads existing in the database are, National Highway, Regional Highway, Upazila road, Union road and Village roads. Combining tsunami hazard map and road network map will provide existing type of roads in tsunami prone areas. The length of all road categories existing in different tsunami prone areas at division level is given in Table 3.28.

Table 3.28: Length of road types exposed to tsunami inundation depth at national level

Division	National High Way	Regional High Way	Union Road	Upazila Road	Village Road
Barisal	105.17	343.14	2203.33	1420.66	7917.30
Chittagong	67.71	544.70	1097.17	900.89	5886.11
Khulna	128.88	265.50	1052.02	1365.54	5611.86
Total Length (Km)	**301.76**	**1153.35**	**4352.52**	**3687.08**	**19415.27**

National Highway is not exposed to tsunami hazard prone areas.

The length of Regional highway existing in tsunami prone areas at division level is given in Table 3.29.

Table 3.29: Length of Regional highway exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Road length (Km)				Not affected
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0	
Barisal	0.12				343.02
Chittagong		0.44	0.20	0.16	543.90
Khulna					265.50
Total	0.12	0.44	0.20	0.16	1152.42

The length of Road existing in different tsunami prone areas at division level is given in table 3.30.

Table 3.30: Length of Road exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Road length (Km)				Not affected
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0	
Barisal	0.57	0.28		0.32	1419.49
Chittagong	1.06	0.20		1.29	898.34
Khulna					1365.54
Total	1.63	0.48	0.00	1.61	3683.36

The length of Union Road existing in tsunami prone areas at division level is given in table 3.31.

Table 3.31: Length of Union Road exposed to tsunami inundation depth at division level

Division	Inundation depth (m) / Road length (Km)				Not Affected
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0	
Barisal	4.44	0.05	0.10	5.46	2193.28
Chittagong	0.58		0.07	0.24	1096.27
Khulna					1052.02
Total	5.03	0.05	0.16	5.70	4341.57

Exposure of all major roads to tsunami at district level is shown in figure 3.51.

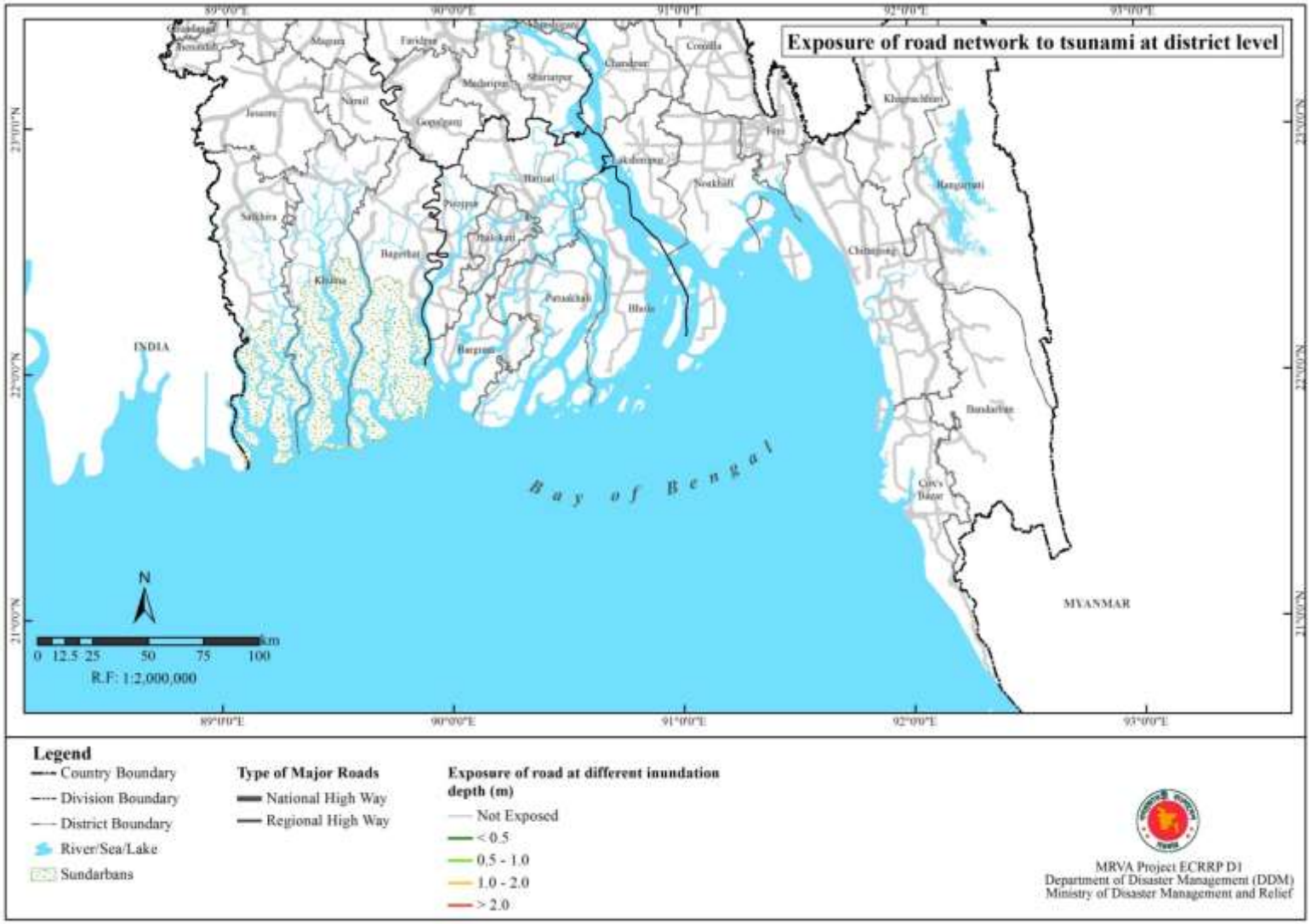

Figure 3.37: Exposure of Major roads for tsunami inundation at district level

3.1.5.2 Bridge

The number of bridges existing in different tsunami prone areas at division level is given in Table 3.31.

Table 3.32: No. of Bridges exposed to tsunami inundation depth at division level

Name	Inundation depth (m) / Number of Bridges				Not Affected	Total
	< 0.5	0.5 - 1.0	1.0 - 2.0	> 2.0		
Barisal	0	0	0	0	912	912
Chittagong	1	2	0	1	2390	2394
Khulna	0	0	0	0	3280	3280
Total	1	2	0	1	6582	6586

3.1.5.3 Railway

Existing Railway network based on database are not exposed to Tsunami hazard.

3.1.5.4 Air, Seas and River Ports

Existing Air, Seas and River Ports based on database are not exposed to Tsunami hazard.

3.1.5.5 Power

Existing Power stations and sub-stations based on database are not exposed to Tsunami hazard.

3.2 Risk Assessment

3.2.1 Household structures

The damage curves representing the vulnerability of household structures are developed based on the literature and limited field data analysis (more details in Annexure – I: Probabilistic damage functions report). The damage curves developed for household structure types due to tsunami inundation depth is given as table 3.33 and figure 3.38.

Table 3.33: Damage function table for household structure types due to tsunami inundation depth

Inundation Depth (m)	Damage rate (%)			
	Jhupri	Kutcha	Semi- Pucca	Pucca
< 0.5	4.1	2.7	0.3	0.2
0.5 – 1.0	41.1	28.6	5.6	3.6
1.0 – 2.0	77.6	68.0	29.5	20.2
> 2.0	97.0	93.0	73.4	62.8

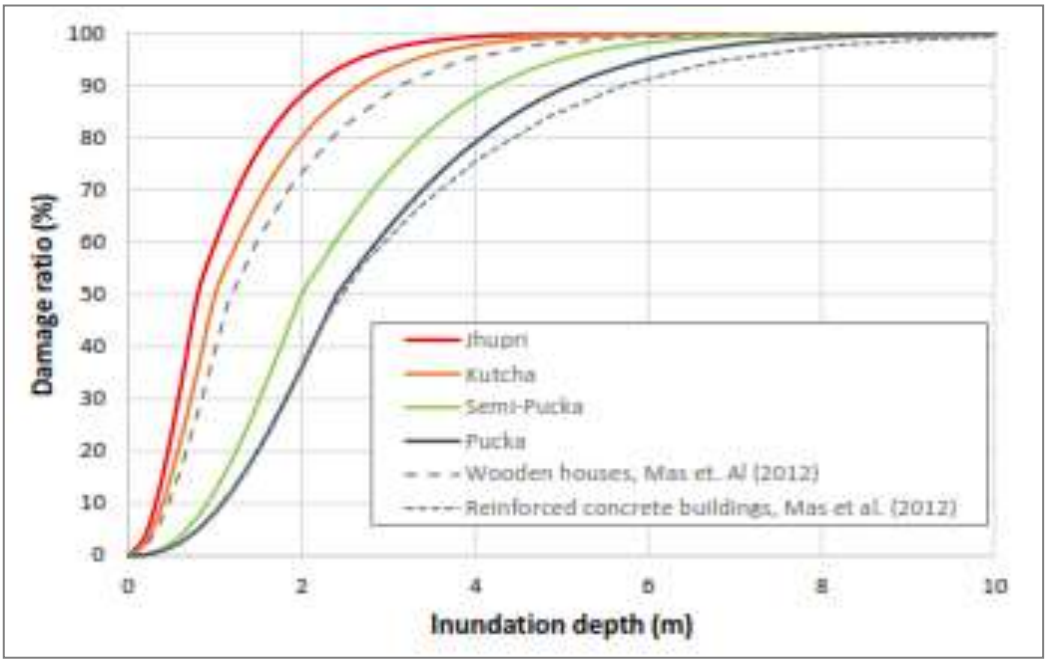

Figure 3.38: Damage functions for housing structure types due to tsunami inundation depth

Using the above damage function table and exposure of household structure types to tsunami inundation depth, possible % of damage of household structure is calculated. The percentage of damages are grouped into 5 risk level (D0: 0, D1:1-15 %, D2: 15-35%, D3:35-60%, D4:>60%) as explained in section 1.6. The number of Pucca household structure in different risk levels at district level is given table 3.34 and figure 3.39. Percentage of Pucca household structures at high risk is given in figure 3.40.

Table 3.34: Number of Pucca household structures in different risk levels at division level

District	Risk levels / household structures				
	0	**0-15**	**15-35**	**35-60**	**>60**
Bagerhat	2716	1	0	0	1
Barguna	3202	9	8	0	11
Bhola	1247	19	16	0	50
Chittagong	11772	0	2	0	12
Cox's Bazar	19603	117	28	0	111
Feni	5213	0	0	0	4
Noakhali	4966	52	5	0	4
Patuakhali	1693	35	17	0	56
Satkhira	5492	0	0	0	1
Total	55903	233	76	0	250

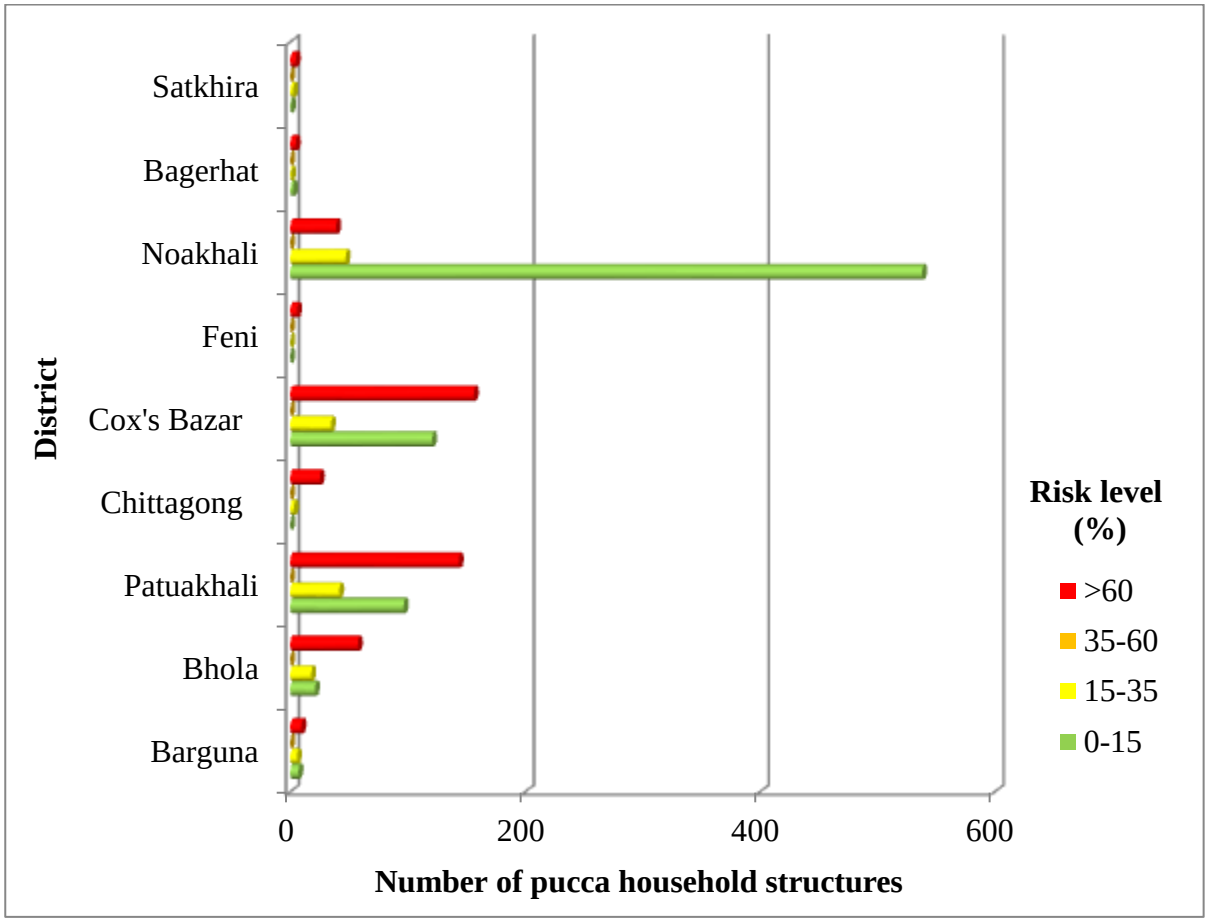

Figure 3.39: Number of Pucca household structures in different risk levels at district level

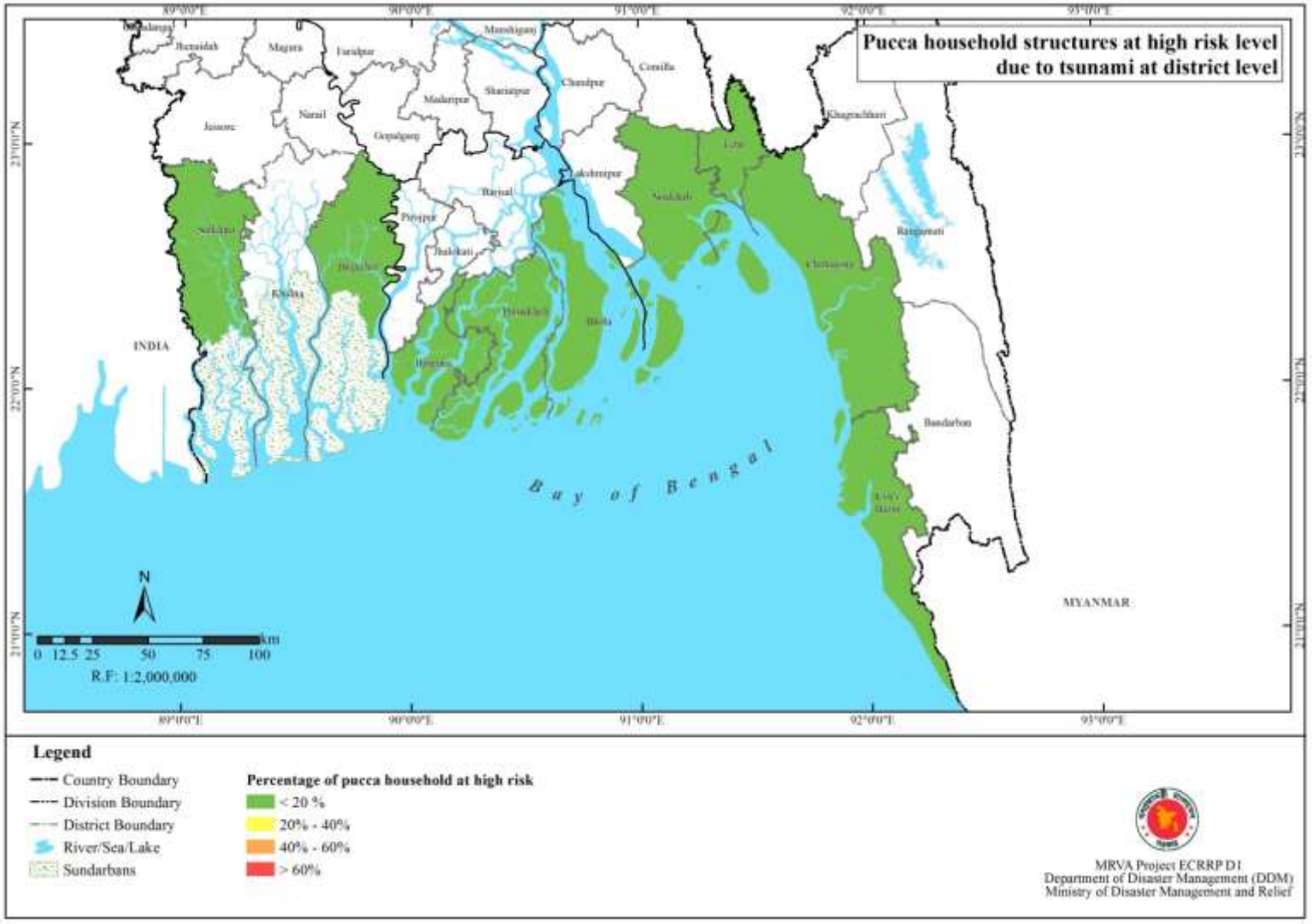

Figure 3.40: Pucca household structures at high risk levels due tsunami in each district

The number of semi-Pucca household structures in different risk levels at district level is given table 3.35 and figure 3.41. Percentage of Semi-Pucca household structures at high risk level is given in figure 3.42.

Table 3.35: Number of Semi-Pucca household structures in different risk levels at district level

Name of District	Risk levels / semi-pucca household structures				
	0	**0-15**	**15-35**	**35-60**	**>60**
Bagerhat	4410	1	0	0	3
Barguna	8078	20	19	0	26
Bhola	6425	103	86	0	267
Chittagong	13343	0	2	0	14
Cox's Bazar	37420	231	55	0	245
Feni	4561	0	0	0	4
Noakhali	6487	208	19	0	15
Patuakhali	4529	116	52	0	163
Satkhira	6214	0	0	0	1
Total	91468	681	233	0	738

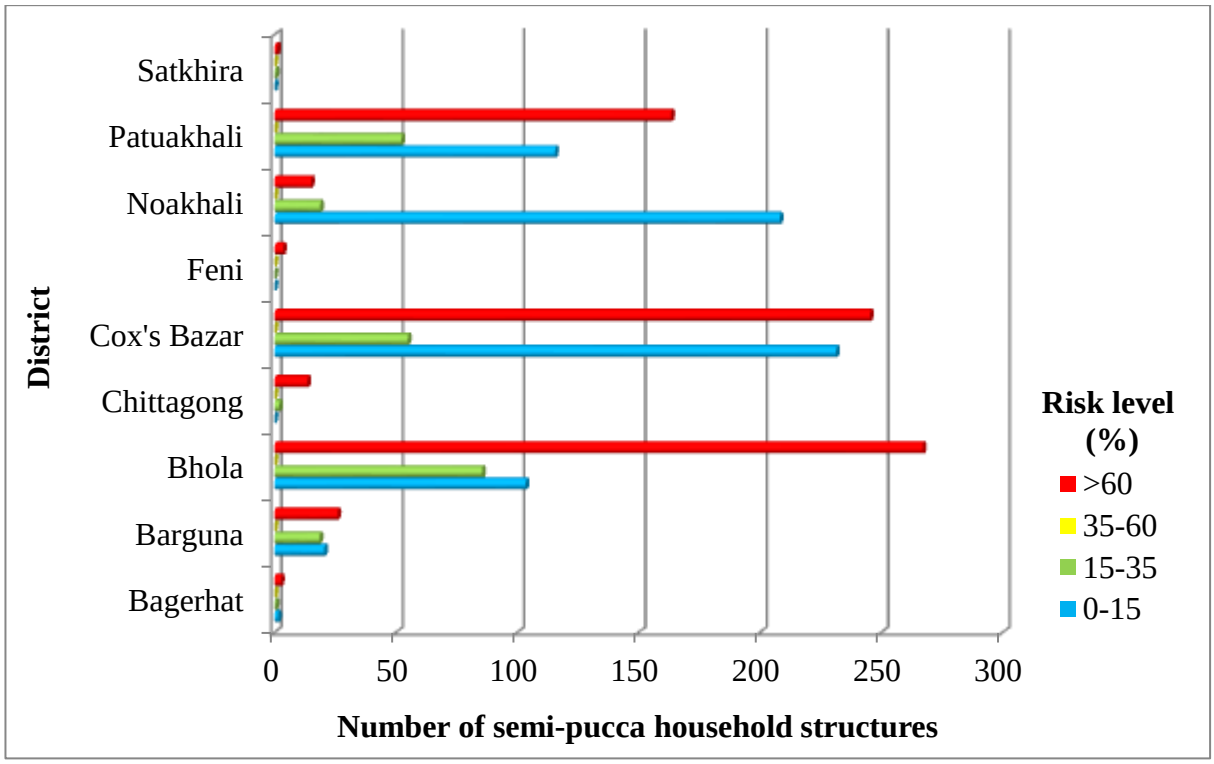

Figure 3.41: Number of Semi-Pucca household structures in high risk levels at district level

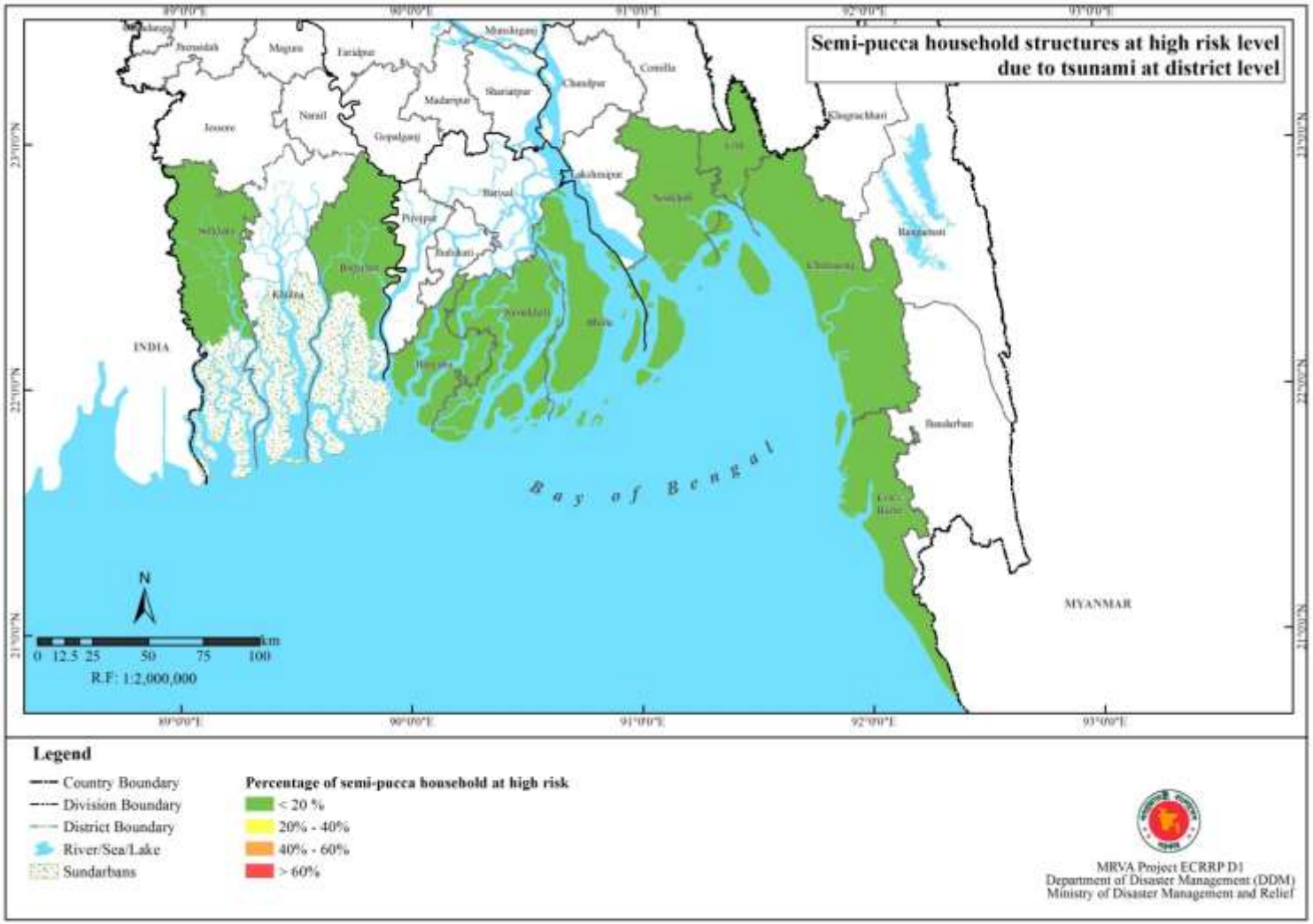

Figure 3.42: Semi-Pucca household structures at high risk levels due tsunami in each district

The number of Kutcha household structures in different risk levels at district level is given table 3.36 and figure 3.43. Percentage of Kutcha household structures at high risk level due to tsunami is given in figure 3.44.

Table 3.36: Number of Kutcha household structures in different risk levels at district level

Name of District	Risk levels / Kutcha household structures				
	0	0-15	15-35	35-60	>60
Bagerhat	50,822	59	16	0	36
Barguna	147,885	909	397	0	798
Bhola	85,816	3,076	1,264	0	4,313
Chittagong	88,689	0	0	0	70
Cox's Bazar	220,717	1,117	1,076	0	1,793
Feni	39,751	0	0	0	31
Noakhali	112,408	1,474	4,501	0	731
Patuakhali	104,636	3,716	2,627	0	5,036
Satkhira	59,877	26	2	0	14
Total	910,602	10,376	9,884	0	12,822

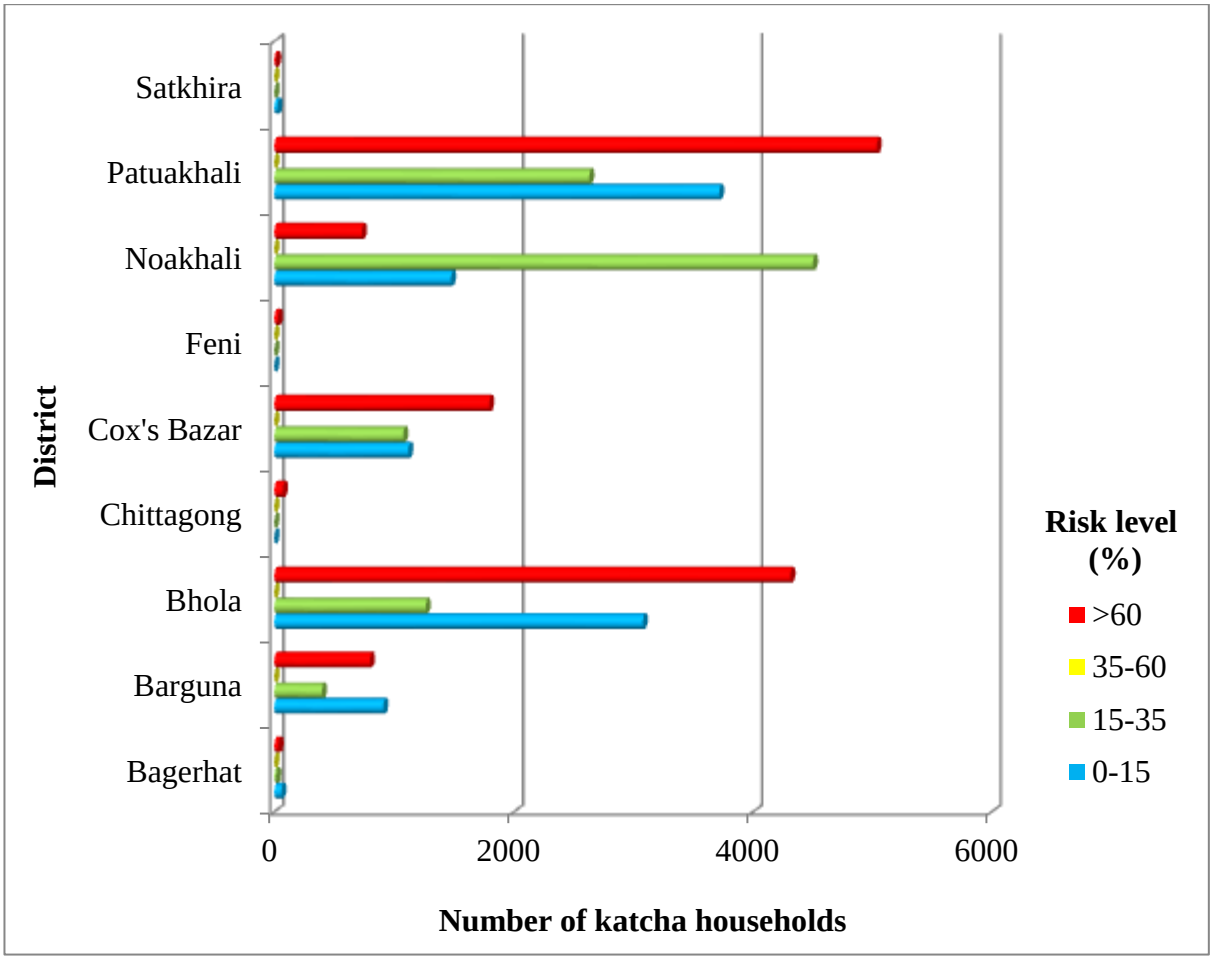

Figure 3.43: Number of Kutcha household structures in different risk levels at district level

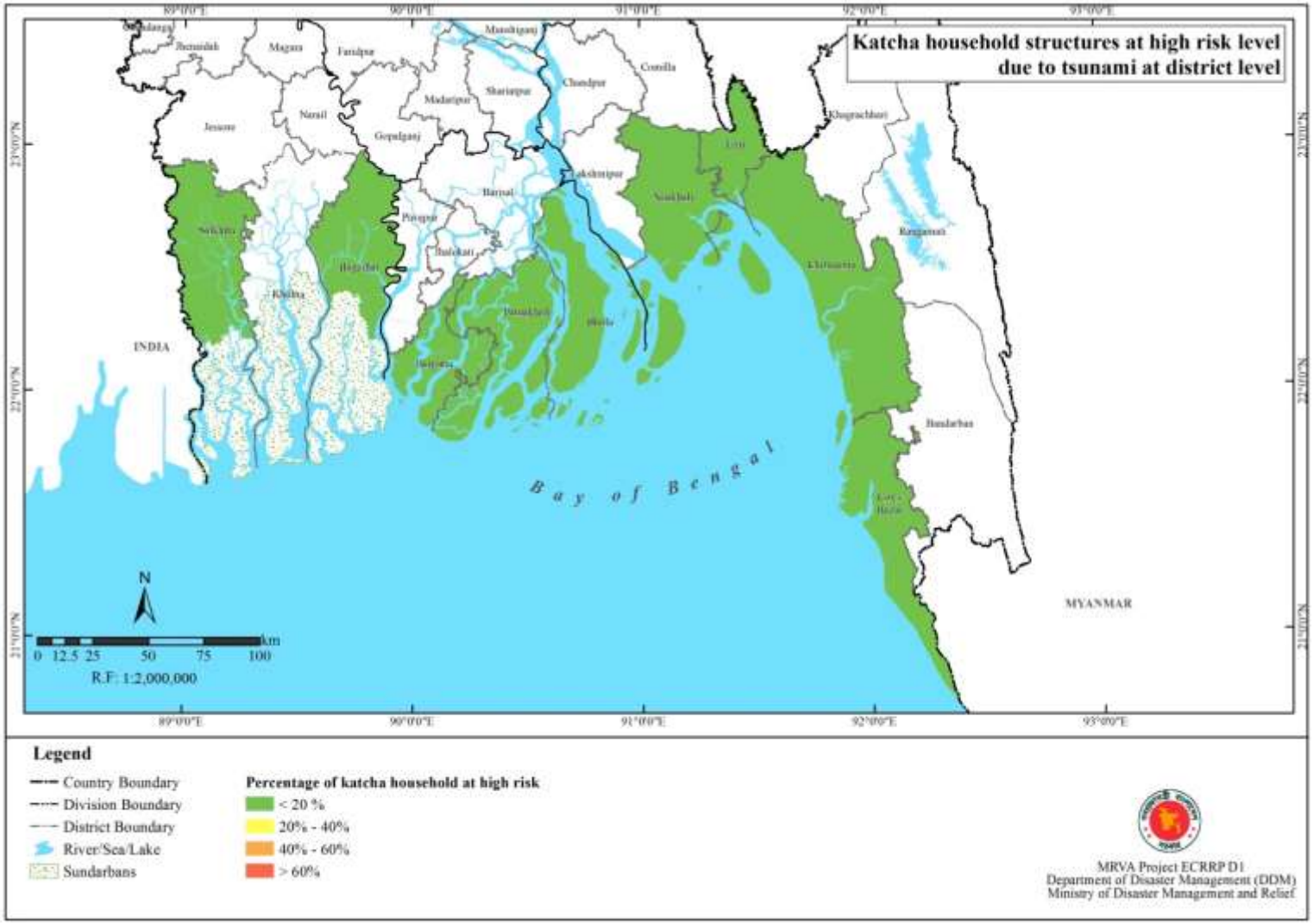

Figure 3.44: Kutcha household structures at high risk levels due to tsunami in each district

The number of Jhupri household structures in different risk levels at division level is given table 3.37 and figure 3.45. Percentage of Jhupri household structures at high risk due to tsunami is given in figure 3.46.

Table 3.37: Number of Jhupri household structures in different risk levels at district level

Name of District	Risk levels / Jhupri household structures				
	0	0-15	15-35	35-60	>60
Bagerhat	2892	3	0	1	2893
Barguna	6952	28	0	11	6972
Bhola	8416	223	0	92	8655
Chittagong	20264	0	0	0	20277
Cox's Bazar	43999	271	0	301	44385
Feni	602	0	0	0	602
Noakhali	8498	145	0	442	8530
Patuakhali	13376	501	0	359	13880
Satkhira	651	0	0	0	651
Total	105650	1170	0	1205	106844

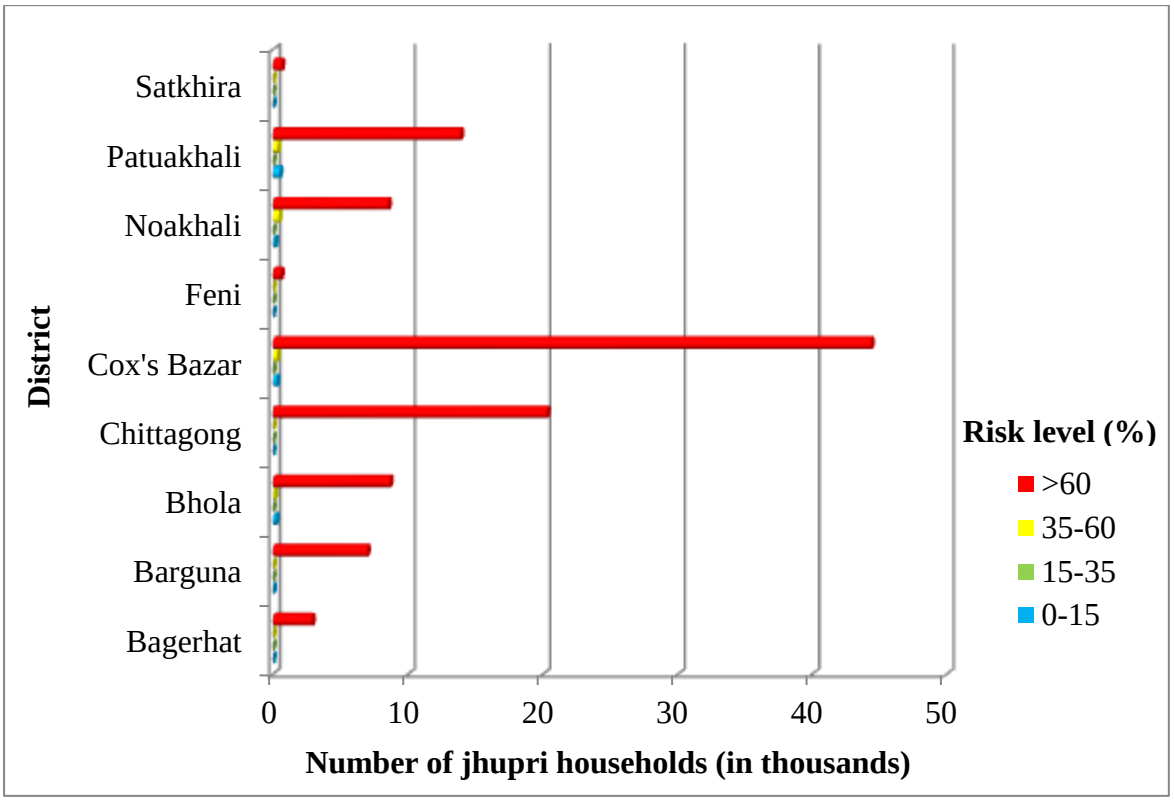

Figure 3.45: Number of Jhupri household structures in different risk levels at district level

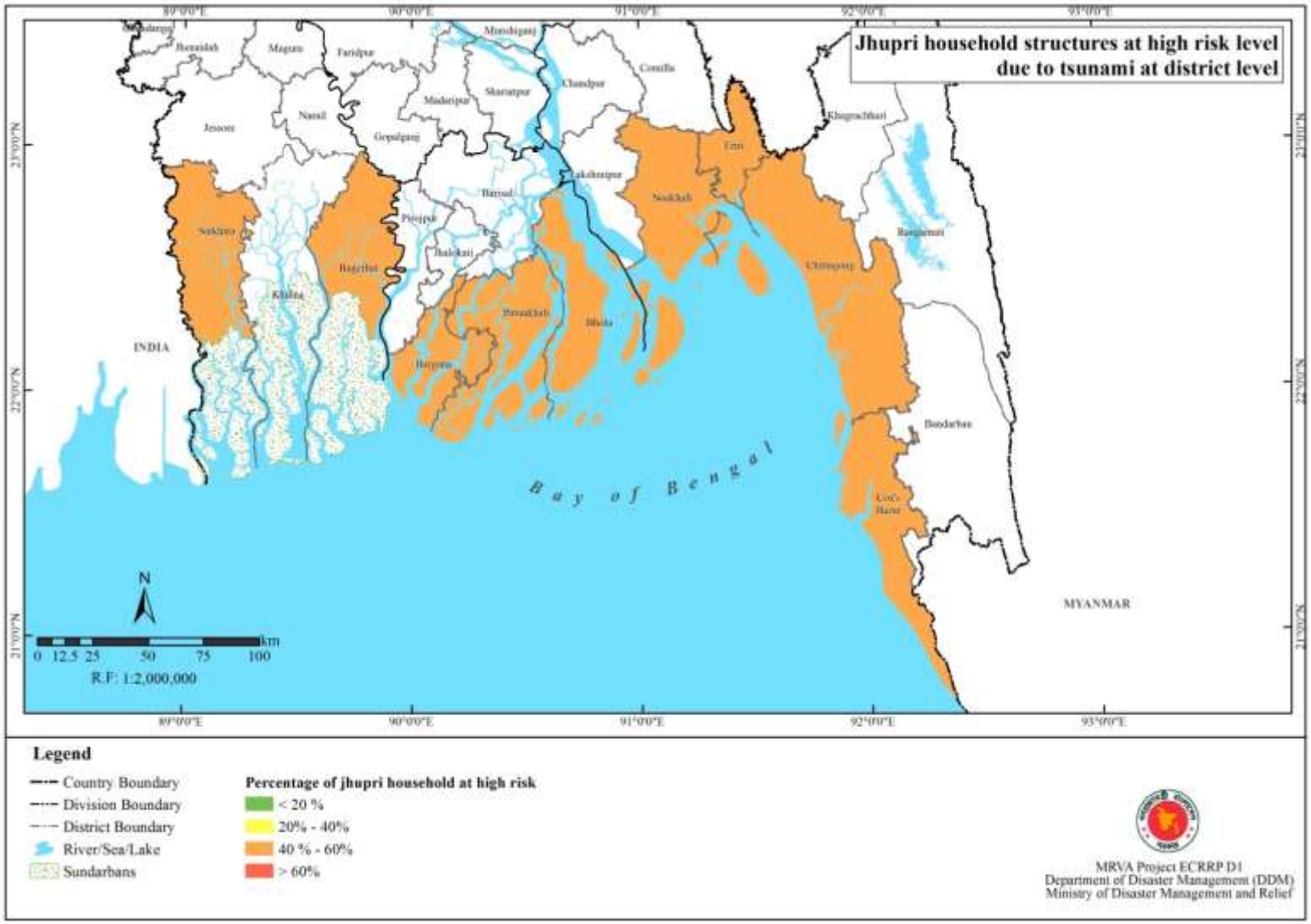

Figure 3.46: Jhupri household structures at high risk levels due tsunami in each district

3.2.2 Livelihood

Exposure of livelihood (agriculture) i.e. transplanted Aman to tsunami hazard is used for risk assessment. Since crop duration of paddy is approximately 110 days, it is divided into 4 crop growth stages (seedling, vegetative stage, reproductive stage and mature). The number of days from the date of sowing and also risk levels of transplanted aman crop (assuming tsunami may occur in the month of September) is given in table 3.38, based the literature and also discussion with Prof. Mirza, Share-e-Bangla Agriculture University, Dhaka. Based on this risk matrix transplanted aman crop at different risk level is assessed and given in table 3.39 and shown in figure 3.47.

Table 3.38: Risk matrix of rice crop to Depth of inundation due to Tsunami

Floods in October	**Crop growth stages (cumulative days)**			
	Seedling (7-10)	**Vegetative state (45-50)**	**Reproductive stage (60-75)**	**Mature (90-110)**
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
< 0.5 m	D0	D1	D2	D3
0.5 – 1 m	D0	D2	D3	D3
1 – 2 m	D0	D3	D4	D4
> 2 m	D0	D4	D4	D4

Table 3.39**:** Transplanted aman area (km^2) at different risk levels due to tsunami at district level

Name of District	Risk levels / transplanted aman area (km^2)				
	0	**0-15**	**15-35**	**35-60**	**>60**
Barguna	1,222.96	3.18	0.54	0.32	0.90
Bhola	1,703.60	8.22	4.39	3.09	3.52
Patuakhali	2,278.21	40.58	13.87	4.13	14.25
Chittagong	2,384.57	0.00	0.00	0.03	0.19
Cox's Bazar	886.84	5.47	2.79	1.21	2.83
Feni	870.05	0.00	0.00	0.00	0.16
Noakhali	1,745.25	0.01	0.00	0.00	0.04
Total	11,091.48	57.46	21.59	8.77	1.23

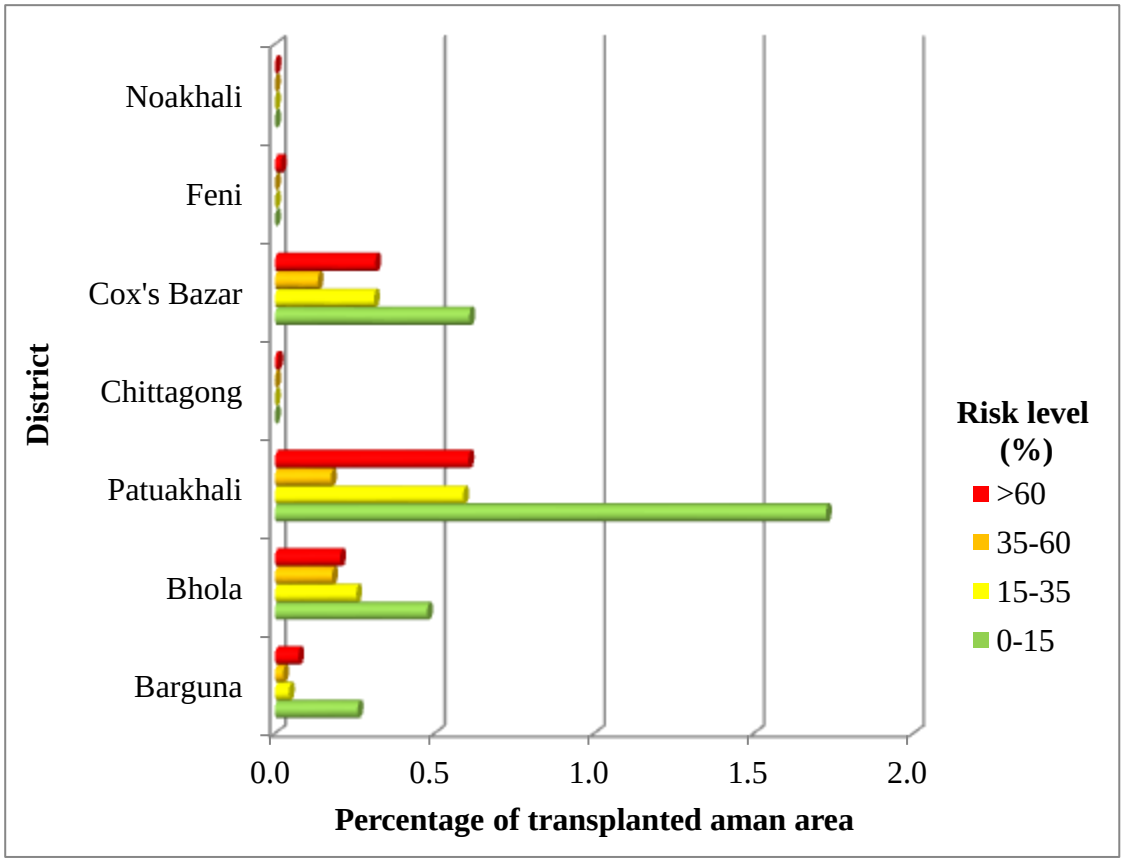

Figure 3.47: Percentage of transplanted aman area (km^2) at different risk levels due to tsunami at district level

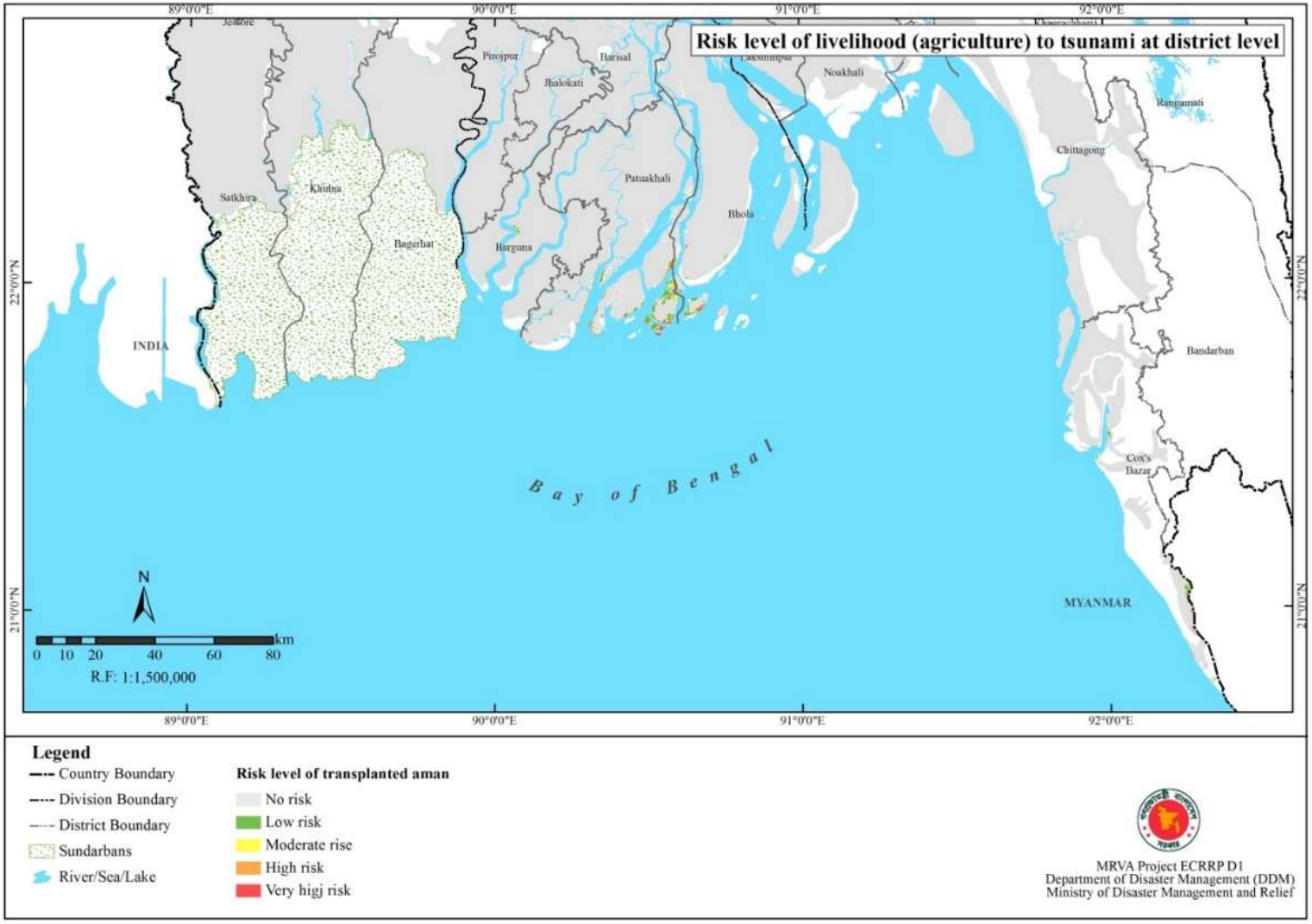

Figure 3.48: Risk level of livelihood (agriculture) to tsunami at district level

Chapter 4: Exposure Assessment to Technological Hazard

Simulation of possible leakage of ammonia using Areal Locations of Hazardous Atmospheres (ALOHA) methodology in the 6 chemical industries for which data was available is carried out for technological hazard assessment. The hazard zones of each industry are combined with population database and analysis is carried out to assess the exposed population.

4.1 Exposure Assessment

4.1.1 Population

Population considered for exposure assessment to Technological (industrial / chemical) hazards are, Gender (male, female), Age (0-14 years). Exposure assessment results are given below.

Gender: Distribution of population based on gender exposed to Technological (industrial / chemical) hazards is given in table 4.1.

Table 4.1**:** Population (gender) exposed to technological (chemical) hazard

S.No.	Name of the Industry	Hazard Zone / Length of influence	District	Upazillas	Population	
					Male	Female
1	Ashuganj Fertilizer & Chemical Company Factory Limited (AFCCL)	AEGL- 1 (1100 ppm) / 1.1 km	Brahmanbaria	Ashuganj	15	16
					742	709
		AEGL- 2 (160 ppm) / 3.2 km	Brahmanbaria	Ashuganj	4,471	4,808
					5,356	5,430
					6,225	5,944
			Kishoreganj	Bhairab	10,279	10,010
			Narsingdi	Roypura	3,470	3,362
		AEGL- 3 (30 ppm) / 7.8 km	Brahmanbaria	Ashuganj, Brahmanbaria Sadar , Nabinagar	160,354	167,402
			Kishoreganj	Bhairab	108,059	109,526
			Narsingdi	Belabo , Roypura	96,949	102,959
2	Chittagong Urea Fertilizer Ltd. (CUFL)	AEGL- 1 (1100 ppm) / 1.0 km				
		AEGL- 2 (160 ppm) / 2.9 km	Chittagong	Anowara	4,560	4,278
					4,448	4,571
					657	684

S.No.	Name of the Industry	Hazard Zone / Length of influence	District	Upazillas	Population	
					Male	Female
		AEGL- 3 (30 ppm) / 7.0 km	Chittagong	Anowara, Patiya	159,963	160,394
3	DAP Fertilizer Company Ltd. (DAPFCL)	AEGL- 1 (1100 ppm) / 1.0 km				
		AEGL- 2 (160 ppm) / 2.9 km	Chittagong	Anowara	3,522	3,305
					275	282
				Patiya	1,083	1,047
		AEGL- 3 (30 ppm) / 7.0 km	Chittagong	Anowara , Patiya	175,283	175,522
4	Jamuna Fertilizer Company Ltd. (JFCL)	AEGL- 1 (1100 ppm) / 1.2 km	Jamalpur	Sarishabari	151	153
		AEGL- 2 (160 ppm) / 3.3 km	Jamalpur	Sarishabari	167	181
					2,059	2,197
					2,703	2,736
		AEGL- 3 (30 ppm) / 7.9 km	Jamalpur	Sarishabari	129,300	134,112
			Tangail	Dhanbari , Gopalpur	55,152	58,249
			Sirajganj	Kazipur	10,632	10,657
5	Natural Gas Fertilizer Factory Ltd. (NGFFL)	AEGL- 1 (1100 ppm) / 1.1 km	Sylhet	Balaganj	937	1,026
				Fenchyganj	428	433
		AEGL- 2 (160 ppm) / 3.0 km	Maulvibazar	Rajnagar	190	197
			Sylhet	Balaganj	1,667	1,827
				Fenchyganj	6,094	6,157
		AEGL- 3 (30 ppm) / 7.2 km	Maulvibazar	Kulaura	25,835	27,233
				Rajnagar	41,153	43,083
			Sylhet	Balaganj , Fenchuganj	44,555	47,074
6	Polash	AEGL- 1	Gazipur	Kaliganj	667	667

S.No.	Name of the Industry	Hazard Zone / Length of influence	District	Upazillas	Population	
					Male	Female
	Fertilizer Factory Limited (PFFL)	(1100 ppm) / 1.1 km			83	85
			Narsigdi	Palash	934	973
					257	238
		AEGL- 2 (160 ppm) / 3.2 km	Gazipur	Kaliganj	4,027	4,028
					3,366	3,424
			Narsigdi	Palash	4,124	4,297
					12,902	11,948
					949	990
		AEGL- 3 (30 ppm) / 7.7 km	Gazipur	Kaliganj , Kapasia	109,642	109,326
			Narsingdi	Narsingdi Sadar , Palash , Shibpur	149,470	151,578

Population based on gender exposed to Ashuganj Fertilizer & Chemical Company Factory Limited (AFCCL) is shown in figure 4.1 for Population (male) and in figure 4.2 for population (female).

As shown in table 4.1 and figures 4.1 and figure 4.2, population in Bhairab Paurashava in Bhairab upazila in Kishoreganj district are likely to be most exposed from Ashuganj Fertilizer & Chemical Company Factory Limited, population living in Sakibaha union in Patiya Upazila in Chittagong district are likely to be most exposed due to Chittagong Urea Fertilizer Ltd. and DAP Fertilizer Company Ltd.. Because of Jamuna Fertilizer Company Ltd., population living in Sarishabari Paurshava in Sarishabari upazila in Jamalpur district are likely to be exposed most. Natural Gas Fertilizer Factory Ltd. (NGFFL) may affect population living in Fenchuganj union, Fenchuganj upazila of Sylhet district. Polash Fertilizer Factory Limited (PFFL) may affect population in Ghorashal Paurashava in Polash Upazila in Narisngdi district.

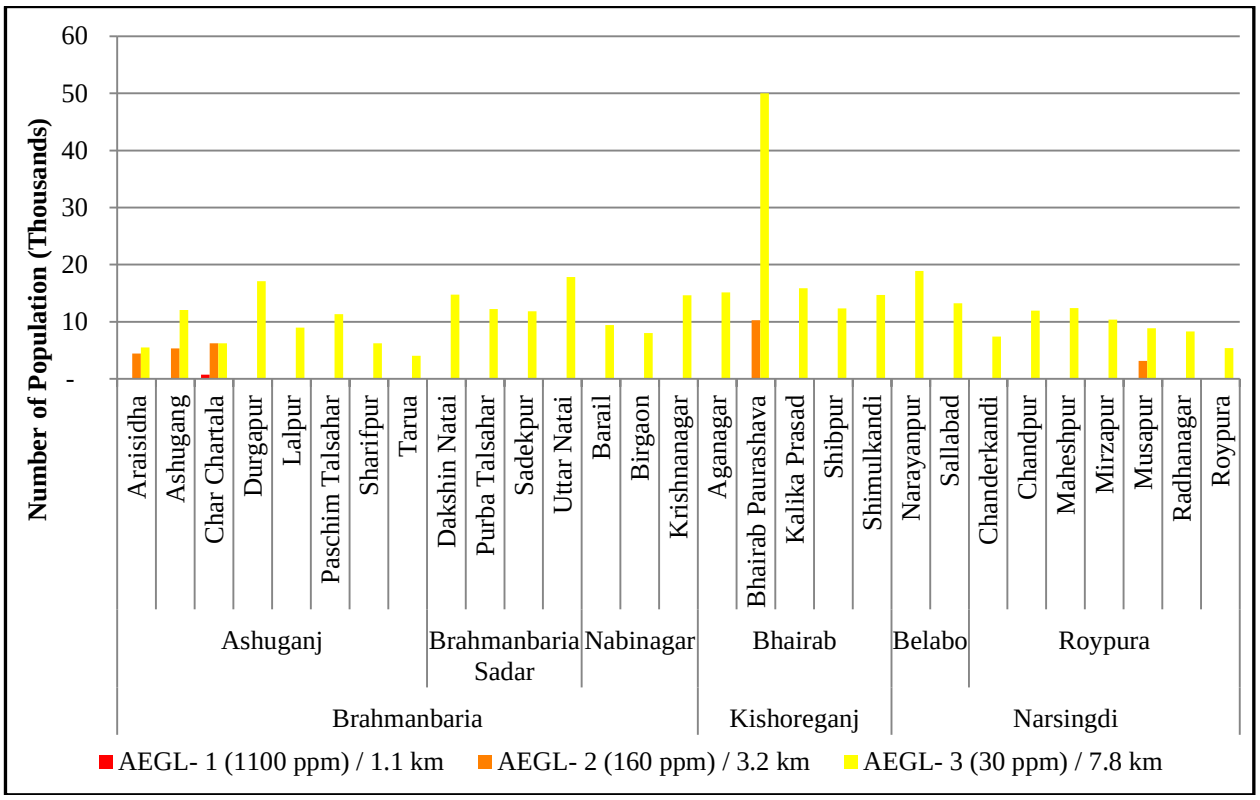

Figure 4.1: Population (male) exposed to Ashuganj Fertilizer & Chemical Company Factory Limited (AFCCL)

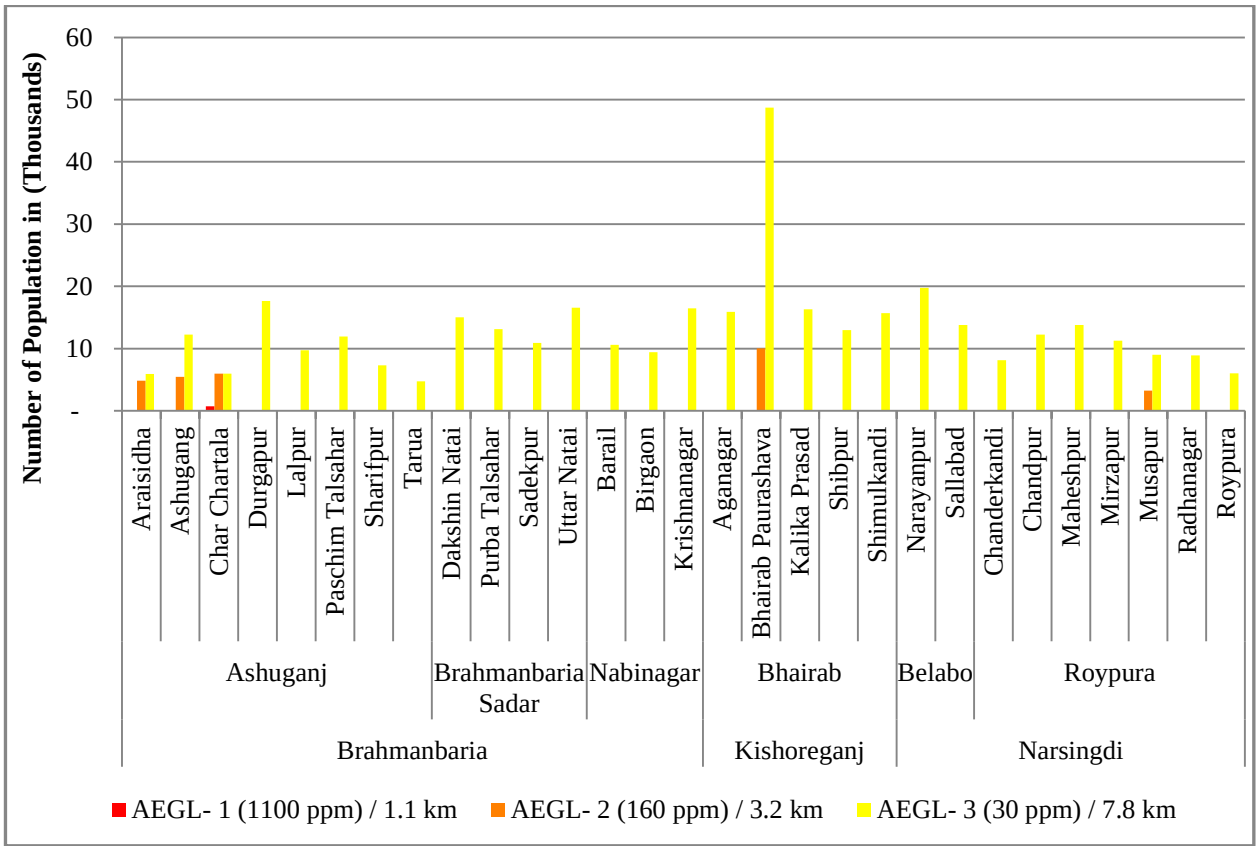

Figure 4.2: Population (female) exposed to Ashuganj Fertilizer & Chemical Company Factory Limited (AFCCL)

Population based on gender exposed to Chittagong Urea Fertilizer Ltd. (CUFL) is shown in figure 4.3 for Population (male) and in figure 4.4 for population (female).

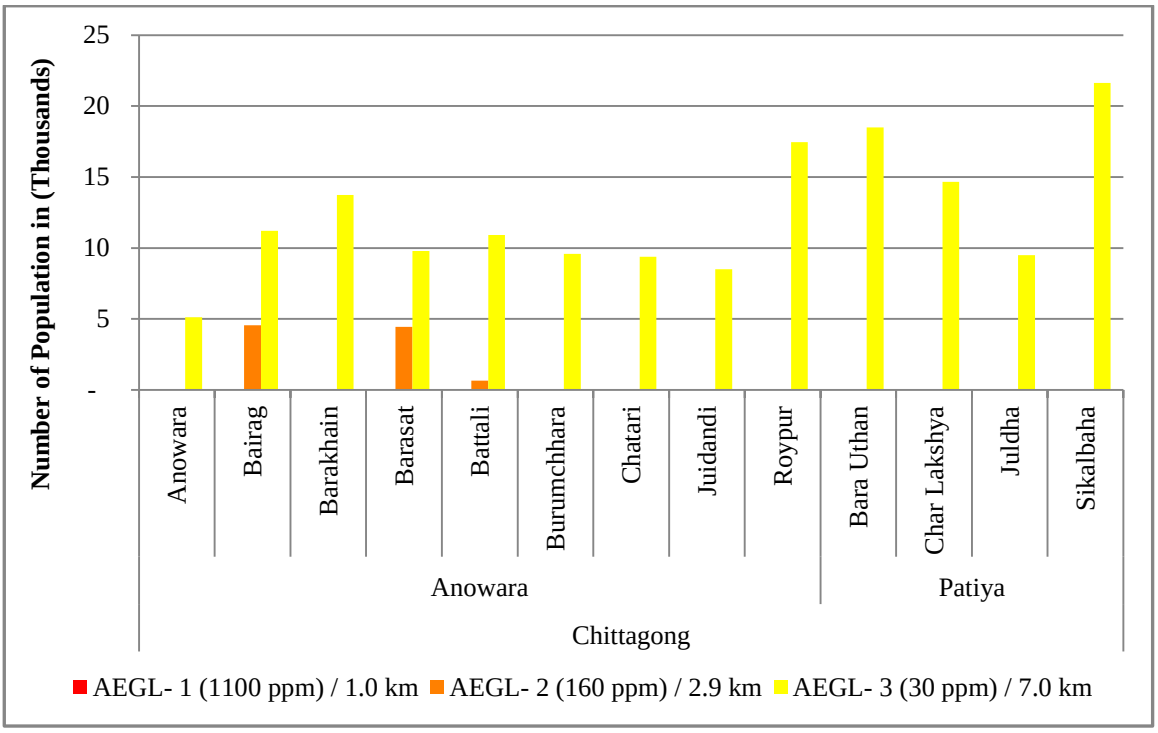

Figure 4.3: Population (male) exposed to Chittagong Urea Fertilizer Ltd. (CUFL)

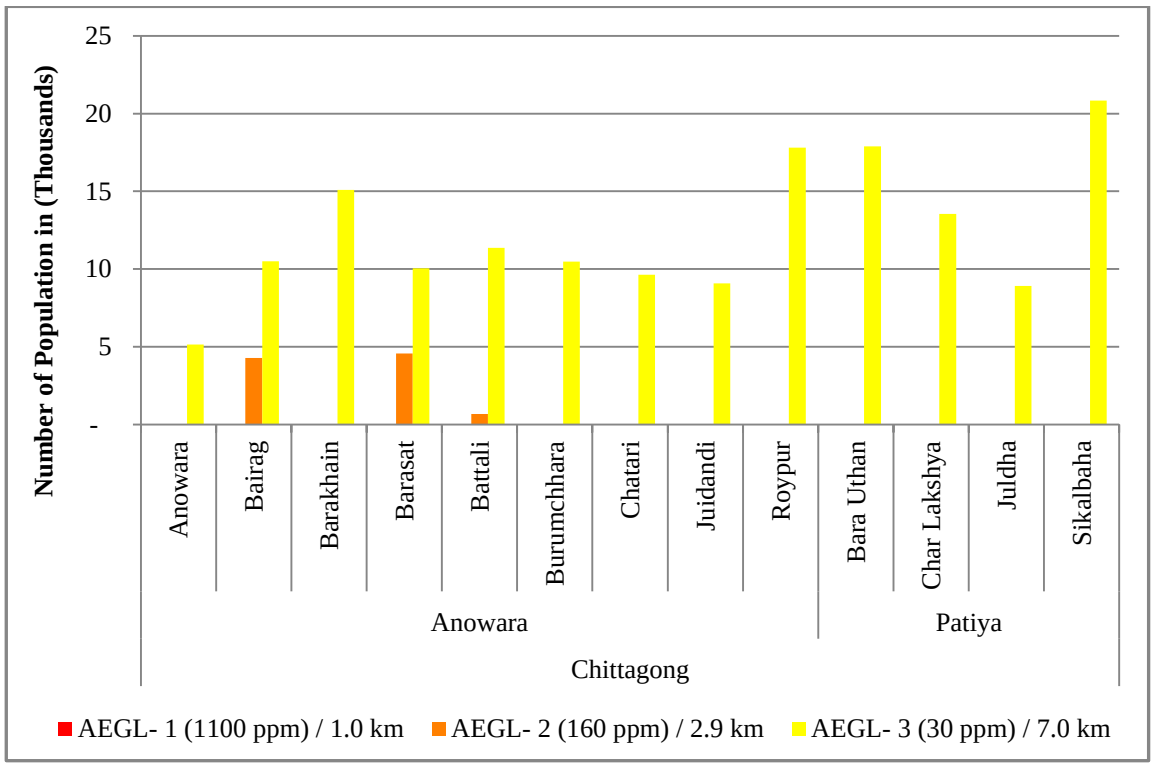

Figure 4.4: Population (female) exposed to Chittagong Urea Fertilizer Ltd. (CUFL)

Population based on gender exposed to DAP Fertilizer Company Ltd. (DAPFCL) is shown in figure 4.5 for Population (male) and in figure 4.6 for population (female).

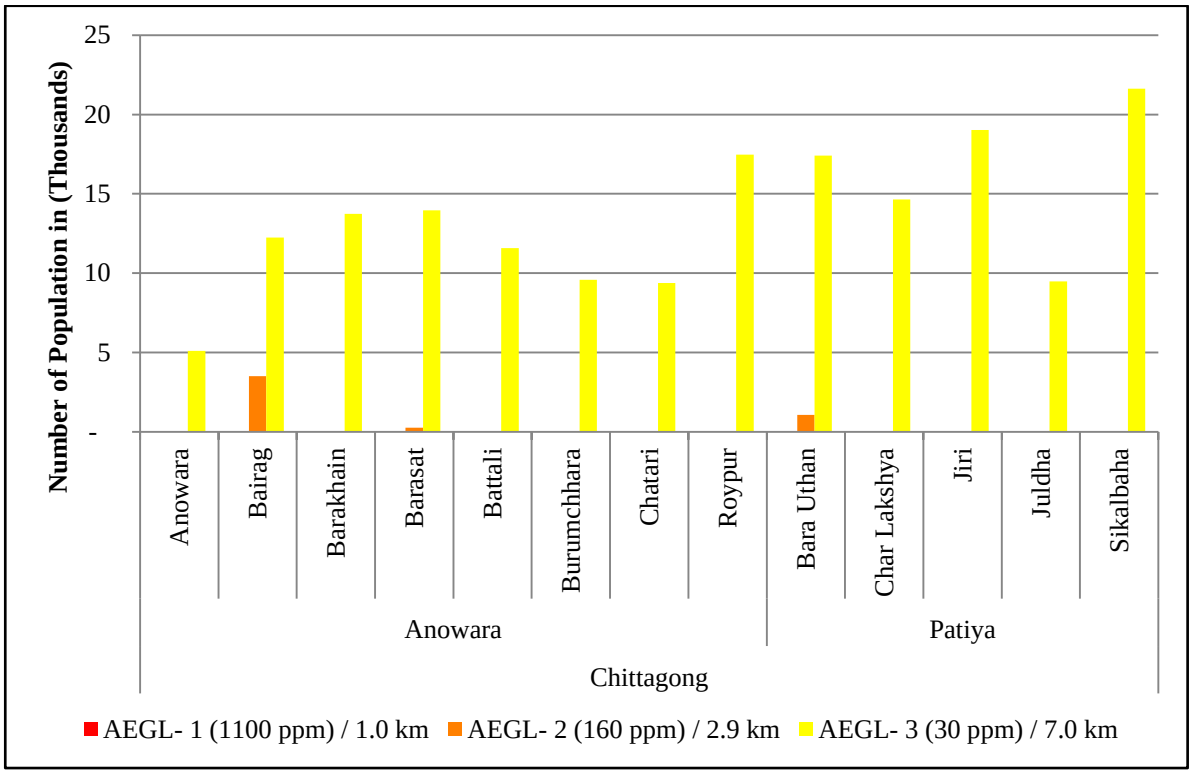

Figure 4.5: Population (male) exposed to DAP Fertilizer Company Ltd. (DAPFCL)

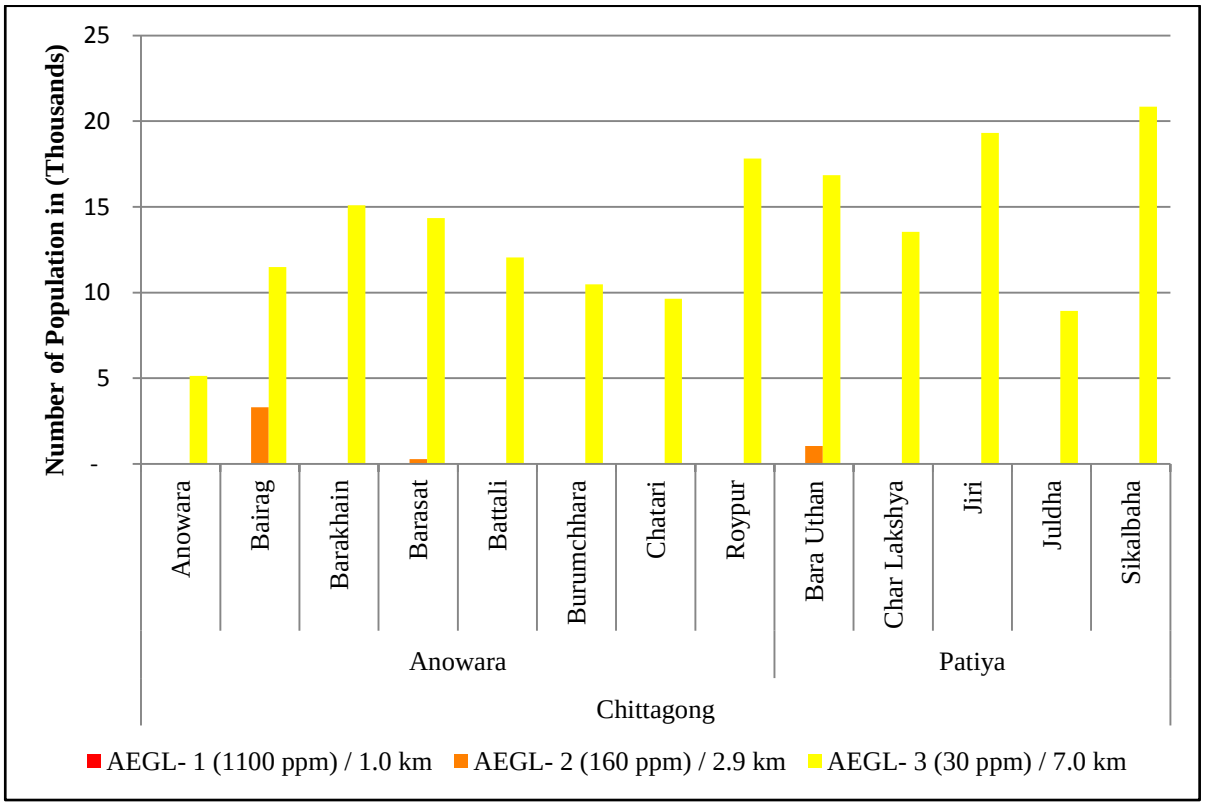

Figure 4.6: Population (female) exposed to DAP Fertilizer Company Ltd. (DAPFCL)

Population based on gender exposed to Jamuna Fertilizer Company Ltd. (JFCL) is shown in figure 4.7 for Population (male) and in figure 4.8 for population (female).

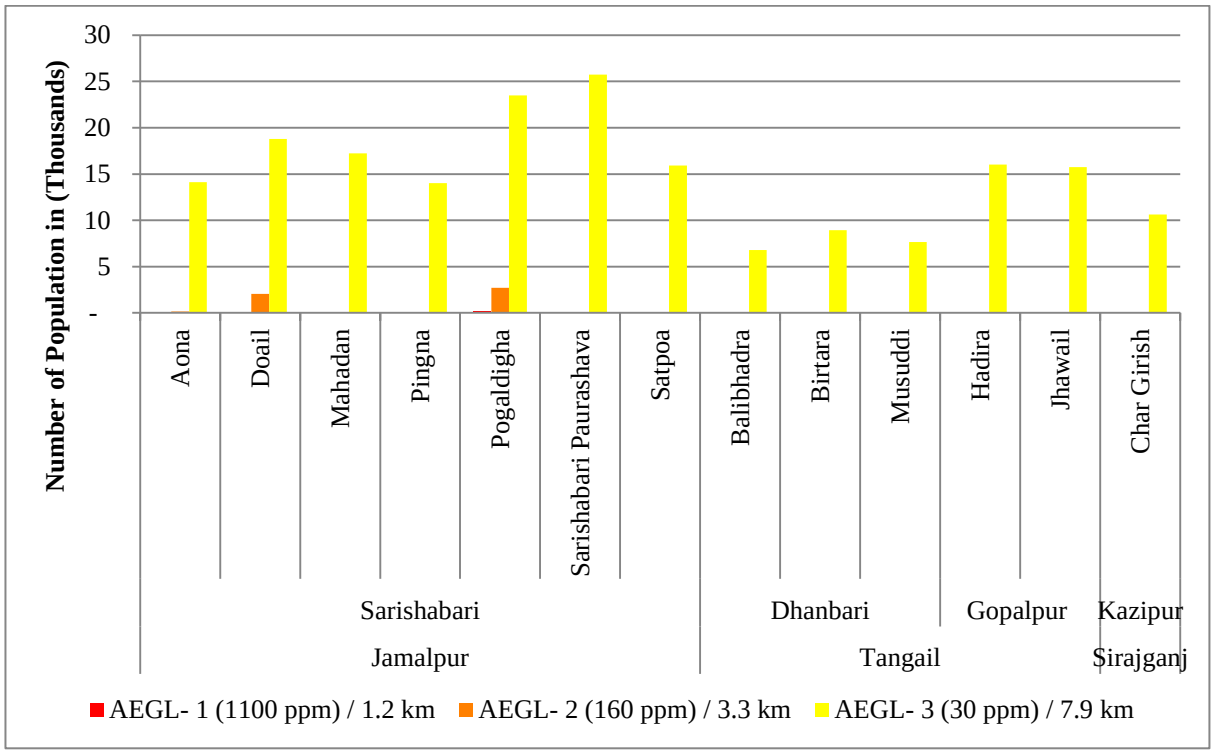

Figure 4.7: Population (male) exposed to Jamuna Fertilizer Company Ltd. (JFCL)

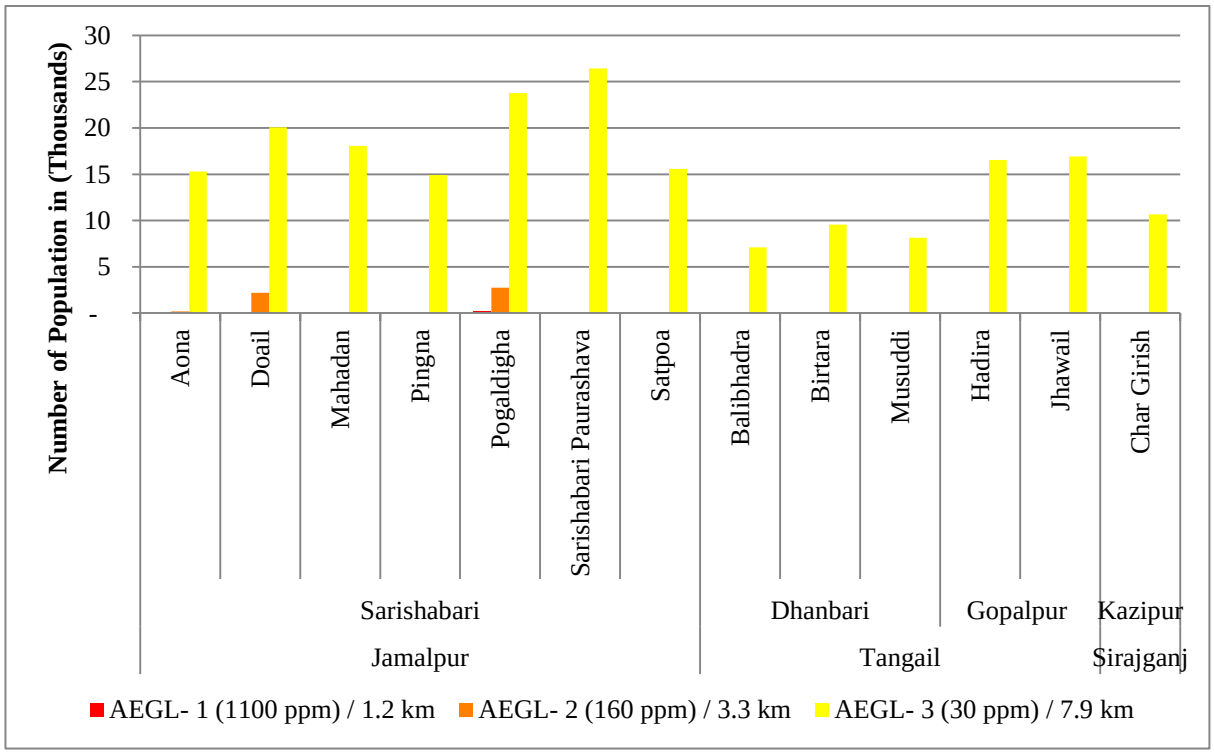

Figure 4.8: Population (female) exposed to Jamuna Fertilizer Company Ltd. (JFCL)

Population based on gender exposed to Natural Gas Fertilizer Factory Ltd. (NGFFL) is shown in figure 4.9 for Population (male) and in figure 4.10 for population (female).

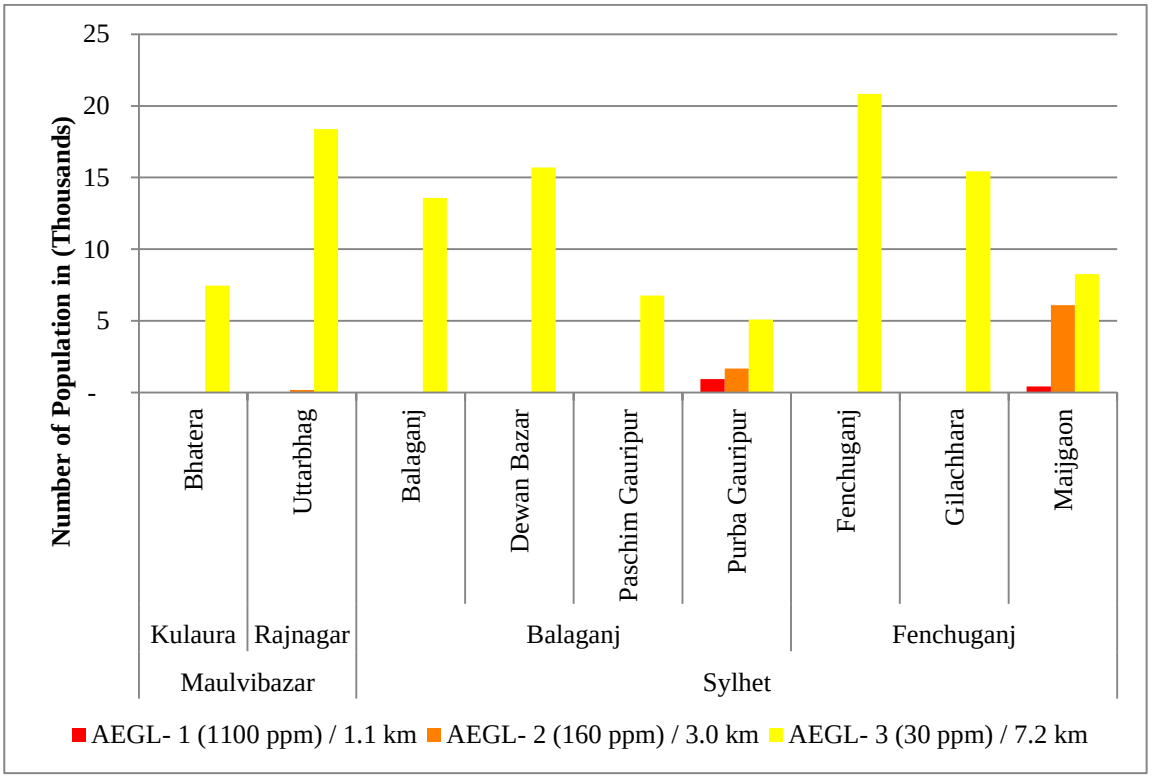

Figure 4.9: Population (male) exposed to Natural Gas Fertilizer Factory Ltd. (NGFFL)

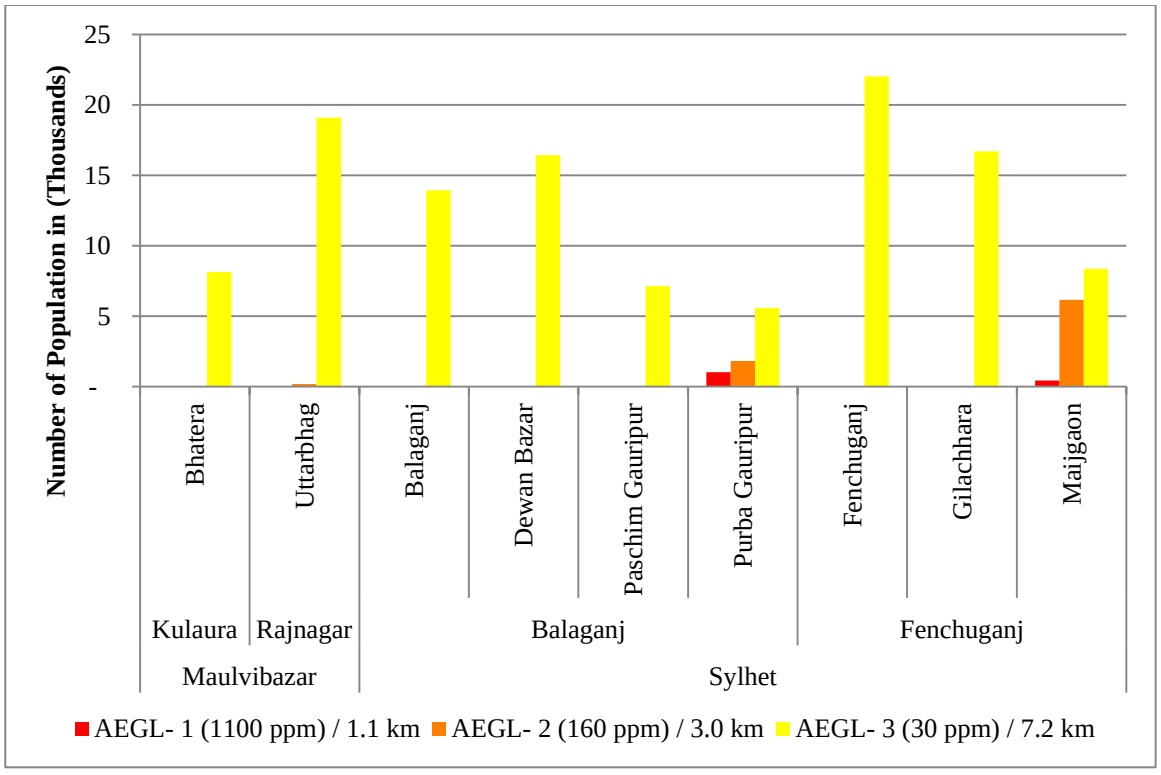

Figure 4.10: Population (female) exposed to Natural Gas Fertilizer Factory Ltd. (NGFFL)

Population based on gender exposed to Polash Fertilizer Factory Limited (PFFL) is shown in figure 4.11 for Population (male) and in figure 4.12 for population (female).

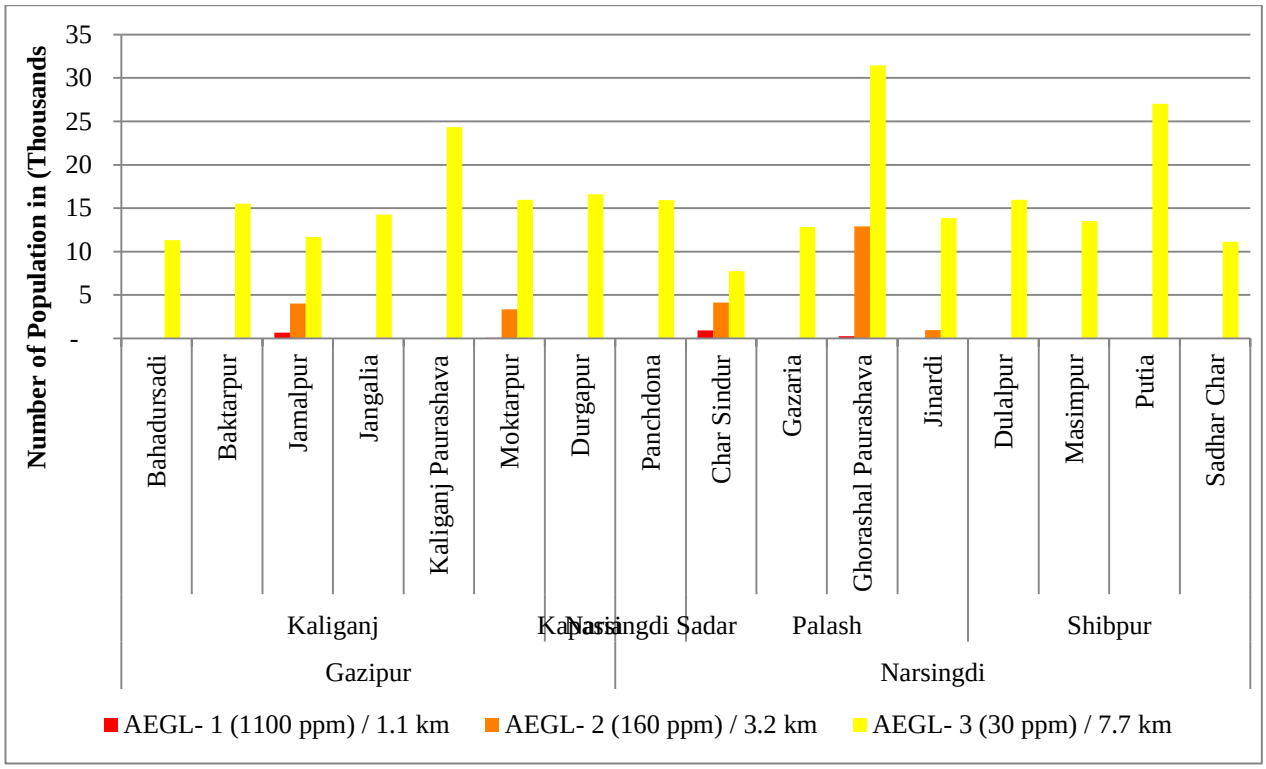

Figure 4.11: Population (male) exposed to Polash Fertilizer Factory Limited (PFFL)

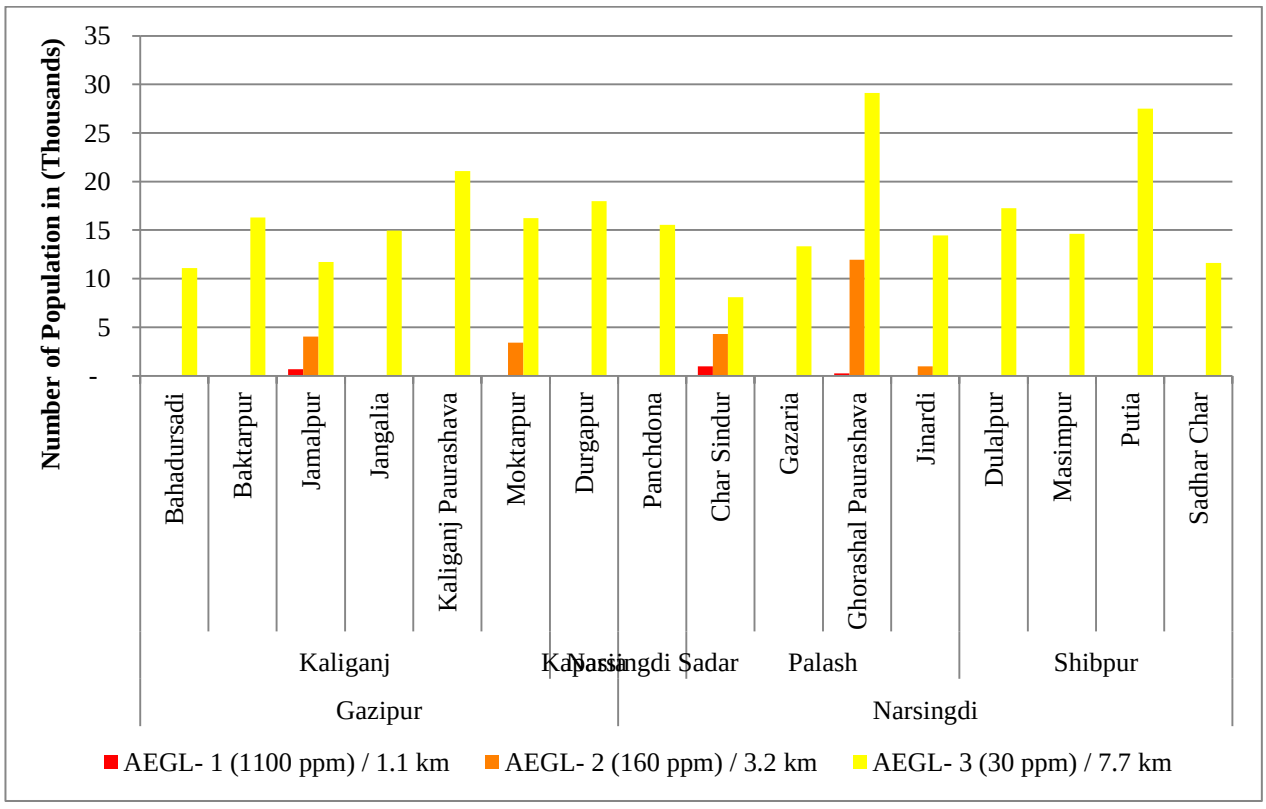

Figure 4.12: Population (female) exposed to Polash Fertilizer Factory Limited (PFFL)

Age: Population exposed to Technological (industrial / chemical) hazards based on Age (0-14 years) is shown in figures 4.13 to 4.18.

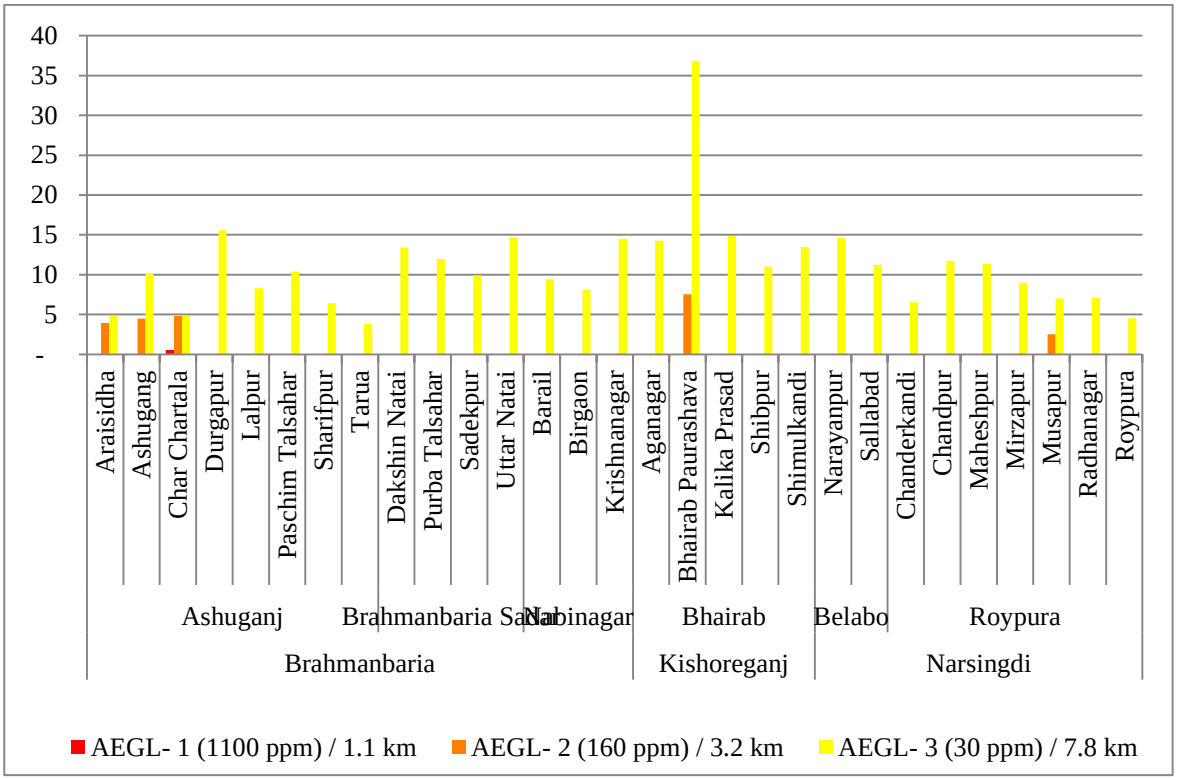

Figure 4.13: Population in age group 0-14 exposed to Ashuganj Fertilizer & Chemical Company Factory Limited (AFCCL)

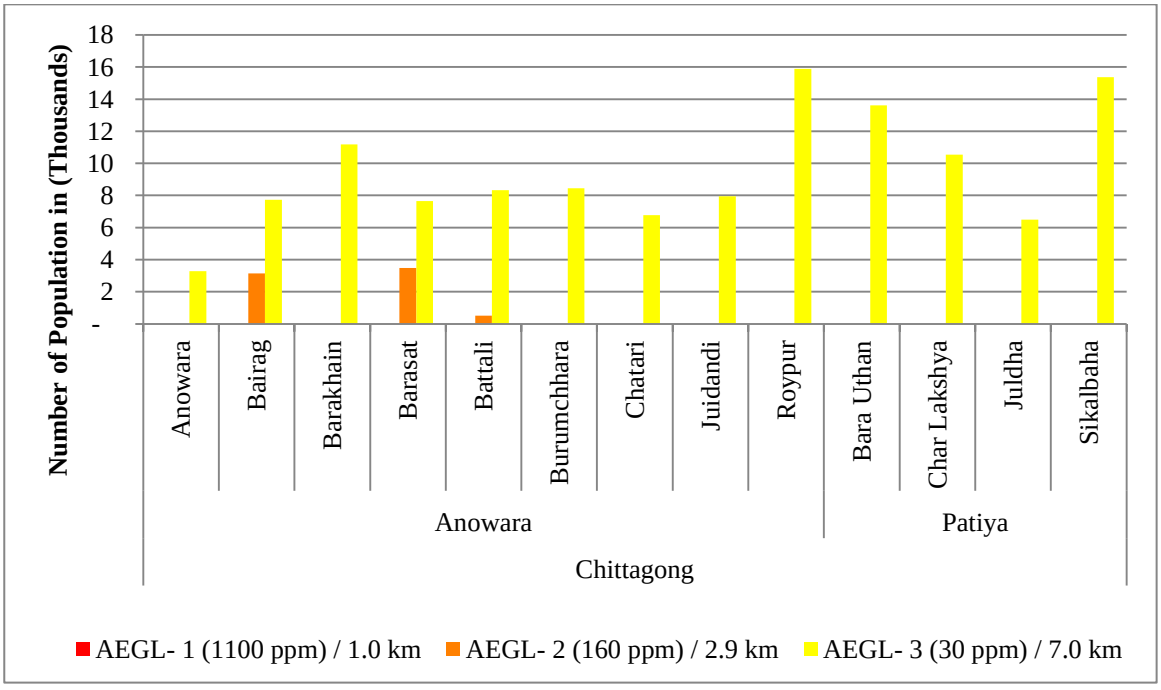

Figure 4.14: Population in age group 0-14 exposed to Chittagong Urea Fertilizer Ltd. (CUFL)

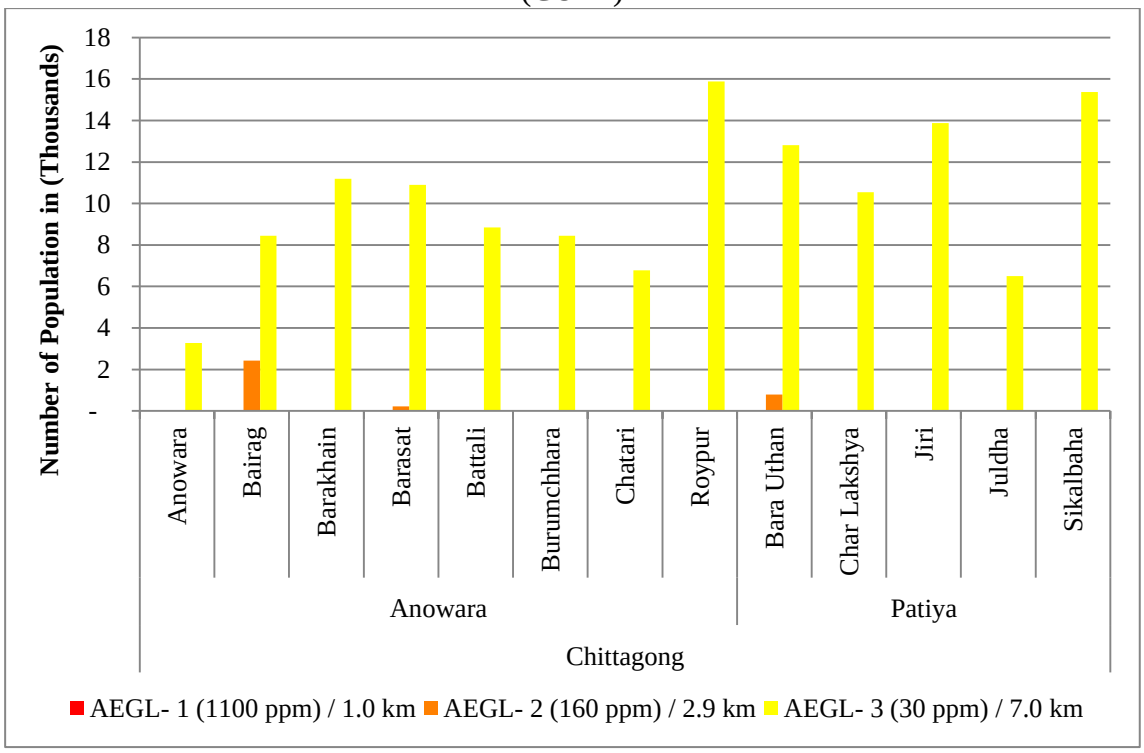

Figure 4.15: Population in age group 0-14 exposed to DAP Fertilizer Company Ltd. (DAPFCL)

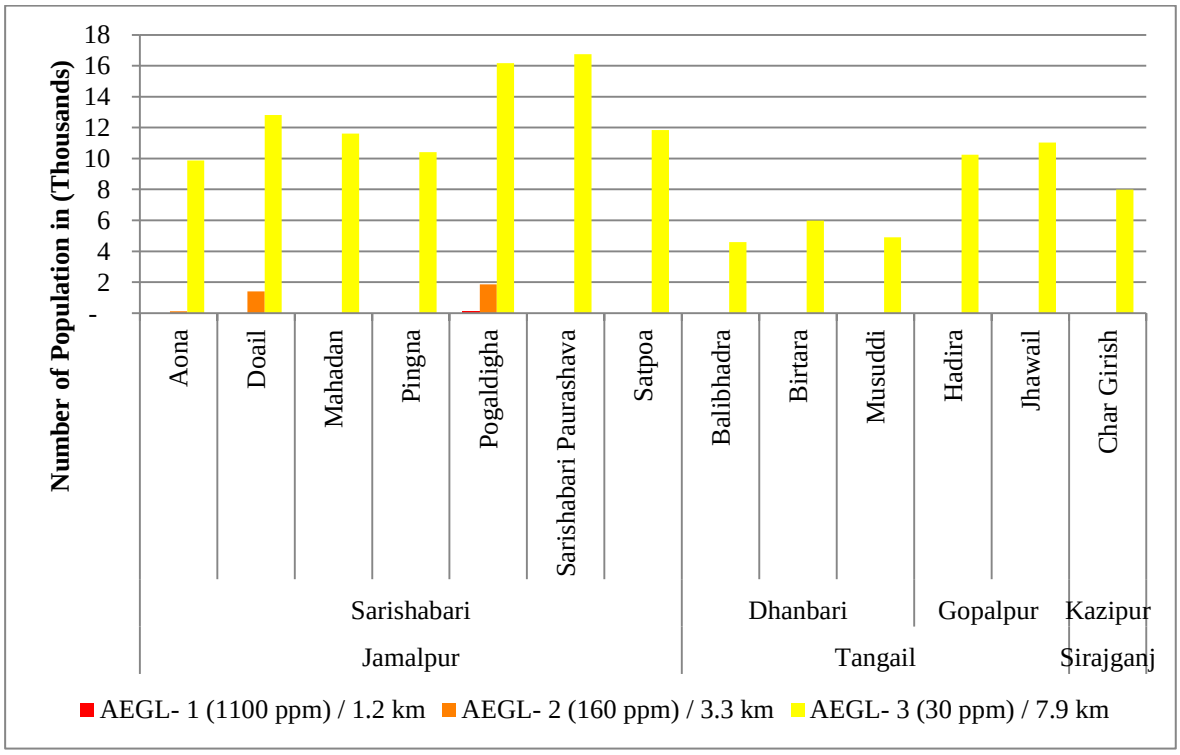

Figure 4.16: Population in age group 0-14 exposed to Jamuna Fertilizer Company Ltd. (JFCL)

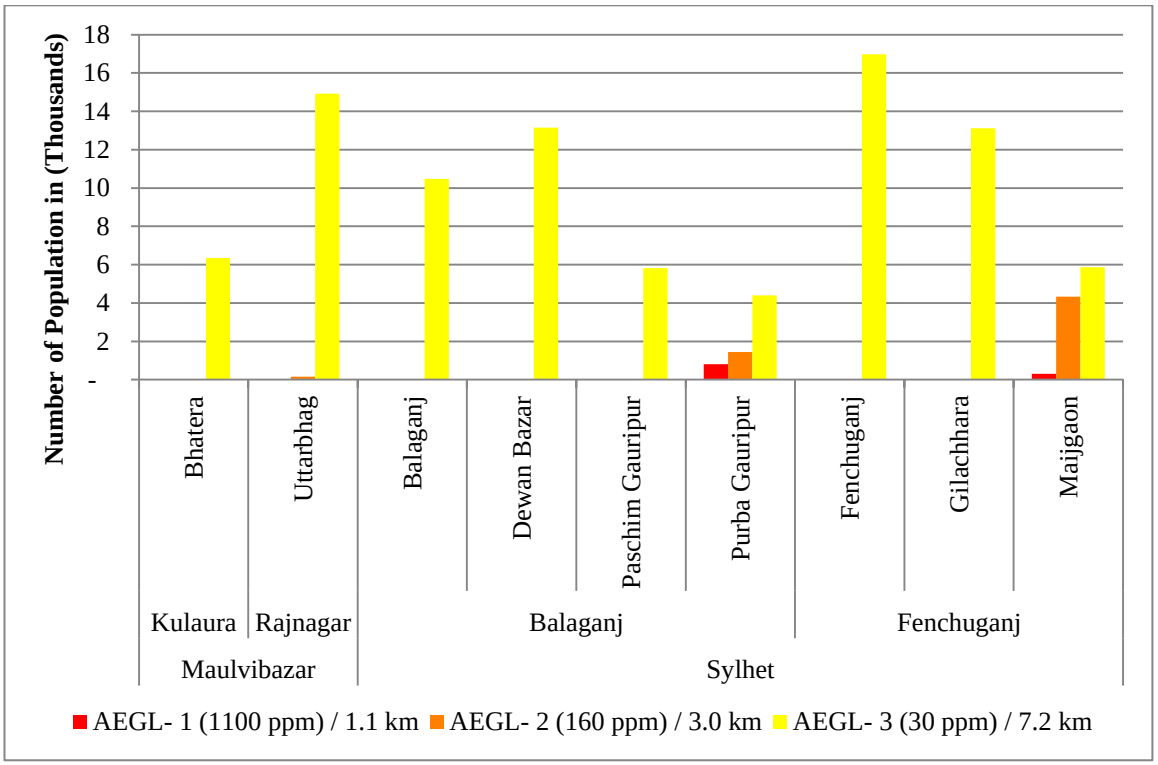

Figure 4.17: Population in age group 0-14 exposed to Natural Gas Fertilizer Factory Ltd. (NGFFL)

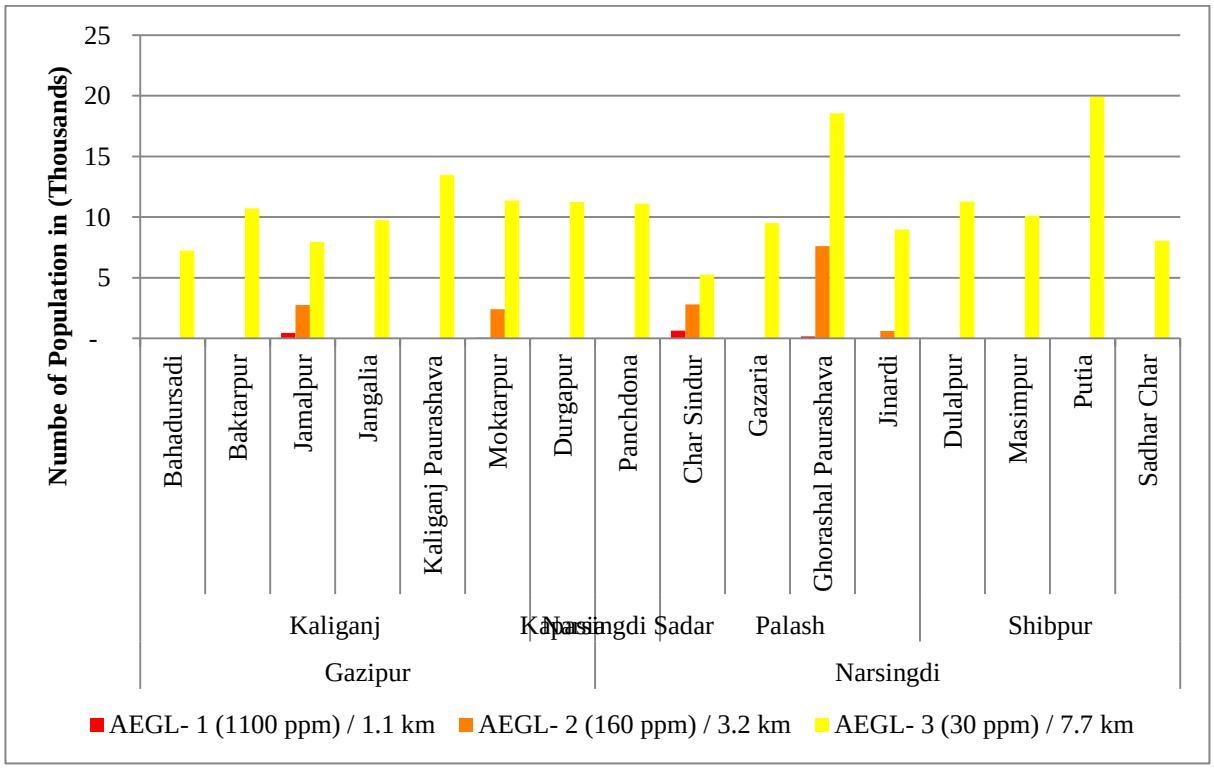

Figure 4.18: Population in age group 0-14 exposed to Polash Fertilizer Factory Limited (PFFL)

Population in age group of 0 to 14 are at highest exposure in Bhairab Paurashava in Bhairab upazila in Kishoreganj district are likely to be most exposed from Ashuganj Fertilizer & Chemical Company Factory Limited, population in Roypur union, in Anowara upazila in Chittagong district are likely to be most exposed due to Chittagong Urea Fertilizer Ltd. and DAP Fertilizer Company Ltd., because of Jamuna Fertilizer Company Ltd., population in Sarishabari Paurshava in Sarishabari upazila in Jamalpur district are likely to be exposed most Natural Gas Fertilizer Factory Ltd. may affect population (0-14 years) living in Fenchuganj union, Fenchuganj upazila of Sylhet district. Polash Fertilizer Factory Limited may affect population in Ghorashal Paurashava in Polash Upazila in Narisngdi district.

Chapter 5: Exposure Assessment to Health Hazard

Monthly disease profile database indicating number of people reported for eight most communicable diseases, namely Dengue, Diarrhea, Encephalitis, Filariasis, Kalaazar, Leprosy, Malaria, Tuberculosis (Pulmonary), are considered for health hazard assessment, along with water borne diseases such as Arsenicosis. These results are presented in section 1.5 (page 87 to 131) of MRVA Report Volume II.

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Annexure – I

Probabilistic Damage Functions_MRVAM_NGI_Report.pdf

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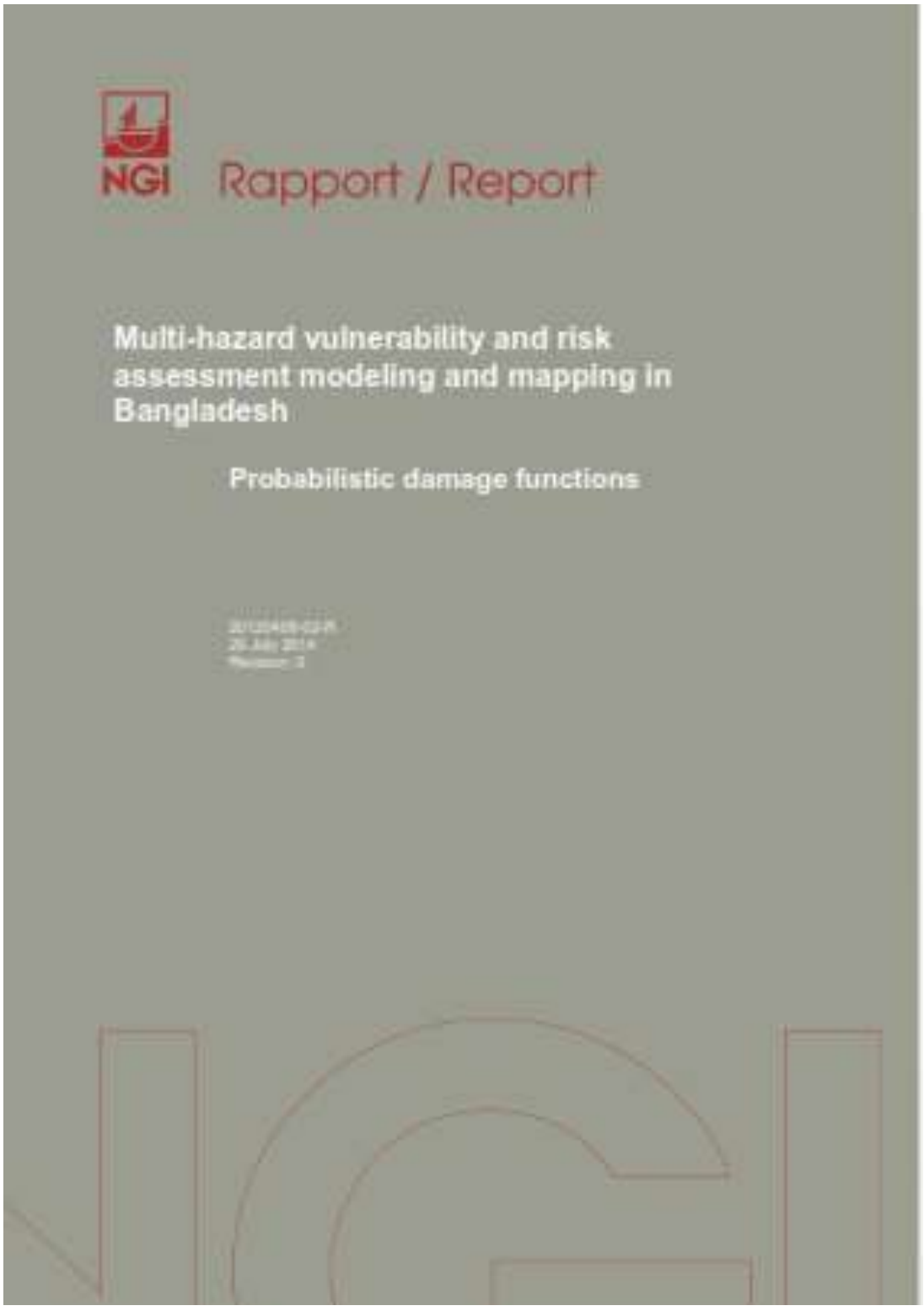

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